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Preface

The Second Issue of Volume 37, 2024

Greetings,

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Prof. Dr. Marei El-ajaily

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Feature Distribution and Word Order Variation in Arabic Clauses: A Minimalist Account

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ABSTRACT

Arabic subject-verb agreement is asymmetrical: in VSO order the verb agrees with the subject in person and gender (partial agreement), whereas in SVO order the verb exhibits number agreement as well (full agreement). This agreement asymmetry has received a lot of attention in the generative literature over the past three decades. In fact, more than twenty proposals have been put forward in a number of different theoretical frameworks. At the same time, there have been no attempts for a formal treatment of OVS word order constructions. With respect to agreement, the OVS verb exhibits both of the properties that exist in the other word order types (VSO and SVO): partial agreement with the post-verbal subject and full agreement with the pre-verbal DP. A more thorough consideration of the data reveals that pre-verbal DPs share a number of other rather interesting properties. Our empirical findings lead to the conclusion that pre-verbal DPs (i.e., the superficial subject and object of SVO and OVS, respectively) are actually topics. The real subject of SVO and, similarly, the object of OVS is in fact verbally bound pronominal clitics. Using a Merge, Move and Agree-based theory of phrase structure and feature checking; and a Multiple Spell-Out model of phasal derivation, we hope to demonstrate that the computational systems of Minimalist Syntax can provide an adequate treatment of seven constructions: VSO, SVO and OVS, as well as four related variants (ʔinna-headed SVO and OVS, and pro-drop SVO and OVS).

KEYWORDS: agreement, Arabic, case, topicalization, word-order.

1. INTRODUCTION

This paper examines the Arabic agreement-word order asymmetry (partial VS agreement vs. total SV agreement), taking into consideration OVS word order agreement as well. Significantly, the OVS-verb simultaneously hosts two verbally bound forms. We will argue that one is an affix, marking partial agreement with the post verbal Subject (vis-à-vis partial VS agreement); while the other is a pronominal clitic which is coreferential with the preverbal Object. Furthermore, the SV-subject and the OVS-object (i.e., preverbal DPs) are reanalyzed as discourse Topics. Theoretically, we will adopt a Minimalist Theory of phrase structure/feature checking; and a Multiple Spell-Out model of phasal derivation.

The aim of this work is to apply a Minimalist treatment to Arabic OVS, SVO and VSO word order constructions, taking into consideration a number of other related grammatical phenomena. These include agreement-word order co-variation (§2); the pronominal nature of the agreement marker and whether or not pro-drop is permissible (§3.1); the case properties of preverbal DPs in the absence and presence of the emphatic complementizer ʔinna (§3.2); and definiteness constraints (§3.3).

We will attempt to explain the interaction of these phenomena in the light of developments in Minimalist Syntax. These developments include a Merge, Move and Agree-based theory of phrase structure and feature checking; and a Multiple Spell-Out model of phasal derivations, as argued for in Chomsky[1-6] and Uriagereka[7]. After outlining the basic theoretical assumptions in §3, a step-by-step derivation of the three constructions in question will be proposed in section in §4. We hope to demonstrate that the computational systems of Minimalist Syntax can adequately deal with the level of complexity exhibited by the three constructions. The paper will also identify what constitutes a phase in the syntax of these word order types. It will argue that OVS is derived in two phases (vP and CP), SVO in three (DP, vP and CP), and VSO in two (DP and TP).

2. EXPANDING THE DATA SET

In Arabic subject-verb agreement is asymmetrical. When the verb precedes the subject, as in VSO word order (1a), the verb agrees with the subject in person and gender but not in number. On the other hand, when the subject precedes the verb, as in SVO word order (1b), the agreement involves three morphosyntactic categories: person, gender and number:

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(1) a. ʃakar-a aṭ-ṭullaab-u al-muʕalim-aat-i
thank.PAST-3M.SG DEF-student.3M.PL-NOM DEF-teacher-3F.PL-ACC
'The students thanked the teachers.'

b. aṭ-ṭullaab-u ʃakar-uu al-muʕalim-aat-i
DEF-student.3M.PL-NOM thank.PAST-3M.PL DEF-teacher-3F.PL-ACC
'The students, they thanked the teachers.'

We will follow the established convention of referring to the latter type of agreement as *rich* agreement, a term that is used in contrast with *poor* agreement, the type exhibited by VSO word order.

There is an abundance of literature on the Arabic VSO-SVO agreement asymmetry, and it spans back more than fourty years. Proposals have been put forward in a number of different theoretical frameworks. In the Government and Binding era, the topic was addressed by a number of scholars[8-12]. Within the Principles and Parameters framework, proposals have been put forward by others[13-16]. More recently, Benmamoun[17] Mohammad[18], Mahfoudhi[19], Soltan[20-21] and Fehri[22] have provided a Minimalist treatment to the data in (1). For an LFG treatment of the Arabic VSO-SVO agreement asymmetry see Fehri[23]. At the same time, there have been no attempts for a formal treatment of OVS word order constructions, exemplified in (2):

(2) al-muʕalim-aat-u ʃakar-a-hun aṭ-ṭulaab-u
DEF-teacher-3F.PL-NOM thank.PAST-3M.SG-3F.PL DEF-student.3M.PL-NOM
'The teachers, the students thanked them.'

What makes Arabic OVS word order of particular importance to the study of agreement and word order co-variation in Arabic is that the OVS verb bears two affixes: in (2) the suffix *-a* shows poor verbal agreement with the postverbal subject (the same scenario as in (1a) with VSO order), but a second suffix *-hun* shows rich verbal agreement with the preverbal object (i.e., much like the scenario we observed with preverbal subjects in SVO (1b), only now it is with the preverbal object). When the agreement asymmetry data set is expanded to include OVS word order, a wider picture emerges in that (i) poor verbal agreement is a property of postverbal subjects (i.e., the subject of VSO order in (1a), and the subject of OVS order in (2)); and that (ii) rich verbal agreement is a property of preverbal DPs in general (i.e., the subject of SVO order in (1b), and the object of OVS order in (2)). A more thorough consideration of the data reveals that preverbal DPs share a number of other rather interesting properties, which will be discussed in §3.

3. MORE ON PREVERBAL DPS

As mentioned above, the rich verbal agreement associated with preverbal DPs seems to correlate with a number of formal and functional properties. These will be discussed in §3.1-3.3, and a summary of the empirical findings will be provided in §3.4.

3.1 Pro-drop and the pronominal nature of the agreement marker

In Arabic, there is a correlation between rich verbal agreement and pro-drop, as only preverbal DPs can be pro-dropped. In OVS constructions, when the preverbal object is pro-dropped (3a), the rich agreement marker (*-hun*) on the verb gets interpreted as a pronominal object. The example in (3b) demonstrates that the same relation holds with the preverbal subject and its corresponding rich agreement marker (*-uu*) in SVO constructions:

(3) a. ʃakar-a-hun aṭ-ṭulaab-u
thank.PAST-3M.SG-3F.PL DEF-student.3M.PL-NOM
'The students thanked them.'

b. ʃakar-uu al-muʕalim-aat-i
thank.PAST-3M.PL DEF-teacher-3F.PL-ACC
'They thanked the teachers.'

In contrast with the examples in (3), postverbal subjects cannot be pro-dropped. Even though (4a) is grammatically well-formed, it cannot be considered the prop-drop counterpart of the VSO sentence in (1a). This is because the subject in (1a) cannot be interpreted as the antecedent of the agreement marker on the verb. The two are incompatible in number: the subject is plural, while the agreement marker is singular in number. In fact, (4a) is the pro-drop counterpart of (4b), an SVO construction with a singular subject:

(4) a. ʃakar-a al-muʕalim-aat-i
thank.PAST-3M.SG DEF-teacher-3F.PL-ACC
'He thanked the teachers.'

b. aṭ-ṭaalib-u ʃakar-a al-muʕalim-aat-i
DEF-student.3M.SG-NOM thank.PAST-3M.SG DEF-teacher-3F.PL-ACC
'The student, he thanked the teachers.'

Pro-drop is possible with preverbal DPs because their corresponding rich verbal agreement marker is an argument of the predicating verb. Since the Theta Criterion requires that each thematic role be uniquely assigned, it is safe to assume that in OVS constructions the theme/object role is either assigned to the rich agreement marker or the

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preverbal DP, but not simultaneously to both. Similarly, in SVO constructions, the agent/subject role can be assigned either to the rich agreement marker or the preverbal DP, but not to both. We will take the position that the object of OVS and the subject of SVO are not the preverbal DP, as the superficial label suggests, but rather the bound pronominal clitics *-hun* and *-uu*, respectively. This position is supported by the fact that the preverbal DPs in these constructions can be pro-dropped and therefore cannot be considered as arguments of the verb. They are not assigned a thematic role or a grammatical function, but they function as discourse topics in the two topic-comment constructions, OVS and SVO. We shall provide more support for this analysis in §3.3.

3.2 Case properties: with and without *ʔinna*

In addition to the possibility of pro-drop, preverbal DPs share interesting case properties. In Arabic, objects typically receive the accusative case, as indicated by the pair of examples in (1). However, when an object is topicalized, it receives nominative case instead, as in (2). This is also a property shared by the topicalized subject (1b), though in the case of topicalized subjects the observation is obscured by the fact that nominative case is also assigned to postverbal subjects (1a).

A second case property shared by preverbal topic DPs is that they can be preceded by the emphatic complementizer *ʔinna*, which assigns accusative case to the topicalized DP. In (5a), *ʔinna* precedes the topicalized object of OVS, and in (5b) it precedes the topicalized subject of SVO. However, *ʔinna* is not permitted with VSO word order, hence the ungrammaticality of (6):

(5) a. ʔinna al-muʕalim-aat-u ʃakar-a-hun aṭ-ṭulaab-u
COMP DEF-teacher-3F.PL-ACC thank.PAST-3M.SG-3F.PL DEF-student.3M.PL-NOM
'That the teachers, the students thanked them.'

b. ʔinna aṭ-ṭulaab-u ʃakar-uu al-muʕalim-aat-i
COMP DEF-student.3M.PL-ACC thank.PAST-3M.PL DEF-teacher-3F.PL-ACC
'That the students, they thanked the teachers.'

(6) *ʔinna ʃakar-a aṭ-ṭullaab-u al-muʕalim-aat-i
COMP thank.PAST-3M.SG DEF-student.3M.PL-NOM DEF-teacher-3F.PL-ACC

3.3 Definiteness and topicalization

Another property shared by preverbal DPs is definiteness. The topicalized object of OVS and the subject of SVO are obligatorily definite, as in (2) and (1b), respectively. Replacing these definite DPs with indefinite ones would result in ungrammaticality, as demonstrated by the OVS-SVO pair in (7a-b):

(7) a. *muʕalim-aat-u ʃakar-a-hun aṭ-ṭullaab -u
teacher-3F.PL-NOM thank.PAST-3M.SG-3F.PL DEF-student.3M.PL-NOM

b. *ṭulaab-u ʃakar-uu al-muʕalim-aat-i
student.3m.pl-nom thank.past-3m.pl DEF-teacher-3F.PL-ACC

This definiteness constraint is a very compelling argument for analyzing preverbal DPs as topics. In fact, several typological studies (Li[24], Gundel[25]) have established a close relationship between topicalization and definiteness. We will therefore treat OVS and SVO word order constructions as topic-comment structures.

At the same time, notice that with VSO word order, this constraint does not apply. The postverbal subject can be definite, as in (1a), or indefinite, as in (8).

(8) ʃakar-a ṭullaab-u al-muʕalim-aat-i
thank.PAST-3M.SG student.3M.PL-NOM DEF-teacher-3F.PL-ACC
'Students thanked the teachers.'

In this regard, let us evoke that, compared to the OVS and SVO topic-comment constructions, the VSO construction is syntactically more basic, and it requires fewer mechanisms of interpretation and derivation. Also, this is the word order used in pragmatically neutral contexts. Topic-comment structures, on the other hand, can be used only in contexts that are pragmatically marked, where the topic DP must already be discourse active and therefore definite. The pragmatic factors (see Belnap[26], in particular, for a sociolinguistic study of agreement variation in Cairene Arabic) that affect a speaker's choice of agreement/word order pattern are independent of the syntactic mechanisms that license such configurations.

3.4 Summary of the empirical findings

In our suggestion, the superficial word order label OVS is misleading, as the OVS word order is actually a topic-comment structure. The preverbal DP (*al-muʕalim-aat-u*) is the discourse topic, and it can be pro-dropped. The rest of the sentence is the comment, i.e., what is said about the topic. The comment is a fully-fledged grammatical sentence consisting of a verb (*ʃakar*), a subject (the DP – *aṭ-ṭulaab-u*) and an object (the verbally bound pronominal clitic *-hun*). The pronominal object and the topic DP are coreferential. The verbal suffix *-a* is a marker of the grammatical agreement in person and gender with the postverbal subject. A multi-layered schematic representation of our analysis of the Arabic OVS word order is given in *Figure 1*:

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superficial order	**(O)** al-muʕalim-aat-u DEF-teacher-3F.PL-NOM	**V** ʃakar-a-hun thank.PAST-3M.SG-3F.PL	**S** aṭ-ṭulaab-u DEF-student.3M.PL-NOM
discourse function	*Topic*	*Comment*	
grammatical function	Ø	V+O	S
constituency	DP	VP+PRN^{clitic}	DP
semantic role	Ø	predicator + theme	agent

Figure 1: Schematic representation of OVS

The superficial word order label SVO is also misleading. Similar to OVS, the SVO word order is also a topic-comment structure. The preverbal DP (*aṭ-ṭulaab-u*) is the discourse topic that can be pro-dropped. The rest of the sentence is the comment. The comment is a fully-fledged grammatical sentence consisting of a verb (*ʃakar*), a subject (the verbally bound pronominal clitic -uu), and an object (the DP – *al-muʕalim-aat-i*). The pronominal subject and the topic DP are coreferential. A multi-layered schematic representation of our analysis of SVO is given in *Figure 2*:

superficial order	**(S)** aṭ-ṭulaab-u DEF-student.3M.PL-NOM	**V** ʃakar-uu thank.PAST-3M.PL	**O** al-muʕalim-aat-i DEF-teacher-3F.PL-ACC
discourse function	*Topic*	*Comment*	
grammatical function	Ø	V+S	O
constituency	DP	VP+PRN^{clitic}	DP
semantic role	Ø	predicator + agent	theme

Figure 2. Schematic representation of SVO

The VSO word order is the syntactically basic counterpart of the two topic-comment structures, OVS and SVO. The superficial word order label VSO and the actual order of grammatical functions coincide. The verb bears a suffix (*-a*), which marks the grammatical agreement in person and number with the postverbal subject (the DP: *aṭ-ṭulaab-u*). The object is formally realized by an overt DP (*al-muʕalim-aat-i*). Again, a multi-layered schematic representation of our analysis of VSO is offered in *Figure 3*:

superficial order	**V** ʃakar-a thank.PAST-3M.SG	**S** aṭ-ṭulaab-u DEF-student.3M.PL-NOM	**O** al-muʕalim-aat-i DEF-teacher-3F.PL-ACC
grammatical function	V	S	O
constituency	VP	DP	DP
semantic role	predicator	agent	theme

Figure 3. Schematic representation of VSO

4. THEORETICAL PRELIMINARIES

The syntactic model adopted in this paper is schematized in *Figure 4* below. In Minimalist Syntax (Chomsky[27] and subsequent work), the idiosyncratic properties of words, including their morphology, are relegated to the lexicon. In other words, when items are numerated from the lexicon and brought into the syntactic derivation, they are fully inflected, meaning that they are specified for their syntactic and morphological inflection features. Two types of features are distinguished: *interpretable*, which are meaningful and can be accessed by the Conceptual-Intentional (CI) and Articulatory-Perceptional (AP) computational systems at interface levels (LF and PF); and *uninterpretable*, which are non-meaningful features and are used for the theory-internal purpose of driving the derivation.

Feature interpretability collaborates with the Principle of Full Interpretation, which, in Minimalist terms, imposes "bare output conditions" on the derivation by requiring that only interpretable features be represented at the interface levels. In this context, the role of the syntactic operations Merge, Move and Agree is to rid the derivation of all uninterpretable features by checking and deleting them from the syntactic representation. The arrows forming the circle in *Figure 4* reflect the recursive nature of these syntactic operations. If at LF and PF the syntactic representation does not violate the Principle of Full Interpretation, the derivation is said to *converge* at that level; otherwise it is said to *crash*. Spell-out is the point in the derivation where the Phonetic Representation is separated from the Semantic Representation. In earlier versions of Minimalist Syntax (Chomsky[27-28]), Spell-Out was assumed to apply only once, at the end of the derivation. In more recent versions (Chomsky[1-6] and Uriagereka[7]), this assumption has been revised in favor of a Multiple Spell-Out model of phasal derivations. This will be discussed in §4.2, but first we shall turn to the syntactic operations Merge, Move and Agree.

superficial order	**V** ʃakar-a thank.PAST-3M.SG	**S** aṭ-ṭulaab-u DEF-student.3M.PL-NOM	**O** al-muʕalim-aat-i DEF-teacher-3F.PL-ACC
grammatical function	V	S	O
constituency	VP	DP	DP
semantic role	predicator	agent	theme

Figure 4. The Syntactic model.

4.1 The syntactic operations

Merge is a structure-building operation. Triggered by feature checking requirements, Merge builds new phrase-markers in a bottom-up fashion by taking two syntactic objects X and Z (either numerated from the lexicon or constructed previously during the syntactic derivation) and combining them to form a larger syntactic object XP. We are assuming here that X is the element that is responsible for the selection and is therefore the head of the newly built structure. The new syntactic object XP is said to contain the original syntactic objects X and Z, which are sisters but are not linearized. To trigger the syntactic

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operation, the two syntactic objects X and Z will have a matching feature. Typically, the matching features will be uninterpretable [uF] on the head and interpretable [F] on the object it selects. As a result of the Merge operation, the uninterpretable feature will be deleted [uF]:

(9) *Merge: complement*

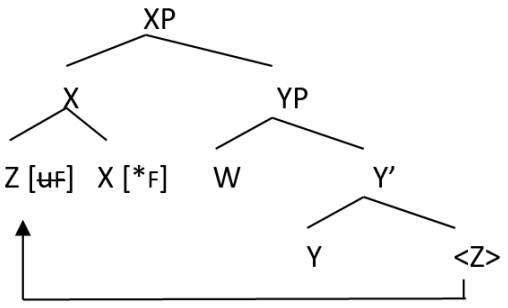
To Merge a specifier Y into (9), the feature that triggers the Merge operation would be allowed to percolate or trickle up to the node that immediately dominates the X-head from where it can check the matching feature of Y under sisterhood:

(10) *Merge: specifier*

In Minimalist Syntax (see Chomsky[28]), the X-bar schema is abandoned and replaced by the structural building operation Merge and the notion of bare phrase structure. So, although the structure built by the successive applications of Merge resembles the earlier Spec-Head-Comp structure of the X-bar schema (see Kayne[29]), Merge does not actually distinguish the X-bar and XP levels of projection. Each node receives the label of its projecting sub-node, and a maximal projection is simply the highest projection of a specific category. We are using the X-bar notation here only for its expository convenience.

Move is also a structure-building operation. Move takes a syntactic object Z, makes a copy of it, and moves it to a position higher up in the tree where it is adjoined to another syntactic object X. Move is triggered by feature strength: the syntactic object X contains in its feature specification a strong feature [*F], which attracts the closest constituent with a matching feature [uF]. Strong features must be checked locally under sisterhood:

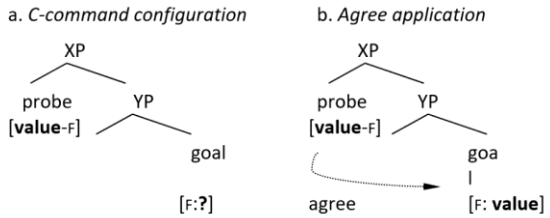
(11) *Move and adjoin*



Chomsky[2] treats movement simply as a form of Merge. He distinguishes External Merge, which involves taking an item from a lexical array and merging it with some other constituent, and Internal Merge, where an item contained within an existing structure is moved to a new position. An example of the latter would be V-raising, where the lexical V-head raises and adjoins to little *v* – see Step 2 of the OVS, SVO and VSO derivations in §5. An example of External Merge would be the head movement V to T to derive VSO word order – see Step 4 in §5.3.

Agree is a feature checking operation. It is responsible for structural dependency relations such as phi-feature (person, gender and number) agreement between DP controllers and verbal targets, and case assignment by a verbal controller to a DP target. The terms *controller* and *target* are used in the sense introduced in typology by Corbett[30], where agreement relation is seen to hold between a controller and a target within an *agreement domain*, and is said to involve *features* and *values* and be subject to *conditions*. The operation Agree allows features to be checked in situ without the need for movement. It establishes a c-command relation between an element (the *probe*) containing a valued feature [value-F] and another element (the *goal*), which bears a matching feature but which is unvalued [F: ?]: the goal is commanded by the probe. Under Agree, the unvalued feature on the goal is valued by the matching feature of the probe:

(12)



4.2 Phases and multiple spell-out

As we mentioned before, Chomsky[2,5] and Uriagereka[7] argue that Spell-Out and LF/PF convergence need not necessarily apply only once to the final syntactic object at the end of the derivation. Instead, during the course of the derivation, any "well-defined" sub-part, whose derivation is complete and whose presence/absence will have no consequence on the rest of the derivation, can be spelt out. The derivational complexity, therefore, can be reduced by dividing the lexical array that is numerated from the lexicon into sub-arrays, which are fed into the computational system to derive a particular phase. Upon the completion of the derivational cycle, each phase is separately transferred to the interfaces. This, of course, entails Multiple Spell-Out.

In our analysis, the syntactic objects that qualify as phases are CPs, TPs, *v*Ps and DPs (see Chomsky[4] for DPs being considered as phases). Chomsky[5] argues that phases are propositional in nature. By this criterion, CPs and transitive *v*Ps are ruled in, but TPs are not. CPs are complete clausal complexes containing full propositions, and transitive *v*Ps are complete thematic complexes. Along the same lines, there is evidence to support that in Arabic TPs also qualify as phases. We shall see that the maximal

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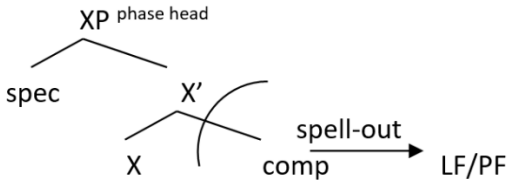
projection for the derivation of VSO word order, a complete clause that contains a full proposition, is TP (not CP) – see Step 4 in §5.3. Likewise, the maximal projection for the derivation of the pro-drop variants of OVS and SVO, both of them being complete clauses that contain full propositions, is TP (not CP) – see Step 4 in §5.1 and §5.2.

The spell-out of a phase head XP only triggers the LF/PF interpretation of the complement, but not the head and the specifier. The Phase Impenetrability Condition renders the complement of XP inaccessible to further operations in the syntax. The head and specifier – the edge of the phase – will remain accessible to further operations in the syntax, and ultimately, they will be spelt-out only at the next higher phase:

(13)



5. TREATMENT OF THE DATA

In what follows, we shall apply to our data (described in §2-3) the theoretical constructs of Minimalist Syntax explicated in §4 above. For expository convenience, we shall deal with the three constructions in descending order of complexity. This way, the derivational tools deployed to deal with the most complex of the three constructions (OVS in §5.1) can be redeployed to deal with the syntactically more basic word orders (SVO and VSO in §5.2 and 5.3, respectively). In other words, the derivation of the simpler constructions will largely follow from the derivation of the more complex one.

5.1 Deriving OVS

In order to derive the example sentence in (2), repeated here as (14), a lexical and functional array with the feature specification presented in *Table 1* would need to be numerated from the lexicon:

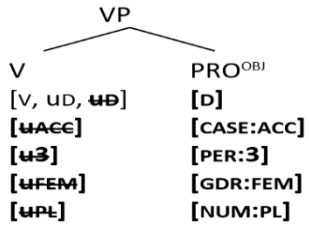
Table 1: Numeration for deriving OVS

Features	Lexical and Functional Categories						
node	(C)	(DP^{TOP})	T	DP^{SUBJ}	*v*	V	PRO^{OBJ}
category	[C]	[TOP]		[D]	[*V]	[V]	[D]
c-selection			[uTOP]			[uD, uD]	
tense			[PAST]		[INFL: ?]		
case	[uACC]	[CASE: ?]	[uNOM]	[CASE: ?]		[uACC]	[CASE: ?]
person		[3]		[3]	[PER: ?]	[u3]	[PER: ?]
gender		[FEM]		[MASC]	[GDR: ?]	[uFEM]	[GDR: ?]
number		[PL]		[PL]		[uPL]	[NUM: ?]

(14) al-muʕalim-aat-u ʃakar-a-hun aṭ-ṭulaab-u
DEF-teacher-3F.PL-NOM thank.PAST-3M.SG-3F.PL DEF-student.3M.PL-NOM
'The teachers, the students thanked them.'

The derivation would then proceed in two phases: the *v*P phase (Steps 1-4) and the CP phase (Steps 5-6):

(15)

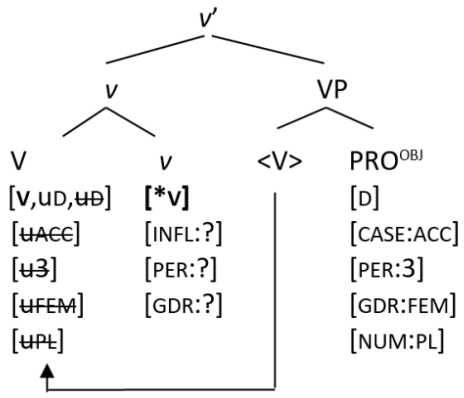


Step 1.1: Merge the verb (V – *ʃakar-a-hun*) with the null object (PRO^{OBJ}), satisfying the uninterpretable c-selection feature [uD] associated with the object argument. The unvalued case feature [CASE: ?] of PRO^{OBJ} and the uninterpretable case feature [uACC] of V agree. As a result, the case feature of PRO^{OBJ} is valued as [CASE: ACC] and the uninterpretable case feature of V is deleted [uACC]. The unvalued person [PER: ?], gender [GDR: ?] and number [NUM: ?] features of PRO^{OBJ} are treated in the same way: they are valued by their corresponding uninterpretable features on V via operation Agree. This configuration checks the rich agreement features of the verbally bound pronominal clitic *-hun*.

In dealing with the VSO-SVO agreement asymmetry, Soltan[20] claims that the difference is simply a consequence of whether the structure contains a PRO or not: the presence of PRO always requires rich agreement at the interface. This suggestion is extended here to tackle rich agreement with a topicalized object.

Step 1.2: Though the PRO^{OBJ} now contains only interpretable features, it cannot be spelt-out as it is a null category that lacks a phonological form and therefore would be uninterpretable at PF. It will remain in the derivation together with the lexical V-head, which still contains an uninterpretable c-selection feature [uD].

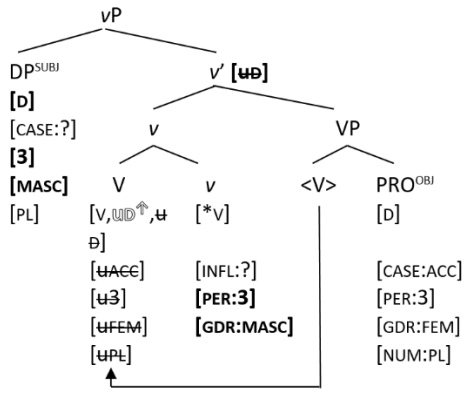
(16)



Step 2.1: Merge the null functional head, little *v*, with the output of Step 1. Attracted by the strong verb feature [*V], the lexical head V raises and adjoins to little *v*. Little *v* hosts the tense feature of the verb [INFL: ?], as well as the person [PER: ?] and gender [GDR: ?] features responsible for the poor verbal agreement with the subject. For now, they will remain unvalued. Poor agreement is accounted for simply by not specifying little *v* with a number feature.

Step 2.2: In addition to the uninterpretable c-selection feature [uD] hosted by V (carried over from Step 1), the syntactic representation of the verb complex [*v*'[*v*][VP[V][PRO^{OBJ}]]] now contains an unvalued tense [INFL: ?], as well as person [PER: ?] and gender [GDR: ?] agreement features hosted by little *v*:

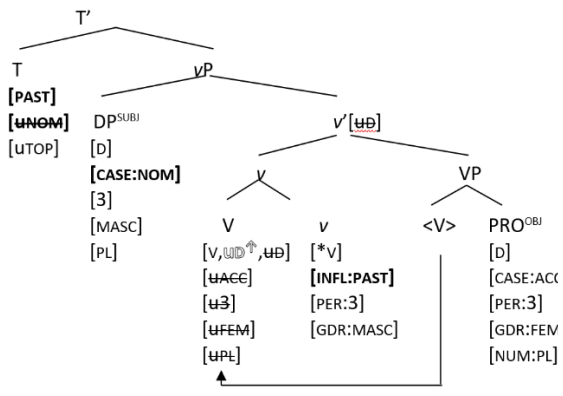
(17)



Step 3.1: Merge the subject (DP^{SUBJ} – *aʃ-ʃulaab-u*) with the output of Step 2. The uninterpretable c-selection feature [uD] on the V-head percolates up to the little *v*-bar node, where it is checked under sisterhood against the category feature [D] of the DP^{SUBJ}. The unvalued person [PER: ?] and gender [GDR: ?] agreement features on the little *v*-head are valued by the interpretable person [3] and gender [MASC] features of the DP^{SUBJ} under command via operation Agree.

Step 3.2: Little *v*-head still contains an unvalued tense feature [INFL: ?], while the DP^{SUBJ} contains an unvalued case feature [CASE: ?]:

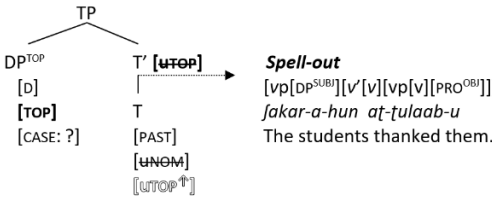
(18)



Step 4.1: Merge the functional head of the sentence, the null T, with the output of Step 3. The unvalued tense feature [INFL: ?] on little *v* is valued under c-command by the interpretable tense feature [PAST] of T via operation Agree. The unvalued case feature [CASE: ?] on the NP^{SUBJ} is treated in the same way, as it is valued by the uninterpretable case features [uNOM] of T.

Step 4.2: The syntactic representation of the little *v*P does not contain any uninterpretable or unvalued feature. The little *v*P complex [*v*P[DP^{SUBJ}][*v*'[*v*][VP[V][PRO^{OBJ}]]]] can now be spelt-out. This marks the end of the *v*P derivational phase. The phase is transferred to the interfaces and thus no longer bothers the computation with its weight. The Phase Impenetrability Condition renders the *v*P complex inaccessible to further operations in the syntax. This conceptual advantage is supported by empirical data. Step 4 seems like a natural place to end a phase. The difference between the pro-drop variant of OVS – see example (3a) – and the OVS topic-comment structure in (2), repeated as (14), hinges on whether the numerated T-head contains the discourse feature [uTOP] or not. If the T-head does not contain the discourse feature [uTOP], the derivation ends at Step 4 and the pro-drop variant of OVS is generated. In that case, the need to spell-out the *v*P phase separately could be alleviated, and the entire structure represented in Step 4 would simply be spelt-out as a TP. On the other hand, if the T-head contains an uninterpretable discourse feature [uTOP], the derivation will continue until ultimately the OVS topic-comment structure is generated. In this case, the T-head is a phase edge, accessible to further syntactic operations:

(19)



Step 5.1: Merge the topic (DP^{TOP} – *al-muʕalim-aat-u*) with the output of Step 4. The uninterpretable c-selection feature [uTOP] of T percolates up to T-bar, where it is checked under sisterhood by the category feature [TOP] of the DP^{TOP}. We shall account for the definiteness constraint discussed in §1.3 simply by postulating that the category feature [TOP] on the DP^{TOP} will ensure that it is definite.

Step 5.2: The syntactic representation of the DP^{TOP} still contains an unvalued case feature [CASE:?] and will therefore remain in the syntactic derivation:

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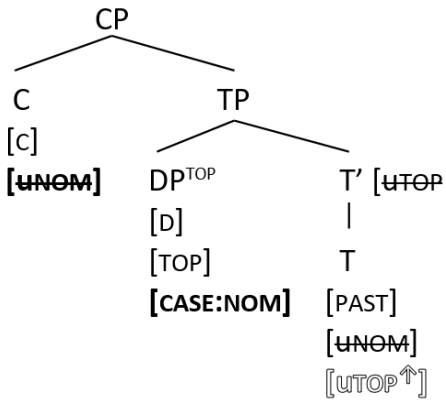
(20)



Step 6.1: Merge the null C-head with the output of Step 5. The unvalued case feature [CASE:?] on the DP^{TOP} is valued under command by the uninterpretable case feature [uNOM] of C via operation Agree. This checking configuration accounts for the fact that topicalized objects are assigned nominative case.

Step 6.2: To account for the fact that the topicalized object may be assigned accusative case by the emphatic complementizer *ʔinna* (see (5a)), we could simply assume that when *ʔinna* is numerated in place of the null C-head, it is specified for an uninterpretable case feature [uACC].

Step 6.3: The syntactic representation of the CP has been rid of all uninterpretable features, and all unvalued features have been valued. The CP complex [CP[TP[DP^{TOP}][T'[T]]]] can now be spelt-out, marking the end of the CP derivational phase and the end of OVS derivation.

At this stage, there is no further syntactic operation that can apply. The derivation has "run out of fuel", meaning that all of the uninterpretable features have been checked and deleted, and all unvalued features have been correctly valued. All of the properties of OVS word order discussed in §3.1-3.3 and summarized schematically in *Figure 1* have been adequately accounted for. These include verbal agreement by multiple controllers (subject and object), case properties of the topicalized object (nominative and accusative), and the possibility of pro-dropping the topicalized object.

5.2 Deriving SVO

In order to derive the example sentence in (1b), repeated here as (21), a lexical and functional array with the feature specification presented in *Table 2* would need to be numerated from the lexicon:

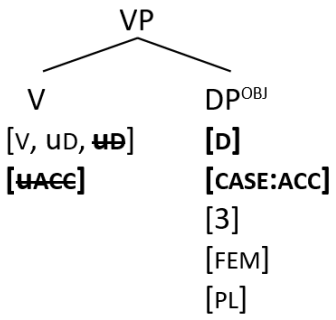
Table 2: Numeration for deriving SVO

Features	Lexical and Functional Categories						
node	(C)	(DP^{TOP})	T	PRO^{SUBJ}	*v*	V	DP^{OBJ}
category	[C]	[TOP]		[D]	[*V]	[V]	[D]
c-selection			[uTOP]			[uD, uD]	
tense			[PAST]		[INFL: ?]		
case	[uACC]	[CASE: ?]	[uNOM]	[CASE: ?]		[uACC]	[CASE: ?]
person		[3]	[u3]	[PER: ?]			[3]
gender		[MASC]	[uMASC]	[GDR: ?]			[FEM]
number		[PL]	[uPL]	[NUM: ?]			[PL]

(21) aʈ-ʈulaab-u ʃakar-uu al-muʕalim-aat-i
DEF-student.3M.PL-NOM thank.PAST-3M.PL DEF-teacher-3F.PL-ACC
'The students, they thanked the teachers.'

The derivation of SVO would involve three phases: the DP phase (Step 1), the *v*P phase (Steps 2-4) and the CP phase (Steps 5-6):

(22)

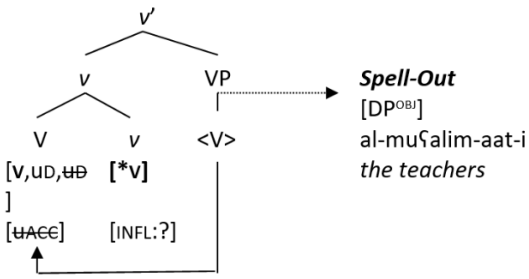


Step 1.1: Merge the verb (V – *ʃakar-uu*) with the object (DP^{OBJ} – *al-muʕalim-aat-i*), satisfying the uninterpretable c-selection feature [uD] associated with the object argument. The case feature of DP^{OBJ} is valued as [CASE: ACC] and the un-interpretable case feature is deleted [uACC].

Step 1.2: Unlike the PRO^{OBJ} of OVS, the object of SVO is an overt DP, which can be spelt-out at this stage. The DP derivational phase is transferred to the interfaces, and the computation is no longer bothered with its weight.

Step 1.3: The lexical V-head, which still contains an uninterpretable c-selection feature [uD], is a phase edge, accessible to further syntactic operations:

(23)



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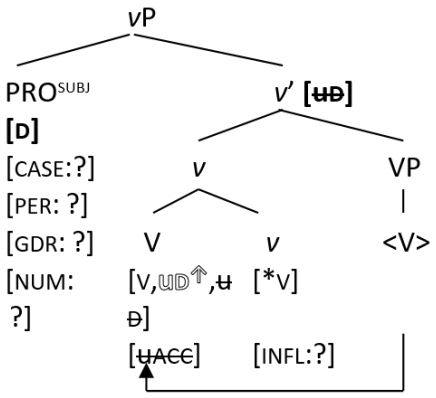
Step 2.1: Merge the null functional head, little *v*, with the output of Step 1. The lexical head V raises and adjoins to little *v*. Little *v* hosts the tense feature of the verb [INFL:?], which for now will remain unchecked.

Step 2.2: In addition to the uninterpretable c-selection feature [uD] hosted by V (carried over from Step 1), the syntactic representation of the verb complex [*v*'[*v*][VP[V][DP^{OBJ}]]] now contains an unvalued tense feature [INFL: ?] hosted by little *v*:

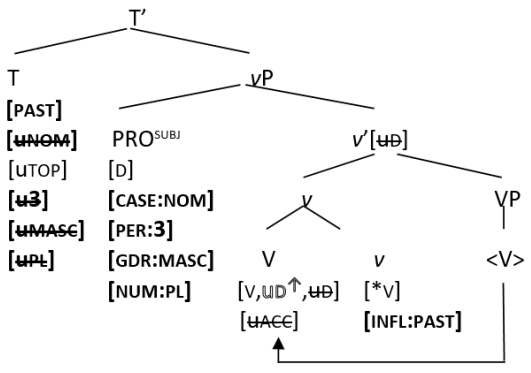
(24)



Step 3.1: Merge the null subject (PRO^{SUBJ}) with the output of Step 2. The uninterpretable c-selection feature [uD] on the V-head percolates up to the little *v*-bar node, where it is checked against the category feature [D] of the PRO^{SUBJ}.

Step 3.2: The little *v*-head still contains an unvalued tense feature [INFL: ?], while the PRO^{SUBJ} contains an unvalued case feature [CASE: ?], as well as the unvalued person [PER: ?], gender [GDR: ?] and number [NUM: ?] features responsible for rich verbal agreement with the topicalized subject:

(25)



Step 4.1: Merge the functional head of the sentence, the null T with the output of Step 3. The unvalued tense feature [INFL: ?] on little *v* is valued under command by the interpretable tense feature [PAST] of T via operation Agree. Similarly, the unvalued person [PER: ?], gender [GDR: ?] and number [NUM: ?] features, and the unvalued case feature [CASE: ?] of the PRO^{OBJ} are valued by their corresponding uninterpretable features of T.

Step 4.2: As with Step 4 of OVS (§5.1), at this stage in the derivation, the syntactic representation of the little *v*P does not contain any uninterpretable or unvalued feature. The little *v*P complex [*v*P[PRO^{SUBJ}][*v*'[*v*][VP[V]]]] can now be spelt-out. The *v*P derivational phase is transferred to the interfaces, and the computation is no longer bothered with its weight.

Step 4.3: Again, as with Step 4 of OVS, the difference between the pro-drop variant of SVO in (3b) and the SVO topic-comment structure in (1b), repeated as (21), hinges on whether the numerated T-head contains the discourse feature [uTOP] or not. If the T-head does not contain the discourse feature [uTOP], the derivation ends at Step 4 and the pro-drop variant of SVO is generated. As with OVS, Step 4 would simply be spelt-out as a TP. If the T-head contains an uninterpretable discourse feature [uTOP], the derivation will continue until ultimately the SVO topic-comment structure is generated. The T-head is a phase edge, accessible to further syntactic operations.

Steps 5 and 6: The rest of the derivation proceeds in the same manner as Steps 5 and 6 of the derivation of OVS, the only difference being that here the DP^{TOP} that is Merged in as a specifier of T is the topicalized subject *aṭ-ṭulaab-u*, rather than the topicalized object *al-muʕalim-aat-i*. Also, the case properties of the DP^{TOP} in the absence and presence of *ʔinna* are accounted for in the same way. Finally, the syntactic representation of the CP has been rid of all uninterpretable features, and all unvalued features have been valued. The CP complex [CP[TP[DP^{TOP}][T]]] can now be spelt-out, marking the end of the CP derivational phase and the end of the SVO derivation.

5.3 Deriving VSO

In order to derive the example sentence in (1a), repeated here as (26), the lexical and functional array with the feature specification presented in *Table 3* would need to be numerated from the lexicon:

Table 3: Numeration for deriving VSO

Features	Lexical and Functional Categories				
node	**T**	**DP^{SUBJ}**	***v***	**V**	**DP^{OBJ}**
category		[D]	[*V]	[V]	[D]
c-selection				[**u**D, **u**D]	
tense	[*PAST]		[INFL: **?**]		
case	[**u**NOM]	[CASE: **?**]		[**u**ACC]	[CASE: **?**]
person		[3]	[PER: **?**]		[3]
gender		[PL]	[NUM: **?**]		[PL]
number		[MASC]			[FEM]

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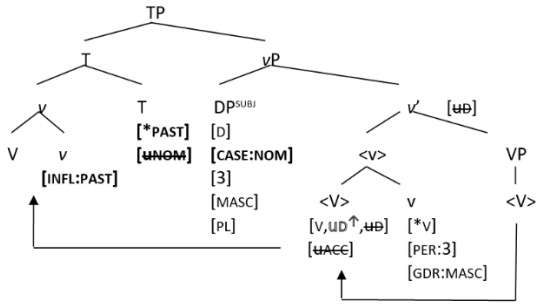
(26) ʃakar-a aṭ-ṭullaab-u al-muʕalim-aat-i
thank.PAST-3M.SG DEF-student.3M.PL-NOM DEF-teacher-3F.PL-ACC
'The students thanked the teachers.'

The derivation would involve two phases: the DP phase (Step 1) and the TP phase (Steps 2-4).

Step 1: Repeat Step 1 of the derivation of SVO, only this time it is the verb *ʃakar-a* (not *ʃakar-uu*) that is merged.

Steps 2 and 3: Repeat Steps 2 and 3 of the derivation of OVS.

(27)



Step 4.1: Merge the functional head of the sentence, the null T, with the output of Step 3. The unvalued case feature [CASE:?] of the DP^{SUBJ} is valued under command by the uninterpretable case feature [uNOM] of T via operation Agree. The unvalued tense feature [INFL: ?] of little *v* is attracted by the strong tense feature [*PAST] of T: little *v* raises and adjoins to T for local checking under sisterhood, thus deriving the superficial VS order.

Step 4.2: The syntactic representation of the TP has been rid of all uninterpretable features, and all unvalued features have been valued. The TP complex [TP[T][*v*P[DP^{SUBJ}][*v*'[*v*][VP[V]]]]] can now be spelt-out, marking the end of the TP derivational phase and the end of the VSO derivation.

6. SUMMARY AND CONCLUSION

The derivations of the word order types OVS, SVO and VSO in §5 account for a total of seven constructions. In addition to the topic-comment OVS and SVO constructions schematized in *Figure 1* and *Figure 2*, we have also accounted for their corresponding *ʔinna*-headed and pro-drop variants. *Table 4* summarizes the derivational phases involved in each construction and accentuates the key properties that distinguish the constructions from each other:

Table 4: Summary of the derivational phases

Construction	Derivational Phases	Distinctive Properties
OVS [topic-comment]	CP > *v*P	T [uTOP], null C [uNOM]
OVS [*ʕinna*-headed]	CP > *v*P	T [uTOP], overt C [uACC]
OVS [pro-drop]	TP	T without [uTOP]
SVO [topic-comment]	CP > *v*P > DP	T [uTOP], null C [uNOM]
SVO [*ʕinna*-headed]	CP > *v*P > DP	T [uTOP], overt C [uACC]
SVO [pro-drop]	TP > DP	T without [uTOP]
VSO	TP > DP	T [*PAST]

OVS is distinct from the other two-word orders in that it does not involve a DP phase. The justification for this is that the object that is base-generated as a complement of the lexical V-head is a PRO, a null category which lacks phonological form and therefore would not be interpretable at PF. In contrast to this, the object of SVO and VSO word orders is an overt DP, which would be interpretable and therefore can be spelt-out.

The highest derivational phase for the pro-drop variants of OVS and SVO word orders, and also for VSO word order is TP, not CP. This claim is empirically supported by the fact that at this stage of the derivation the structural representation of these constructions constitutes a full clause/thematic complex.

In the derivation of the OVS and SVO constructions the difference between the pro-drop variant and the non-pro-drop variants, in other words the OVS [topic-comment] and OVS [*ʔinna*-headed] structures, is that in the case of the latter the T-head is specified for a c-selection feature [uTOP] which forces a DP^{TOP} to Merge into the specifier position of the T-head and ensures that the DP^{TOP} is definite. Since the pro-drop variant does not allow a DP in that position, it is not specified for such a feature.

In relation to the same constructions (OVS and SVO), the difference between the *ʔinna*-headed and the non-*ʔinna*-headed variants is that in the case of the latter the C-head is a null category which assigns nominative case [NOM] to the DP^{TOP}. However, in the case of the *ʔinna*-headed variants the DP^{TOP} is assigned accusative case [ACC] by an over C-head, the emphatic complementizer *ʔinna*.

In the derivation of the VSO construction, the superficial VS word order is achieved by means of a strong tense feature [*past] on the T-head. This feature forces the verb to raise and adjoin to the T-head, where it can be checked in a local configuration under sisterhood.

To conclude, *Table 5* summarizes the mechanisms used to check verbal phi-feature agreement, and *Table 6* the checking mechanisms used to account for the various types of case assignment:

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Table 5: Checking mechanism for verbal phi-feature agreement

Agreement Type	Syntactic Configuration	Checking Configuration	
Rich – Topic of OVS	[VP[**V**][**PRO**^{OBJ}]]	**V** [~~u3~~] [~~uFEM~~] [~~uPL~~]	**PRO**^{OBJ} [PER: 3] [GDR: FEM] [NUM: PL]
Poor – Subject of OVS/VSO	[*v*P[**DP**^{SUBJ}][*v*′[***v***]]]	**DP**^{SUBJ} [3] [MASC]	***v*** [PER: 3] [GDR: MASC]

Table 6: Checking mechanism for case feature assignment

Case Recipient	Syntactic Configuration	Checking Configuration	
Topic of OVS/SVO (by null C)	[CP[**C**][TP[**DP**^{TOP}][T]]]	**C** [~~uNOM~~]	**DP**^{TOP} [CASE: NOM]
Topic of OVS/SV (by overt C)	[CP[**C**][TP[**DP**^{TOP}][T]]]	**C** [~~uACC~~]	**DP**^{TOP} [CASE: ACC]
Subject of SVO (clitic *-uu*)	[TP[**T**][*v*P[**PRO**^{SUBJ}][*v*′]]]	**T** [~~uNOM~~]	**PRO**^{SUBJ} [CASE: NOM]
Subject of VSO	[TP[**T**][*v*P[**DP**^{SUBJ}][*v*′]]]	**T** [~~uNOM~~]	**DP**^{SUBJ} [CASE: NOM]
Object of OVS (clitic *-hun*)	[VP[**V**][**PRO**^{OBJ}]]	**V** [~~uACC~~]	**PRO**^{OBJ} [CASE: ACC]
Object of SVO/VSO	[VP[**V**][**DP**^{OBJ}]]	**V** [~~uACC~~]	**DP**^{OBJ} [CASE: ACC]

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Productivity Enhancement by Re-Perforation in Abu-Attifel Oil Field - Libya: A Case Study

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ABSTRACT

The Libyan National Oil Corporation (NOC) announced a strategic plan at the beginning of 2023 to increase the level of oil production to two million barrels per day. Companies operating in the oil sector have, in turn, started implementing NOC's plan to increase recovery rates from the fields they operate. Mellitah Oil and Gas B.V. Company, Libya branch, started developing measures to enhance production in the Abu-Attifel Oil field. The company sought to enhance the productivity of the two wells, A1 and A3, located in the A100 concession, from the upper Nubian Sandstone reservoir using the Re-perforation technique, as the level of production from these two wells had decreased due to scale formation caused by the accompanying water during production and high temperatures, which led to closing some of perforation intervals. In February 2024, the company succeeded in increasing oil production by 976 STB/D in the A1/A100 well and by 557 STB/D in the A3/A100 well, compared to late 2023 levels, which reflecting the efficacy of the Re-perforation technique in mitigating scale-related issues and optimizing reservoir performance.

KEYWORDS: Productivity Enhancement, Re-perforation Technique, Abu Attifel Oil Field, Sandstone Reservoir.

1. INTRODUCTION

The National Oil Corporation (NOC) has been dedicatedly striving to improve oil production rates from the Libyan oil fields. To achieve this target, the NOC devised a strategic plan in February 2023, to reach a production level of two million barrels per day. As a result, companies operating within the oil sector have undertaken various measures to boost their oil recovery rates.

Different stimulation techniques are employed by these companies to enhance oil recovery. These techniques involve hydraulic fracturing, acid jobs, perforation extension, and re-perforation, which is the simplest and most economical option [(1)]. Mellitah Oil & Gas B.V. Company, in which the NOC shares 85% ownership with the Italian Eni [(2)], has initiated the implementation of this strategic plan across the fields under its operation, including the Abu Attifel oil field. This onshore field is located approximately 60 kilometers away from the city of Gallo, situated in the Sirte Basin, which is the largest sedimentary basin in Libya.

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The Abu Attifel oil field was initially discovered back in 1967 in the A100 concession. Since then, the field has played a crucial role in the country's oil production. The field primarily taps into a sandstone reservoir that operates under a water drive mechanism [(3)]. The company executed the re-perforation process in many wells, including wells A1 and A3, which are the focus of the study.

2. RESERVOIR CHARACTERISTICS

The two clastic units are the main reservoirs of the A100 concession, locally known as Lower Nubian Sandstone and Upper Nubian Sandstone, separated by Varicoloured Shale [(4)]. The main petrophysical characteristics of Upper Nubian Sandstone are shown in Table 1.

Table 1: Reservoir Characteristic

Net Pay ft	Av. Phi %	Av. Sw %	Av. Permeability K, md
633	13	22	50

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3. PRODUCTIVITY ENHANCEMENT

One way to enhance productivity is to stimulate the well, as stimulation refers to increasing the production of the well that has been damaged. This damage obstructs the flow of fluids; one of its causes is the blockage of perforations in the well casing. The clogging of the holes in the casing is due to the precipitation of minerals (the formation of scales) [5].

Water is the major source of all scale formation, and when water is produced along with oil and gas - as in the field of Abu Attifel - different types of scale are formed in the reservoir or the production tubing. The scale can deposit in the form of a thick layer in the wellbore tubing, which reduces the production diameter of the tubing, resulting in impaired flow, production equipment failure, emergency shutdown, and increased maintenance cost [6, 7]. High temperature is also a cause of this problem [8], as the Flowing Tubing Head Temperature (FTHT) reaches up to 236O F in the A1/A100 well and 204O F in the A3/A100 well.

This paper aims to identify the extent of the well's response to the re-perforation process as a stimulation technique for removing scale that closes some of the perforation intervals to enhance productivity.

4. A1/A100 Well History

The A1 Well is the first well drilled in the A100 concession. In February 1968, an A1 oil well was drilled and completed. The well targeted the Upper Nubian Sandstone in the perforation intervals (13,998' – 14,024'), achieving a production rate of 1,654 STB/D and 0% WC. In 1973, after several perforation extension and re-perforation operations, the highest production rate of 19,692 STB/D was achieved. However, by 1988, the water-producing layers 13,645'-13,710' and 13,776'-13,890' had to be isolated due to an increased water cut (WC) of 66%, resulting in a significant decline in the oil production rate to 812 STB/D.

According to the data shown in Table 2, the oil production rate during the period from April to November decreased by approximately 785 STB/D Fig.1. The rate of gas production also decreased by approximately 3,000MSCF/D in the same period Fig.2, with an increase in water cut reaching 72% Fig.3.

Table 2: A1Well Routine Tests History

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
01.Apr.2023	850	236	1577	4305	2504	2733	61	16
05.May.2023	619	233	1529	3520	N/A	2299	52	46
30.Jun.2023	910	232	1365	4706	2350	3449	63	80
11.Aug.2023	850	233	1243	4002	2435	3220	66	12
21.Nov.2023	750	216	792	1411	2035	1783	72	80

In November 2023, a Production Logging Test (PLT) was conducted. The test results were as follows:

- The most significant contribution intervals were observed at the top (13,345' -13,350'), as the test did not cover to the bottom up to 13,444'.
- Some parts of the perforations showed very minor contributions that could not be quantified.
- Gamma Ray (GR) readings indicated the presence of scale, which might potentially impact production efficiency and further complicate operations

4.1 Well Stimulation Decision

Based on the PLT test results indicating the presence of scale and insufficient contribution from some perforations, along with the reservoir characteristics outlined in Table 1 and the well's history spanning over 55 years, which showcased a positive response to improvement through Re-perforation, the decision was made to re-perforate the intervals specified in Table 3.

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Table 3: Required Re-perforation intervals

Interval No.	From ft	To ft	Height ft	Type of gun/SPF/phase
1	13,350	13,360	10	2" power jet nova gun (6SPF,60º)
2	13,368	13,385	17	

4.2 Well Stimulation Results (Re-Perforation)

After completing the procedure of re-perforating in-under-balance conditions with the requested gun, a routine test was conducted on February 11, 2024, and the results were as shown in Table 4 and Fig.1, 2, 3.

Table 4 : A1/A100 Well Routine Test Results

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
11.Feb.2024	928	234	1768	5715	2387	3232	57	52

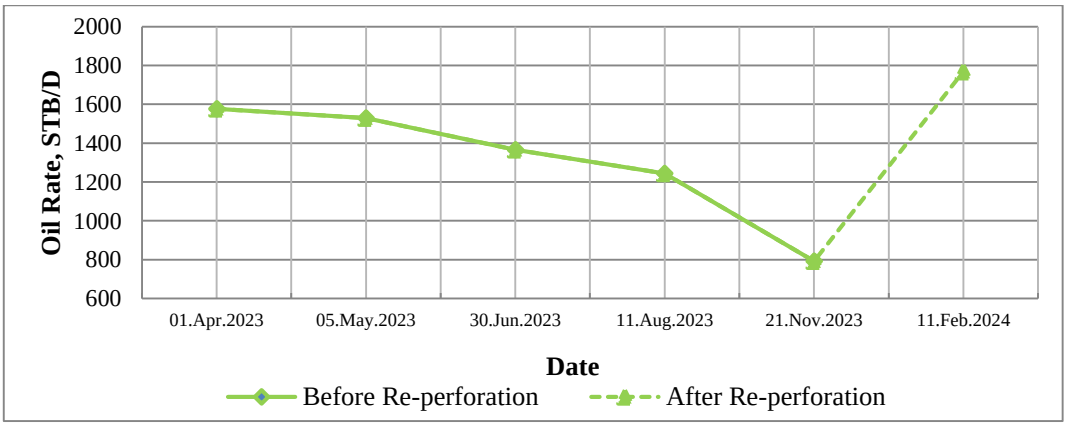

Fig. 1: A1 Well Oil Rate vs. Date

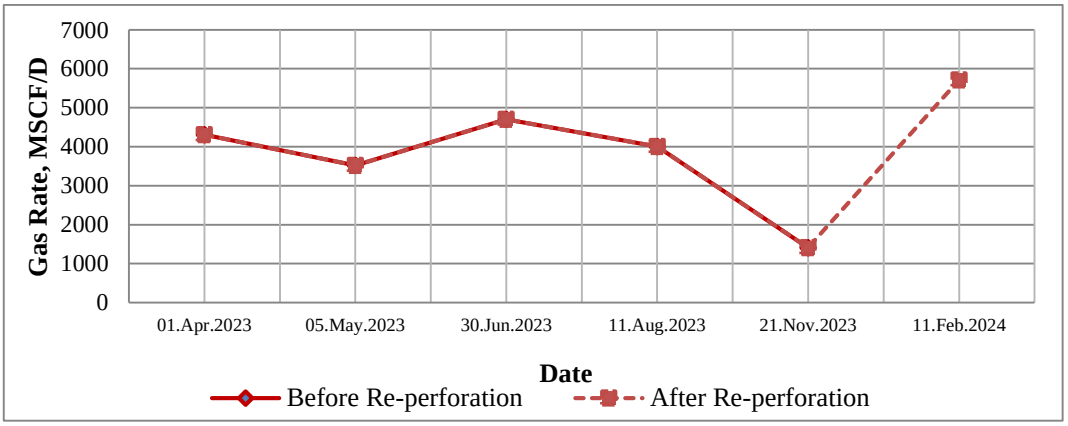

Fig. 2: A1 Well Gas Rate vs. Date

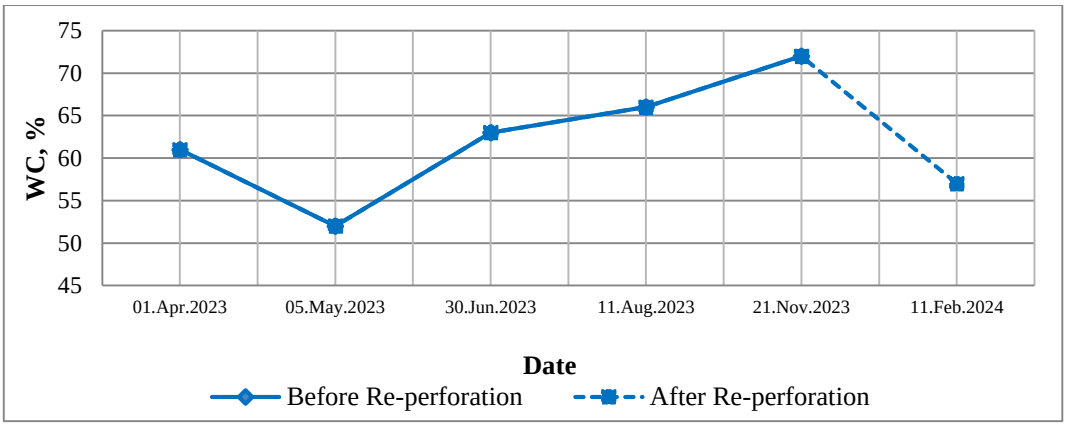

Fig. 3: A1 Well Water Cut vs. Date

5. A3/A100 Well History

The well was drilled and completed in the A100 concession in mid-1969 in the main area of the Upper Nubian Sandstone with perforated intervals (13,814'-14,173') covering a distance of 210 feet. Production commenced in the latter part of the first quarter of 1972, with a production rate of 5,674 STB/D and GOR 1,771MSCF/STB.

As mentioned earlier, the issue of scale formation due to accompanying water and high temperature persists as a common challenge in mature fields. Scale removal jobs were carried out in 1994 and during the years 2002 and 2003. Subsequently, extension perforation and re-perforation procedures were implemented, resulting in an increase in Water Cut.

The history of water cut for well A3 showcases a series of significant increases over the years, with notable spikes occurring in 1998, 2004, and 2007, ultimately peaking at 93% in November 2020. Each time, to address this issue, water shut off (WSO) operations were conducted, the last one was in August 2021, leading to a successful mitigation of the problem. The Top of Cement (TOC) was established at 13,634', resulting in a considerable reduction of the WC percentage to 29%.

With the success of the last operation in 2021, a remarkable 64% reduction in WC was achieved, consequently enhancing oil production from 365 to 1,692 STB/D.

Table 5 presents the results of the routine well test conducted in from March November 2023, while Fig. 4, 5, 6, illustrate the production rates of oil (Qo) and gas (Qg) and WC% plotted against the dates for same period.

Table 5: A3 Well Routine Tests History

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
23.Mar.2023	1650	202	1542	2095	524	1533	23	32
27.May.2023	1440	220	1930	3666	557	1901	22	30
14.Agu.2023	1360	221	1866	4067	487	2179	21	10
30.Nov.2023	1050	204	1529	2700	216	1775	13	32

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Also, in Jan 2024, a PLT test was conducted. The test results were: Slightly contributed to the top interval (13,603' -13,610').

5.1 WELL STIMULATION DECISION

Based on the PLT test results that indicated slight contribution from the top interval (13,603' - 13,610') and considering the reservoir characteristics outlined in Table 1, along with the well's history spanning over 55 years, which exhibited a positive response to enhancing productivity through Re-perforation, the decision was made to re-perforate the interval specified in Table 6.

Table 6: Required Re-perforation interval

Interval No.	From ft	To ft	Height ft	Type of gun/SPF/phase
1	13,603	13,610	7	2" power jet nova gun (6SPF,60º)

5.2 WELL STIMULATION RESULTS (RE-PERFORATION)

After completing the procedure of re-perforating in-under-balance conditions with the requested gun, a routine test was conducted on February 18, 2024. The results are detailed in Table 7 and depicted in Fig. 4, 5, 6.

Table 7 : A3 Well Routine Test Results

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
18.Feb.2024	770	217	2086	3525	770	1709	27	80

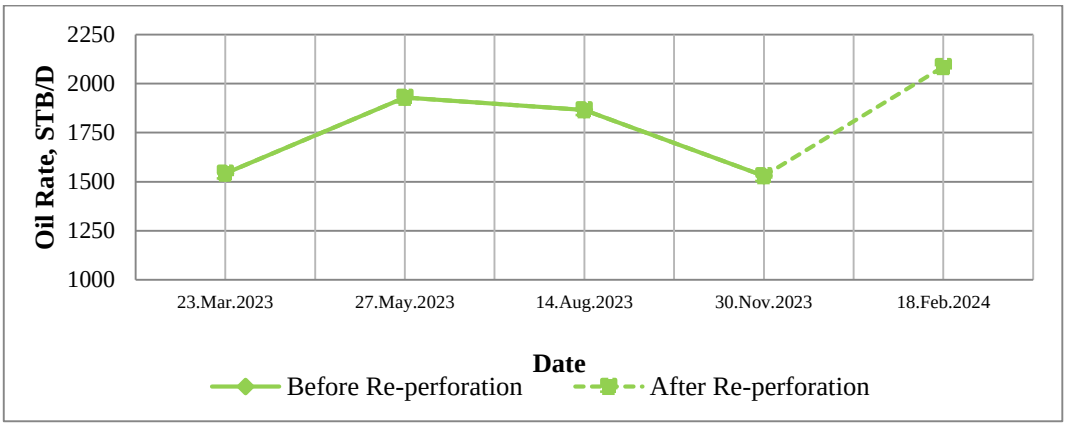

Fig. 4: A3 Well Oil Rate vs. Date

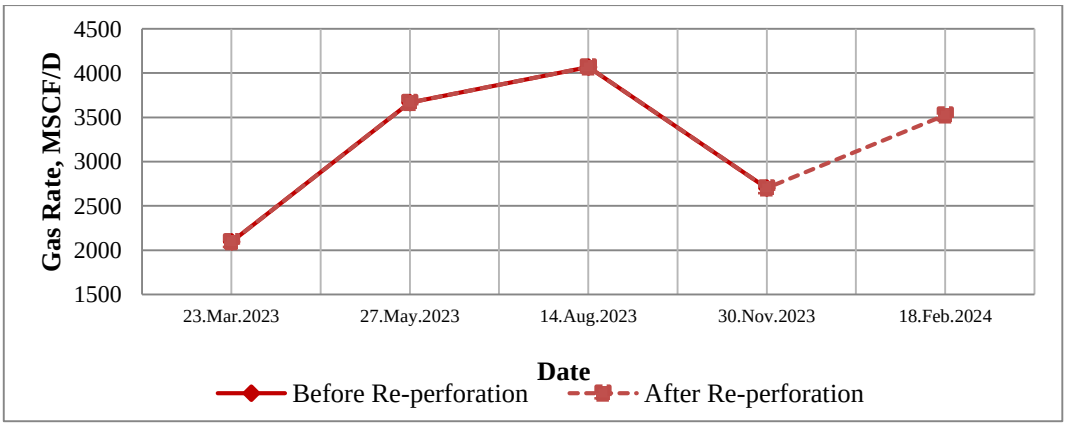

Fig. 5: A3 Well Gas Rate vs. Date

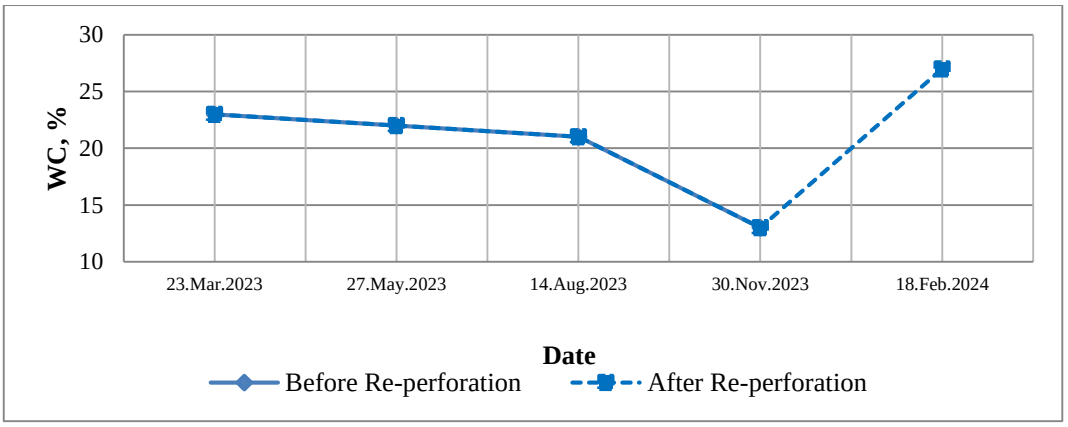

Fig. 6: A3 Well Water Cut vs. Date

6. Discussion and Recommendations

The sandstone reservoir in the A100 concession has demonstrated a notable response to well productivity enhancement techniques such as re-perforating. This has resulted in significant improvements in oil and gas production. Additionally, isolating the water-producing layers has effectively reduced the WC.

However, the historical data from the A1 well reveals a considerable decline in production since May 1973, primarily due to scale formation, which engineers successfully addressed this issue through re-perforation or extending the perforation. Also, the company's reports indicate a successful reduction of the WC to 12% in 2019, either by isolating the water layers or repairing casing patches. However, there has been a concerning increase in the WC reaching 54% in 2022 and 72% by the end of 2023. The decrease by 15% in the WC in 2024 is attributed to the large increase in the oil production rate compared to the water production rate as indicated in the Table 2 and Table 4 after re-perforation process. Therefore, it is recommended to conduct further PLT testing, starting from a depth of 13,444 ft, to isolate the potential water-producing layers or investigate any shifting of the water-oil contact (WOC) by using cased hole saturation tool to check the changing in water saturation.

In the case of well A3, the historical data reveals a series of scale removal jobs conducted between 2001 and 2003, in addition to several perforation extensions and re-perforations were carried out until 2007, where these jobs led to a significant increase in the WC, rising from 25% to 93%, while oil production saw a decline to 365 STB/D. The engineers successfully addressed this issue by implementing several WSO jobs, ultimately reducing the WC to 29% by August 2021. After the last re-perforation job in Feb. 2024, the WC returns to increase by 14%, i.e. from 13% to 27%. This increase is due to the increase in the rate of water production, which is close to the increase in the rate of oil production referred to in the Table 5 and Table7 after re-perforation process. To address this challenge effectively, it is recommended to run reservoir saturation tool RST to monitor the shifting of WOC for closing the perforation intervals that significantly contribute to water production, and conducting a perforation extension process in zones with high oil saturation.

7. CONCLUSION

- Success of the process of enhancing the productivity of wells A1/A100 and A3/A100 by re-perforating in the recommended intervals.
- In February 2024, the oil production rate in the A1/A100 well increased by 976 STB/D (from 792 STB/D to 1,768 STB/D) and in the A3/A100 well by 557 STB/D (from 1,529 STB/D to 2,086 STB/D) compared to November 2023.
- The rate of gas production in Feb.2024 increased by 4304MSCF/D in A1/A100 well and 825 MSCF/D in A3/A100 well i.e. from 1411 MSCF/D to 5715 MSCF/D in A1/A100 well and from 2700 MSCF/D to 3525 MSCF/D in A3/A100 well compared to what it was in late 2023.
- The water cut (WC) increased after Re-perforation by 14% in the A3/A100 well i.e. from 13% to 27%, due to the increased of water rate production and decreased by 15% in A1/A100 well i.e. from 72% to 57%.

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Nomenclature

FTHT: Flowing Tubing Head Temperature

FTHP: Flowing Tubing Head Pressure

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GR: Gamma Ray log

MSCF/D: Thousand Standard Cubic Feet per Day

PLT: Production logging test

Qo: Oil Production Rate

Qg: Gas Production Rate

SPF: Shots per Foot

STB/D: Stock Tank Barrel per Day

TOC: Top of Cement

WC: Water Cut

WSO: Water Shut Off

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Evaluation of Air Quality Status Near the Industrial Zone of Brega City Using Pollution Indicators

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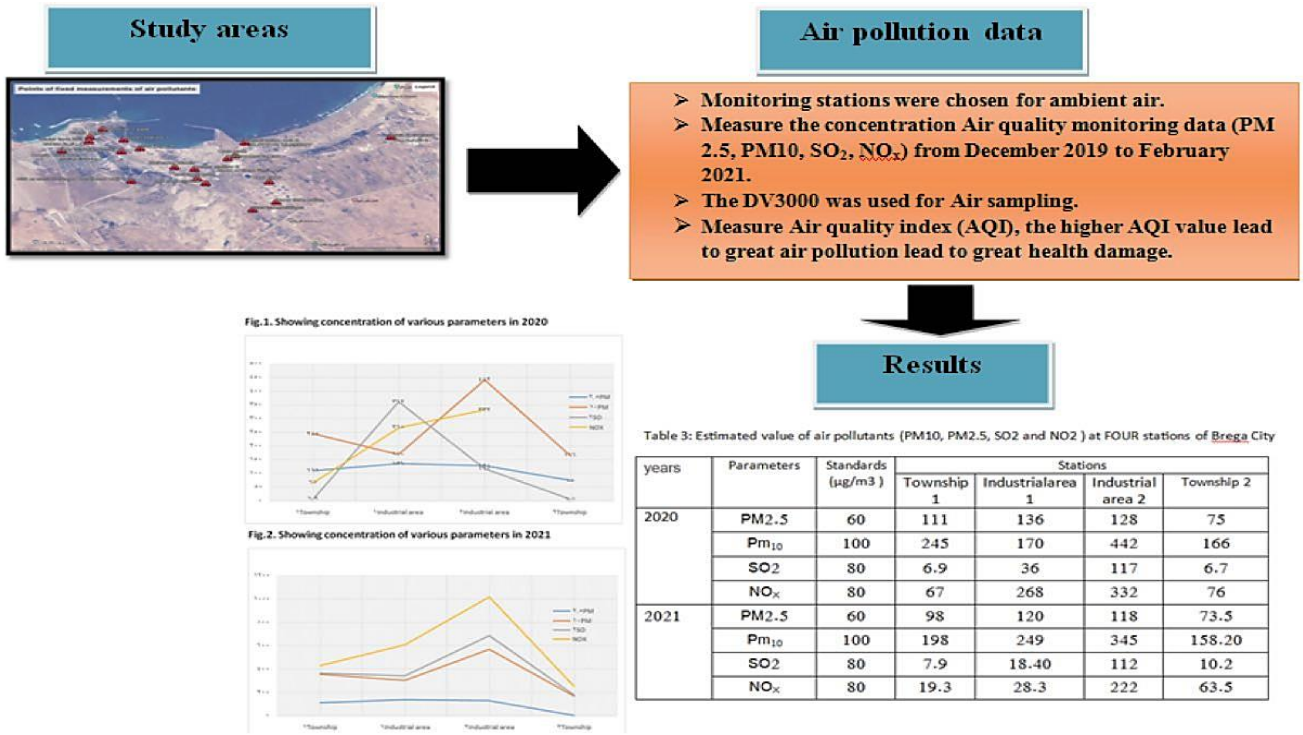
ABSTRACT

Air pollution has grown to be a serious environmental problem in recent years, having an impact on both the environment and human health. Air quality indicators were calculated using the U.S. Environmental Protection Agency procedure in order to assess the state and quality of air surrounding Brega city. The study examined the air quality during the period of February 2020 to June 2021, using an average standard of 24 hours to measure pollutants such as sulfur dioxide, nitrogen oxides, respirable suspension particles, and suspended particles in four different locations. The findings showed that the levels of air pollution for sulfur dioxide, nitrogen oxides, PM10, and PM2.5 were consistently above the allowable limit at all sampling sites and that the relative air quality index fell within the severe air pollution range.

KEYWORDS: air quality- air pollutants- air quality index (AQI)- particulate matter.

GRAPHIC ABSTRACT



years	Parameters	Standards (µg/m3)	Stations			
			Township 1	Industrialarea 1	Industrial area 2	Township 2
2020	PM2.5	60	111	136	128	75
	Pm_{10}	100	245	170	442	166
	SO2	80	6.9	36	117	6.7
	NO_x	80	67	268	332	76
2021	PM2.5	60	98	120	118	73.5
	Pm_{10}	100	198	249	345	158.20
	SO2	80	7.9	18.40	112	10.2
	NO_x	80	19.3	28.3	222	63.5

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1. INTRODUCTION

Rapid industrialization worldwide, along with multiple increases in urbanization and economic expansion, has ended up resulting in a significant rise in air pollution emissions and related severe problems with air quality. [1,2] There are negative effects of air pollution on human health. [17] Air pollution has long been a concern in many nations and areas of the world, contributing to a number of issues like climate change, greenhouse gas emissions, and environmental damage.[10,13,8] It is characterized as a variation in any air ingredient from the value that would have occurred in the absence of human activity and worsens ecological conditions.[18]Air pollution has long been a concern in many nations and areas of the world, contributing to a number of issues like climate change, greenhouse gas emissions, and environmental damage.[19] Refineries in Brega emit a wide range of metals and gases along with petroleum.[9,10] The amount of harmful gasses released into the air by manufacturing smoke worsens the state of the environment and human health, and it's thought that each year, millions of tons of hazardous chemicals are emitted into the atmosphere. Particles and gases are released into the air during any combustion. These can include trace amounts of organic compounds, radioactive isotopes, soot particles, carbon monoxide, and oxides of sulfur and nitrogen. [4]

Particulate matter (PM) pollution, comprising PM2.5 (particles with aerodynamic diameter < 2.5 μm) and PM10 (particles with aerodynamic diameter ≤ 10 μm), has been the focus of attention; nevertheless, the amount of other pollutants, particularly ozone (O3), is also rapidly rising. Since its debut in the summer, O3 pollution has tended to surpass PM2.5 as the primary pollutant in major Chinese cities, according to statistics from national monitoring programs. [3,6]. These automated stations focus on six pollutants, reporting hourly over the internet: carbon monoxide (CO), sulfur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3), particulate matter < 2.5 microns (PM2.5), and particle matter < 10 microns (PM10).[8,12,14]. Like many other nations, Libya experiences air pollution from sources both natural and artificial, including transportation. Lack of access to public transit leads to an increase in private automobiles, which pollute the air and fuel climate change and global warming. Libya has five refineries that are located within its borders: the Sarir refinery, the Brega refinery, the Ras Lanuf oil export port, and the Al Zawiya refinery. The primary source of pollution emissions into the atmosphere is the refining industry. Natural gas and naphtha are among the goods produced by the petrochemical sector. [16,20] Our study was carried out between February 2020 and June 2021. The study aims to evaluate air quality with pollution indicators around the Industrial Zone of Brega City.

2. MATERIALS AND METHODS

2.1. Study areas

Brega is an industrial town situated on the southeast corner of the Gulf of Sirte, at 30°26′06.0″N 19°40′01.0″E (Fig. 1). Nowadays, Marsa al-Brega, the original Brega settlement, is all but abandoned. The contemporary town of Brega, which is separated into three urban sections called Brega Area One, Brega Area Two, and the New Brega, is located about 4 km north of this settlement. North of the local airport and approximately 2 km southwest of the seaport is Brega Area One (30°24'17.95"N, 19°34'17.89"E). Brega Area Two (30°25'2.49" N and 19°38'30.91E) is located approximately 6 km east of Brega Area One, and the New Brega (30°28'51.92" N and 19°43'37.71" E) is located approximately 10 km northeast of Brega Area Two.

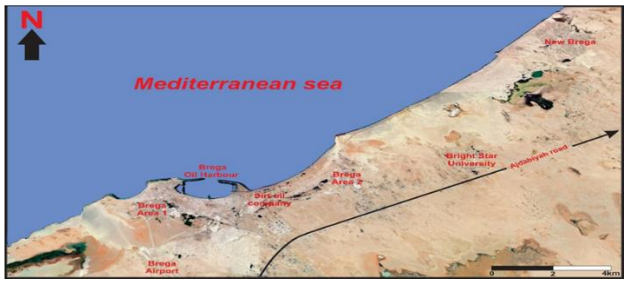

Fig. 1. Map of Brega City (the northern and southern Brega City)

2.2. Study sites

In order to ascertain the present and spatiotemporal aspects of ambient air pollution in Brega City, this study investigated the air pollution data that were gathered there. To measure the concentration of air quality monitoring data (PM2.5, PM10, SO2, and NOx concentrations), data from three monitoring sites in and around Brega city were used. The information utilized covered the months of February 2020 through June 2021.For ambient air, three sample locations were chosen. Brega City's three areas (First Area, Second Area and Third Area) were observed. To gather samples, 8 hours of sampling were conducted at each site.

Air sampling was conducted using the DV3000, and all parameters were examined in accordance with BTEX regulations. In order to compute the monthly moving average concentration, air was added.

2.3. Monitoring of ambient air quality

The air quality index, or AQI, calculates the ratio of the ambient air quality to the quantity of pollutants in a given area. The AQI's simple calculation and strong scientific basis are its main advantages.

Some of the factors taken into account while selecting the parameters to compute the AQI include the index's

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objective, the significance of the air quality indicators, and the availability of data.

The study region's air quality may be evaluated using the air quality index. The AQI may be calculated using a variety of formulae and methods. However, in this instance, the equation shown below [4, 15] has been employed in the AQI value computation.

AQI = ¼ × (IPM10/SPM10 + IPM2.5/SPM2.5 + ISO2 /SSO2 + INO2 /SNO2) × 10

Where PM2.5, PM10, SO2, and NOx indicate the actual pollution values discovered during sampling, and SPM10, S SOx, and SNOx represent the revised ambient air quality requirements as set out by the Central Pollution Control Board of India. Following the findings' compilation, an AQI was created from each pollutant's concentration.

The five categories that comprise the AQI scale define the range of air quality and its potential health impacts (Table 1). There are five levels on the air quality index, ranging from 0 (very low) to > 100 (very high). In this study, mild air pollution was defined as having an index value between 26 and 50, while clean air was defined as having an index value between 0 and 25. The pollutant with the highest AQI number was added up to calculate the total AQI for a particular location. A higher AQI score indicates more air pollution and the ensuing health impacts.

Table 1. Interpretation of the air quality index (AQI) values

Value	Description	Health Effects
0-25	pure air	None or very little impact on health
26-50	minimal air pollution	Potential cardiac or respiratory effects in the most susceptible people
51-75	Mild air pollution	Growing probability of respiratory and cardiovascular disorders and symptoms
76-100	severe air pollution	worsening of lung or cardiac conditions. higher chance of mortality in kids. (Lung and heart problems); heightened consequences among the broader populace
>100	extreme pollution of the air	severe worsening of lung or heart illness; increased chance of dying young. significant risk of cardiopulmonary symptoms in the general public

3. RESULTS AND DISCUSSION

In the four Brega City areas that were chosen for this study, the concentration levels of air contaminants such as NOx, SO2, PM2.5, and PM10 were found to range from low to very high for both years. (Figs. 2 and 3, Tables 1 and 2) The highest recorded PM2.5 value for 2020 was discovered to be 80.9µg/m3 at Industrial Area 2. In 2021, data and the lowest value were recorded at 73.5 µg/m3 in residential area 2. All PM2.5 values at the chosen stations were higher than the allowable limit of 60 µg/m3 for the two years of study.

Similarly, for both of the two years under study, PM10 was found at all of the chosen stations to be above the allowable levels (100 µg/m3). In 2020, the highest recorded value of PM10 was 442 µg/m3 at Industrial Area 2, while in 2021, the lowest recorded value was 158.20 µg/m3 at Residential Area 2. Strong and medium-sized winds produce localized disturbances and turbulent environments, which lead to hazy conditions and dust storms, which increase the size of the particles. 19,21[. Furthermore, SO2 was noted to be higher than the allowed thresholds (80µg/m3) The highest recorded value was 117µg/m3 at Industrial Area 2 in 2020, while the lowest recorded value was 112 mg/m3 at the same location in 2021. Similarly, NOX was also observed beyond the permissible limits (80µg/m3). The maximum value was found at 332µg/m3 at Industrial Area 2 in year 2020, and the minimum value was observed at 222 mg/m3 at Industrial Area 2 in year 2021. A limit of 80 µg/m3 was observed for SO2 and NOx concentrations at Residential Area 1 and Residential Area 2 in the study period. Our findings here are consistent with earlier research evaluating the effects of upcoming emissions changes driven by NOx emission reduction. [19,22,23,24]

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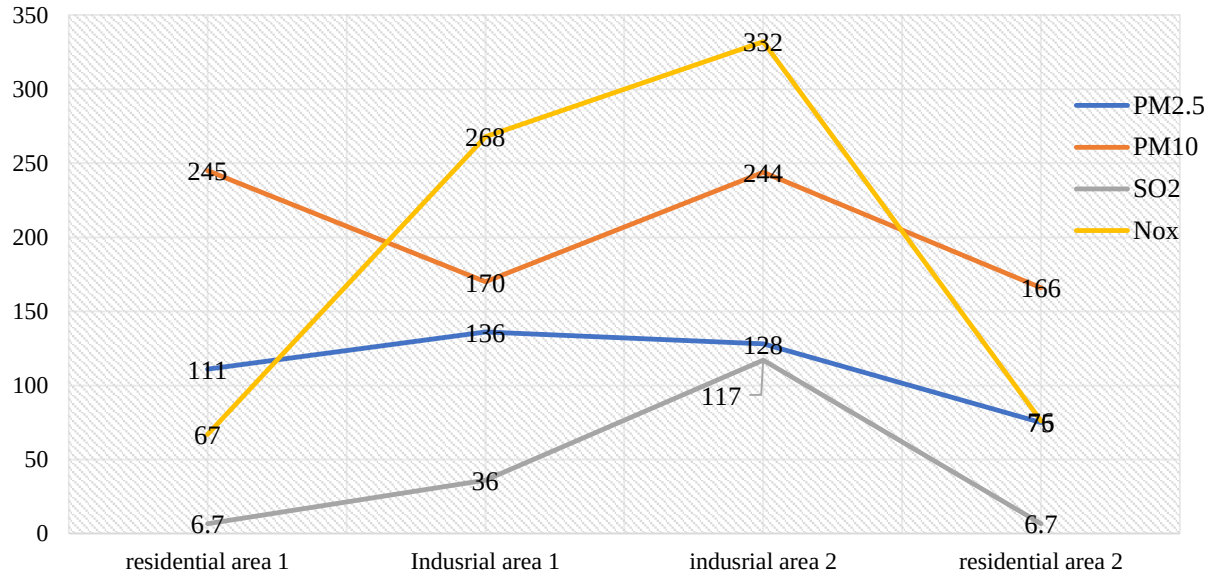

Fig. 2. Showing concentration of parameters (PM2.5, NO2, SO2, and PM10) in 2020

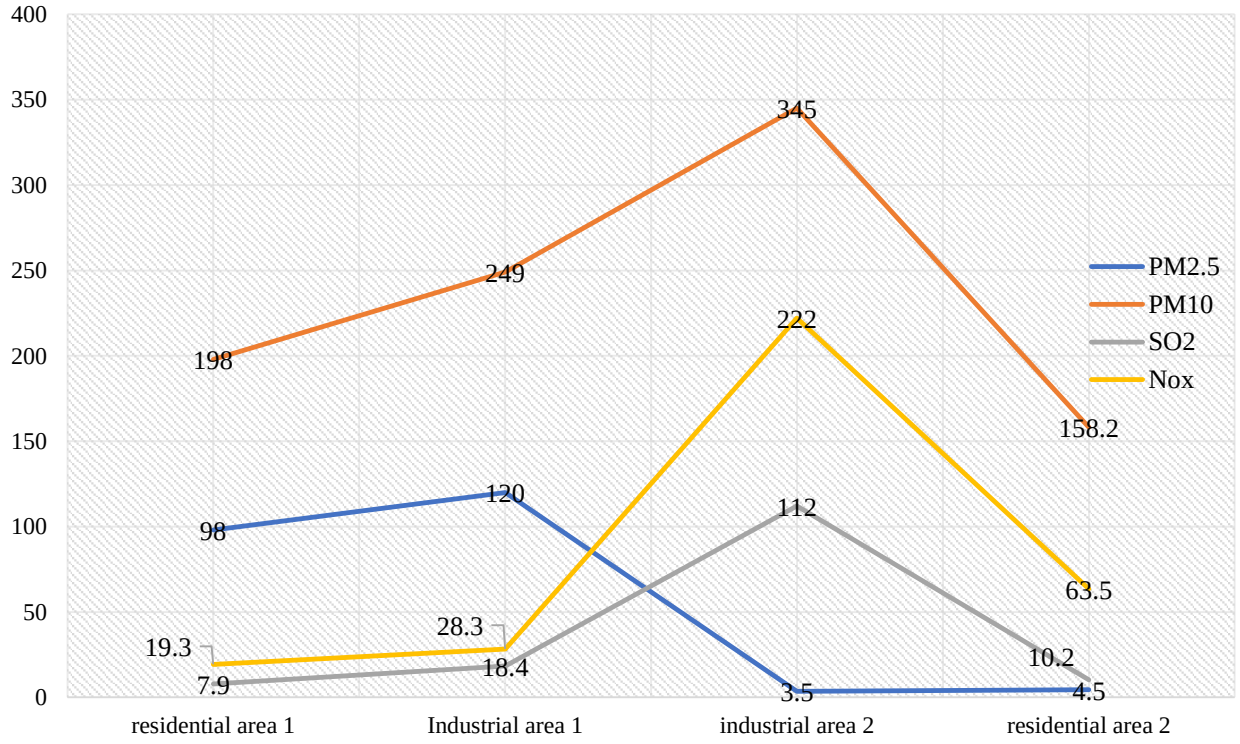

Fig. 3. Showing concentration of (PM10, PM2.5, SO2 and NO2) parameters in 2021

Table 2: Estimated value of our sites measuring air pollutants (PM_{10}, $PM_{2.5}$, SO_2, and NOx) of Brega City

years	Parameters	Standards (µg/m3)	Stations			
			residential area 1	Industrial area 1	Industrial area 2	residential area 2
2020	$PM_{2.5}$	60	111	136	128	75
	Pm_{10}	100	245	170	442	166
	SO_2	80	6.9	36	117	6.7
	NO_X	80	67	268	332	76
2021	$PM_{2.5}$	60	98	120	118	73.5
	Pm_{10}	100	198	249	345	158.20
	SO_2	80	7.9	18.40	112	10.2
	NO_X	80	19.3	28.3	222	63.5

Standards Source: Ministry of Environment and Forest, New Delhi, Notification, Dated 16th Nov, 2009

3.1. Index of Air Quality (AQI)

The AQI score for the ambient quality of the air monitoring data in Al Bubrah City was converted to a value during the study period (Table 2, 5). In 2020 and 2021, the level of air pollution was found to be severe and more common in industrial areas than in residential areas. In 2020, the level of pollution was high in both residential and industrial areas, with the AQI value in residential areas falling between the limits of 117.44 and 130.59 and in industrial areas between 294.15 and 304.14. While the amount of air pollution in industrial regions was high in 2021, only the AQI value was found to be within the range of (126.28-239.78), and the AQI value in residential areas with high air pollution was found to be in the range of (98.20-98.80).

Table 3: Category of air quality determined by AQI of four locations of Brega City in 2020

Stations	AQI	AQI Category
residential area.1	130.59	Severe air pollution
Industrial area 1	294.15	Severe air pollution
Industrial area 2	304.14	Severe air pollution
residential arean.2	117.44	Severe air pollution

Table 4: Category of air quality determined by AQI of four locations in Brega City in 2021

Stations	AQI	AQI Category
residential area 1	98.80	Heavy air pollution
Industrial area 1	126.82	Severe air pollution
Industrial area 2	239.78	Severe air pollution
residential area 2	93.20	Heavy air pollution

4. CONCLUSIONS

Al Brega City has measured air pollution and air quality, and the outcomes show that PM2.5 and PM10 are always outside the allowed limit everywhere. However, nitrogen oxides and sulfur dioxide were consistently below the allowed limit in residential areas and outside the allowed limit in industrial zones. It was discovered that relative AQI accurately represented potential extreme air pollution that could worsen existing health and environmental issues.

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Examining the Subjective Reasons Leading to Disparities in Academic Achievement among Students in the Architectural Design course at the University of Tripoli.

Case study: Architectural Design Students

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ABSTRACT

Architectural education plays a vital role in developing and advancing the urban structure and raising the level of performance of technical departments to achieve a better standard of living for the country's people within international standards. Architectural design is considered one of the most important basic subjects in the crystallization and formation of an architect's personality. Therefore, the disparity and sometimes weakness of the scientific achievement of students in the Department of Architecture in this subject undoubtedly leads to the inability of graduates to contribute to the process of construction effectively in practical life. This research aims to find out the reasons for the disparity in educational achievement among students of the architectural design subject in the Department of Architecture and Urban Planning at the University of Tripoli. The Descriptive Analytical method was employed to identify key challenges hindering students' educational progress in architectural design courses AR 302 and AR 403. The study examined a sample that comprised over [2]5% of the students across the two courses. The results were that all reasons for lack of achievement related to the students themselves. They were represented in order and according to importance in the degree of intelligence; hobbies; method of reading; access to books and references and the extent of benefiting from them; and attention and concentration during lectures. The study found that students did not have the moral courage to answer questions due to shyness (91.7%) and fear of the professor (8.3%). The research resulted in a set of recommendations, the most important of which is that professors should invest in the first meeting with students when presenting the course program. The study also recommends professors provide students with advice and guidance in developing their IQ, aim to reduce or eradicate the effects of shyness, and encourage and motivate students to participate in discussions and ask questions. Implementation of these recommendations will increase the likelihood of fostering an integrated educational institution that is constructive and capable of graduating confident scientific cadres.

KEYWORDS: disparity- academic achievement- intelligence- shyness.

1. INTRODUCTION

Faculty members and educational institutions need to be aware of the underlying causes for the disparity in students' scientific achievement to correct them or contribute to correcting them. The scientific achievement of the academic courses in general and of the architectural design course, in particular, is reflected in the performance of the students of the Department of Architecture and Urban Planning. The scientific achievement of the students is evaluated through different evaluation stages and grades that they obtain in various exercises, tests, and midterm and final exams.

These grades show the extent of the students' understanding and assimilation of the knowledge that they received in lectures, lessons, and discussions when the students use that information and apply it in their work on various exercises during the semester. As mentioned, the subject of Architectural Design is considered one of the most important subjects for students of Architecture and Urban Planning, as it is the backbone of the specialization. However, the results of this important subject frequently vary significantly from one student to another, indicating the disparity in their levels of academic achievement. Such disparity exists even though many of the academic and educational factors are the same and the opportunities are usually equal for all students. From these points, the research problem was identified.

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2. RESEARCH PROBLEM

The disparity of the academic achievement levels among the students of the Architectural Design subject can be inferred from the clear discrepancy in the grades of the students enrolled in this subject; in addition to the level of the projects presented as academic output at the end of the semester. For this reason, the researcher investigates the problems and reasons that lead to this disparity, determining a number of research aims to achieve in this paper.

3. RESEARCH AIMS

- Knowing the reasons that lead to disparity in the levels of academic achievement among students in the Department of Architecture.
- Raising the level of educational achievement of students and graduating capable groups and active cadres in society.

To achieve these goals, the research was addressed by answering the main question of the research.

4. RESEARCH QUESTION

What are the subjective reasons that lead to disparities in academic achievement among students in the Architectural Design subject?

5. METHODOLOGY

The research relied on the Descriptive Approach, which addresses scientific studies on the subject of research and extrapolation of some psychological influences on the composition of students and their impact on their academic achievement. In addition to the analytical approach, a questionnaire tool was used; in which several questions were asked to a sample of students of the Architectural Design subject (branch AR 302-AR403), and the results of the questionnaire were analyzed through Microsoft Excel.

Teaching Methods and Their Impact on Students' Academic Achievement

When researching academic achievement, it is necessary to review some theories and schools that are interested in researching teaching methods. Many educational theories and teaching schools explain the factors for the success of the educational process, such as John Watson's behavioral school, inductive, constructivist, associative, and sensory-to-cognitive schools, which produced the Gestalt school. Gestalt is a German word that means the characteristic of the senses (visual and auditory) and their impact on learning and knowledge. Gestalt theory appeared in Germany in the early 1920s and is considered one of the most influential theories in university education. The Gestalt School focused on the principles of visual sensory effects on learning and knowledge, such as shape, similarity, proximity, sharing, and closure. Therefore, we see it as the closest direction to teaching arts in general, and the field of architecture and design in particular. This theory focuses on many scientific concepts that have a significant impact on university education methods. The most important of these concepts are perception, organization, reorganization, transfer, and internal motivation for learning. The goal of these concepts was to determine the extent to which students understand the lessons given and the internal motivation of the students to make them learn new academic subjects that have a significant impact on their practical life after graduation[1]. The author of this paper studied inductive theory in this school, which relies on research, contemplation, and thinking. In the inductive method of teaching, the student moves in research from one part to the whole. This method is used when producing laws or theories, and it is one of the methods that helps students to research and discover new things on the subject of the study[2].

In implementing design subject courses, professors rely on giving theoretical lectures on the most important design standards and methods for dealing with site characteristics, user characteristics, and function. What they receive is applied in a design project for a building that bears the characteristics of the required function. The history of project-based learning dates to 1897 AD, at the hands of the famous psychologist John Dewey (1896), who proposed the idea of "education by doing." The student has the freedom to investigate and research the scientific subject, and the professor does not have the right to impose any scientific ideas, but his role is to guide his students. This is why scientific attempts began to research new methods and ideas that would help develop science and learning, and one of the most important ideas was "project-based learning." Many psychologists discussed this idea, the most important of whom was Jean Piaget, who described it as one of the best ideas ever proposed. One of its most important principles is that it stresses that the student should be an important part of the lecture by assigning him/her to research a specific problem and propose several solutions to it by studying some similar projects that serve as concrete evidence from which the most important solutions that are considered successful can be deduced by applying them in these projects' list. The scholar Vygotsky had ideas contrary to those proposed by Piaget, as he believed that education and social and collective learning were an important part of the cultural and cognitive development of students. It contributes effectively to increasing students' awareness, and this development will only occur through contributing to positive social interaction among peers and under the care of highly experienced people, represented by the professors. In addition, it helps to filter thoughts and actions based on practice that develops the level of

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cognitive awareness among students[3]. A questionnaire was prepared for this study, containing questions that reflect the above-mentioned information required for the research results.

6. RESULTS

The questionnaire was distributed to the members of the selected sample, who are students of design courses (302Arch and 403Arch) in the Fall semester 2022-2023. After the questionnaire was collected and data extracted, the results were as follows in Table 1.

Table 1. Data extraction from the questionnaire.

No.	Factors	Percentage		
1	IQ among students	Excellent 10 to 20%		
2	IQ in digital and arithmetic	Excellent 0 to 10%		
3	IQ in shape recognition	Excellent 30 to 40%		
4	The hobby (intellectual-physical/intellectual-physical)	Intellectual 40%	Physical 50%	Intellectual physical 10%
5	Residence (near/far)	Near the university 80%		
6	A language he or she is fluent in	Arabic 100%		
7	English language	20%		
8	Availability of books and references	60%		
9	Visiting the Library	60%		
10	Reading/(Full-Partial)	100% Partial		
11	Headache or falling asleep while reading	Headache 10%	Sleep 60%	No 30%
12	Architectural relatives	70% to 90%		
13	Concentration and attention percentage	High 30%	Average 40%	Weak 30%
14	Focus on the lecture and discussion.	(Focusing during discussion) 90%		
15	Language of teaching	Arabic with English terms 100%		
16	The difference between professors	Huge difference 100%		
17	Thinking on questions after lecture	Always 30%	Sometimes 70%	
18	Questions arise during the exercises.	Always 60%	Sometimes 40%	
19	The reason for not asking questions	Belief of Understanding 30%	Shyness 70%	
20	The time allotted for reading	More than an hour 70%	More than 5 hours 30%	
21	Understanding the terminology	60% do not understand	40% weak	
22	Entertainment	10% Physical	30% Intellectual	60% Entertainment
23	Literary and artistic Inclinations	20% Literary	60% Art	20% Both

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7. DISCUSSION

The information that was extracted from the table prepared after transcribing the information collected from the questionnaire was classified into two groups, the first being factors common to more than 80% of the students and the other being factors in which they differed. The results were as follows:

- **Common factors exceeding 80%:**

The results in Table 1 show that 100% of the students' mother tongue is Arabic. 80% believe that they are not proficient in English. They all prefer classroom teaching to be in Arabic with English terminology, and all believe that there is a substantial difference between professors in teaching. They do not read the topics in full; rather, their knowledge of the topics is partial. Their focus rate is 90% during the discussion, and 80% of them live close to the university, which has a favorable effect on attending lectures on time and not being late due to traffic congestion.

- **Varying factors:**

The factors are intelligence, concentration during lectures and visits to the library, headaches or falling asleep while reading, asking questions during lectures and during exercise, time allocated for reading and entertainment, linguistic accuracy, and understanding the meanings of terms, phrases, and words, and intellectual and literary inclinations.

Through this classification, the discussion will be about the factors in which there is a disparity between students, as these will be the source of the discrepancy in academic achievement. Since the research aims to determine the reasons for the disparity in achievement among students, which is shown by their final grades, the comparison will be made between the students with the highest grades and the lowest grades, and this is shown in Table (2), which brings together the factors and the students with the highest achievement and their counterparts with the lowest achievement.

Table 2. Shows the relationship between the highest-achieving students and the lowest-achieving students.

No.	Factors	Evaluate	The highest-achieving students			The lowest-achieving students		
			1	2	3	4	5	6
1	General IQ	Excellent	Excellent		Excellent			
		Very good		Very good			Very good	
		Good						
		Accepted				Accepted		Accepted
2	Arithmetic IQ	Very good						
		Good	Good	Good	Good			
		Accepted				Accepted	Accepted	Accepted
3	IQ in shape recognition	Excellent	Excellent	Excellent				
		Very good			Very good		Very good	
		Good				Good		
		Accepted						
4	Hobby (intellectual, physical, artistic)	Intellectual		Reading				
		Physical			Sport			
		Artistic	Drawing			Drawing	Drawing	Drawing
5	Residence (near and far)	Near	Near	Near	Near	Near	Near	Near
		Far						
6	A language he or she is fluent in	Arabic	Yes	Yes	Yes	Yes	Yes	Yes
7	English language	Yes					Yes	
		No	No	No	No	No		No

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8	Availability of books and references	Available						
		Sometimes	Sometimes	Sometimes	Sometimes	Sometimes		Sometimes
		Unavailable					Unavailable	
9	Visiting the library	Visit	Yes	Yes	Yes	Yes	Yes	Yes
		No						
10	Reading and learning	Full						
		Partial	Partial	Partial	Partial	Partial	Partial	Partial
11	Headache or falling asleep while reading	Both						
		Headache		Yes	Yes			Yes
		Sleep	Yes	Yes			Yes	Yes
12	Architectural relatives	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		No						
13	Concentration and attention percentage	High	High	High	High	High		
		Low					Low	Low
14	Focus on the lecture and discussion.	Discuss	More	More	Less	More	More	More
		Equal						
15	Language of teaching	Arabic- English	Yes	Yes	Yes	Yes	Yes	Yes
16	Difference between professors	Huge		Huge	Huge	Huge	Huge	Huge
		Little	Little					
17	Thinking on questions after the lecture	Always	Always	Always				
		Sometimes			Sometimes	Sometimes	Sometimes	Sometimes
18	Questions arise during the exercises.	Always	Always		Always	Always		Always
		Sometimes		Sometimes			Sometimes	
19	Reason for not asking questions	Professor					The fear	
		Shyness	Shyness	Shyness	Shyness	Shyness		Shyness
20	Time allocated for studying and reading	From 1 to 5			4 hours		4 hours	
		One hour	One	One		One		One
21	Understanding terminology	Yes	Yes	Yes	Yes			

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		No				No	No	No
22	Entertainment	Intellectual			Intellectual			
		Physical				Physical		Intellectual
		Entertainment	Entertainment	Entertainment			Entertainment	
23	Inclinations	Literary %	40%	20%	70%	50%	40%	50%
		Artistic %	60%	80%	30%	50%	60%	50%
24	Best scientific subject		Art	Architectural drawing	History	History	Design	Art
			Prospective	Prospective	Prospective	Design	History	History
25	Subjects of the highest score		Art	Prospective	History	Art	Art	Art

Table 2 shows that factors No. 5, 6, 9, 10, 12, 15, and 20 are the factors that do not affect the disparity in achievement, while the rest of the factors vary to different degrees. The most important factor of which is the degree of intelligence (IQ), which is shown in figure 1. The two categories converge in the visual aspect and shape recognition. On the other hand, we notice in the table that there is a large difference between the two categories in the aspect of mathematical intelligence, sometimes called analytical, which indicates the importance of this aspect in its impact on the students' academic achievement.

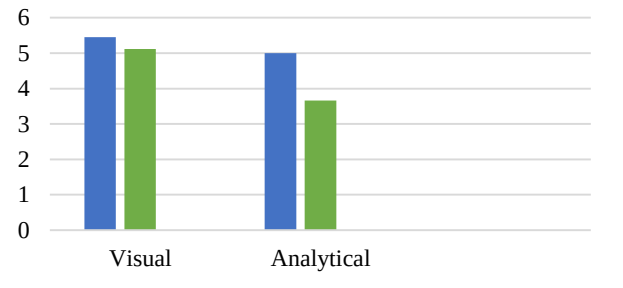

Fig. 1. shows the difference in analytic intelligence (digital) and visual (shape recognition) between the least achieving and the most achieving students. (The highest-achieving students- The lowest-achieving students)

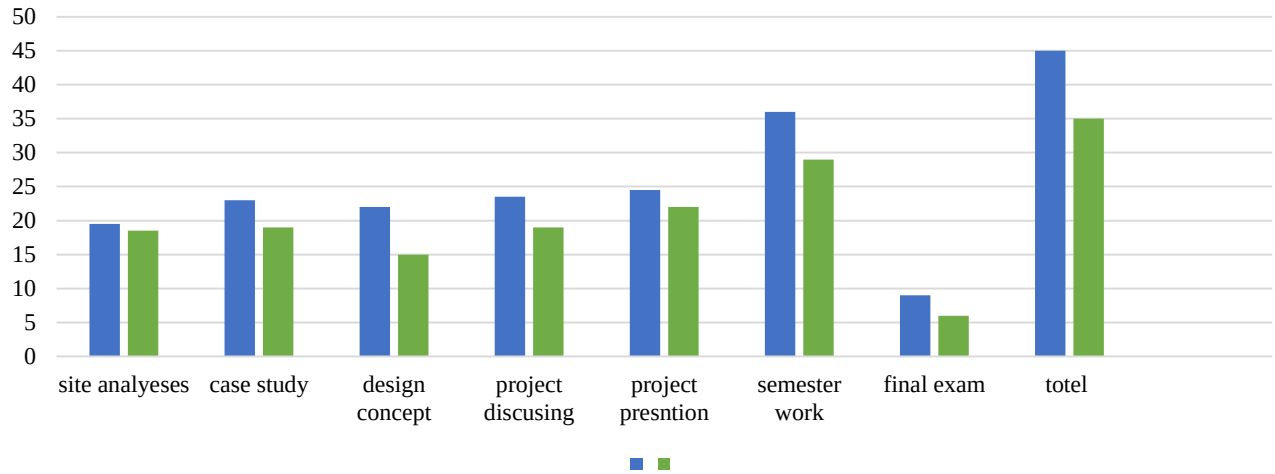

Fig. 2. shows the grades for the semester work and the final exam for both categories.

(The highest-achieving students- The lowest-achieving students)

The distinction of the highest-achieving group was reflected in their grades during the semester, and this appeared clearly in Figure (2), which shows the difference between the two groups in studying and analyzing similar examples and locations of projects. In addition, there is a substantial difference between them in dealing with the idea of design, discussing the elements of the project, and how to deal with it and present it.

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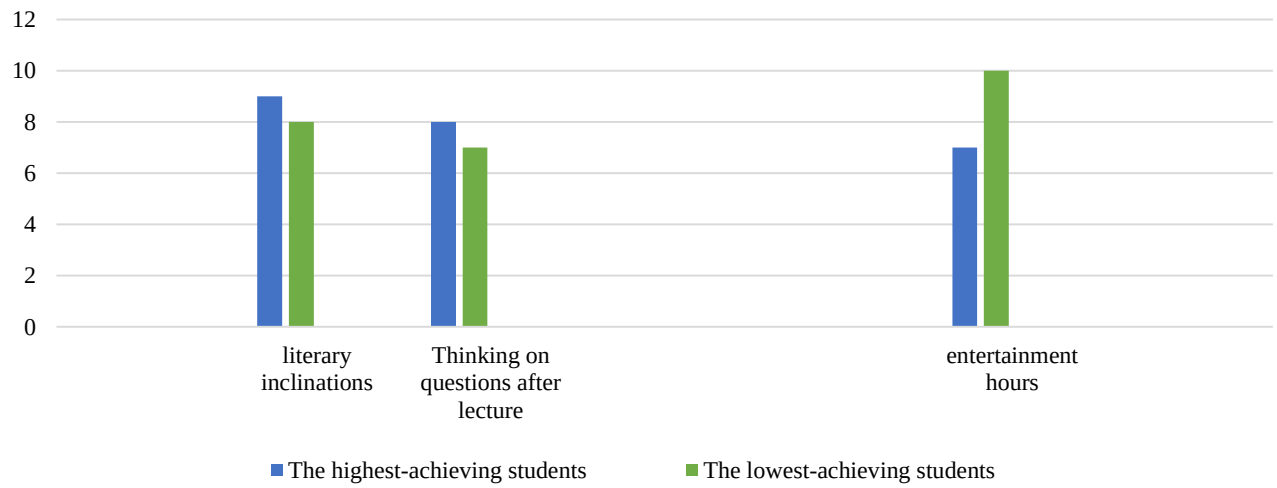

Fig. 3. shows literary tendencies, working on questions after lecture and entertainment hours.

Figure (3) shows the large disparity between the two groups with the highest and lowest achievement in literary Inclination and the use of entertainment time in artistic and intellectual aspects, which had a clear impact on academically distinguished students due to its positive effect on renewing energy and changing the academic routine with various hobbies that benefit the mind and body and develop skills. However, entertainment time had a negative effect on the students with low achievement due to lack of devoting and managing their time for study and activities that develop their academic achievement. In addition, paying attention during the lecture, focusing, and asking questions are among the characteristics that distinguished the highest-achieving students and helped them excel in the final results. The two groups agreed on some subjects that were considered the best for them, such as free drawing, perspective, and history. While completing the questionnaire, the researcher noticed an especially important factor, which is shyness, with a percentage of 70%. This shyness factor was revealed in the answer to the question, "What is the reason behind not asking questions?" "Shyness" was the common answer for both groups.

Therefore, the discussion will focus on two main factors, as these factors support each other. Physical hobbies stimulate blood circulation necessary to enhance memory and are a crucial factor for intelligence. It is smart to use leisure time in aspects that serve the academic program, enhance focus and attention, increase knowledge, and strengthen intelligence. As for shyness, it is an obstacle to achievement. Therefore, we will study and analyze these two factors: intelligence and shyness.

8. INTELLIGENCE

Many scientists have addressed the topic of intelligence from different points of view, the most important of whom are two scientists of Austrian origin, Sternberg (2012) and Freeman (1925). Sternberg (2012) defined "Intelligence is the ability to learn from experience and to adapt to, shape, and select environments"[4]. Sternberg agreed with Deary in defining intelligence, who also defined it as rapid learning from firsthand experiences or learning from the experiences of others. In addition, intelligence involves the person's ability to think deeply to solve problems that are based on the careful analysis of all the data of the problem. This depends on the mental ability to plan, organize, and deal with complex ideas. Deary stressed that intelligence does not depend only on traditional education through books or passing systematic tests. Rather, it is a broader and more comprehensive concept that includes a person's development of his or her abilities in all the aspects that he or she sees, lacks and works to develop[5].

Whatever the definition of intelligence, what concerns us is how it can be cultivated and developed. American scientist Carol Dweck (2006) was interested in the causes of failure among students. After an in-depth study of student behavior, Dweck produced her book titled Mindset, which focused on some basic beliefs about learning and intelligence. Students put in a lot of effort when they want to be smarter, and this gives them strength, self-confidence, and great achievements. The book concluded that IQ can be developed using scientific methods through a healthy life that helps develop it and enhance its performance. In her book, Dweck proposed many methods to improve IQ, including self-care, rest, lack of stress, and self-confidence. The student must enhance his/her self-confidence and his/her ability to develop his/ her physical, mental, and scientific abilities and develop his/her intelligence. In addition, contemplating the nature of things helps in the growth of brain cells. As well, reading across various disciplines is necessary to expand the student's perceptions and increase scientific knowledge. The student must set a program and timetable for reading and reviewing new

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books. Sports and physical exercises are very important, as physical activity develops mental abilities and helps improve memory by 30%. Recreation and laughter lighten the heart, break boredom, and relieve the soul's burdens and worries. Choosing a positive environment by surrounding oneself with people who are like-minded, ambitious, and enthusiastic may affect the development of one's sensory and mental abilities. Humans were not created alone in this world, so a person may need the help of others. Therefore, Dweck advises that a person should not hesitate to ask for help, which is one of the most important steps to being an intelligent person. Always challenge oneself in order to be able to face difficulties and overcome them, and this makes the body and mind ready to renew brain neurons[6].

These points, as we see, were present in the results of the questionnaire, distinguished by the highest-achieving students, and were absent or weak among the lowest-achieving students, confirming the validity of the results of extracting the data from the questionnaire, which is important for the accuracy and validity of the research results.

The factor that affects inversely and weakens students' academic achievement is shyness to ask for help in finding answers to the questions that the student receives in his or her mind.

So, what is shyness, and what are its causes?

Shyness And Its Causes

Shyness is a psychological state that a person experiences and feels many conflicting emotions while interacting with others, such as confusion or anxiety, stuttering, and the inability to communicate his feelings to others. Many psychologists and sociologists diagnose shyness as a social and psychological disease that afflicts a person, affecting his behavior and frustrating his creative abilities because of the fear he displays from contact with others[7].

One of the most important characteristics of a shy person is his tendency toward loneliness and preference for not participating socially with others due to his lack of self-confidence. Shyness has several causes, including marginalization and exposure to persecution in the family, which results in weak self-confidence, a feeling of failure, and weakness in expressing feelings[8]. The American scientist Zimbardo (1996), who conducted a study on shyness, concluded that 80% of Americans had reasons for their shyness due to some social problems they were exposed to, whether in childhood or adolescence[9]. It is worth noting that there is a close relationship between shyness and psychopathological symptoms such as anxiety, depression, and fear among adolescents, and this was proven by the study conducted by Ali (2001)[10].

It is not normal to find university students in advanced years who are ashamed to ask questions to the professor, which of course leads them to a lack of understanding. Shyness is a negative factor that hinders academic achievement, in addition to hindering behavior that enhances intelligence. Shyness does not enable a shy student to ask for help from others, including asking questions to professors when they come to the student's mind during or after a lecture or exercise. Likewise, a student cannot actively participate in the discussion and expression of one's ideas (Author,2023).

From the above, it is clear that shyness is a broad and important topic. It is a topic that has a significant impact on the educational process and educational institutions. In addition, it has a negative effect on the development of intelligence levels and thus on the academic achievement of students at various educational levels (Author,2023).

9. CONCLUSION

The most important results of the research on the subjective reasons for the disparity in academic achievement among students of the Architectural Design subject in the Department of Architecture, College of Engineering, University of Tripoli, were as follows:

- There was a disparity in the IQs of the students in terms of intelligence that deals with arithmetic and form, which is an essential factor for the student's superiority over his/her peers in academic achievement.
- Students' habits, behavior, and daily programs contribute to the development of their abilities and raise their level of intelligence.
- Spending free time reading and pursuing hobbies that are useful to the specialty, taking care of oneself and not stressing, organizing time and paying attention to psychological comfort and physical exercise, and allocating time for meditation and concentration have a positive impact on the student in improving his or her personal and educational level.
- Shyness is a factor that negatively affects the development of intelligence and academic achievement.
- Focusing solely on free drawing skills does not support academic achievement in the Architectural Design subject.

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Reviving the Ruins of Berenice in the Sidi Khrebish Area of Benghazi Old City by Using Holographic Technology

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ABSTRACT

The city of Benghazi contains rich archaeological and historical monuments that form the spirit of the city, its civilization, and its ancient history, which needs to be preserved and revived in order to preserve the cultural and historical heritage of the city and its buildings and sites. Sometimes preservation involves many different aspects, such as celebrating events, people, places, and ideas that we are proud of. It also sometimes involves recognizing moments in our history that can be painful or uncomfortable to remember. Sidi Khreibish is an archaeological area of important historical value for the Old City of Benghazi in particular and for the city of Benghazi in general. Through the lighthouse, which constitutes the main landmark, it needs to be revived and presented again. With the technical development in the use of technology in architecture, especially in virtual reality and simulation applications, it has become possible to create a virtual environment using technology to reformulate the architectural and urban heritage. This is done by illusioning the recipient's eye with non-existent 3D models or surfaces that are shaped in a vacuum using advanced hologram techniques and presenting it as a default model. The current study included an integrated analysis of the study area and how the holographic imaging technique could be used, which has a unique feature that enables it to recreate the image of the original objects in its three dimensions to a very high degree, in order to re-embody the Old City and highlight its features of great historical value for the region and revive it within the fabric of the urban city.

KEYWORDS: Benghazi city, Sidi Khreibish, Berenice, Holographic Technology.

1. INTRODUCTION

1.1 overview

The city of Benghazi is located in eastern Libya. The city's history is characterized by its successive civilizations, and its distinctive urban mix reflects its historical and cultural significance over time. Old Benghazi, the so-called "Berniki" (Sidi Khrebesh), is the second city after Hesperides (Sidi Obeid) and represents the first nucleus of the city's genesis and urban growth. In addition, Sidi Khrebesh is a very important archaeological area in terms of its scarcity, but almost since its disappearance it has lost significance to the city, and Benghazi Lighthouse is an important landmark and a true masterpiece in architectural heritage. They blended Ottoman and Italian influences to create a unique and distinctive structure. Its rich history and cultural significance also make it an important landmark for the people of Benghazi, where it stands as a symbol of strength and resilience in the face of adversity.

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Unfortunately, historical monuments and buildings are neglected and disappear without restoration or attention. The city's history is the most important part of the identity of the city that its people are proud of. This requires action to be properly documented and presented, reflecting the importance of the city and its long history. Trying to study these monuments in Benghazi is of great importance as a first step to highlight their importance, to highlight historical sites, and to revive them through the use of modern technology and means.

1.2 Significance of the study

The city of Benghazi has a rich history, yet its ancient monuments and historical buildings face neglect and are disappearing without restoration or care. Studying these monuments in Benghazi is a crucial first step to highlight their significance, showcase historical sites, and revive them using modern technology and methods. The city's history is an essential part of its identity, which is proudly cherished by its residents. Therefore, it must be documented and presented in a manner befitting the city's stature.

1.3 Aim of the study

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The aim of the study is to understand and protect Khrebish historical and archaeological sites in order to conserve their cultural and historical significance for future generations by reviving the ruins of Berenice by using holographic technology.

1.4 Scope and objectives of the study

The scope of the study is the walls surrounding the archaeological site of the city of Berenice in the Sidi Khrebish area, including the lighthouse building, an attempt to create a new perception of the area that includes re-landscaping after studying the movement within the site, highlighting its historical importance as a vision for the future city of Benghazi.

1.5 Methodology

The research relied on the descriptive method, which addresses scientific studies related to the research topic. Regarding the study site, the research primarily focused on the manuscripts extracted from the archaeological sites in the Sidi Khrebish area. Since the studied region has witnessed multiple civilizations in the same location, digital methods offer greater flexibility in representing this era in a manner close to reality without compromising the integrity of the artifacts. This aspect was explored in the context of holographic technology and its applications. Additionally, the analytical method was employed to analyze the study site from several key perspectives.

2. LITERATURE REVIEW

The preservation of ruins is a global movement that considers human-made environmental history as an important part of human heritage that is worthy of preservation. One of the main issues in preserving ruins is the lack of available funding to protect and maintain them. Sites managed by government bodies face difficulties in maintaining the location, let alone stabilizing and protecting it. Another issue threatening the survival of ruins is the risk of development and new construction. Often, these sites are demolished and new homes are built on the foundations. Ensuring the preservation of ruins for future generations is crucial in educating people about the past. Ruins serve as a reminder of the construction practices used by previous generations. They not only offer stunning views but also act as educational tools. When a building disappears, the best alternative is what remains of the ruins [1].

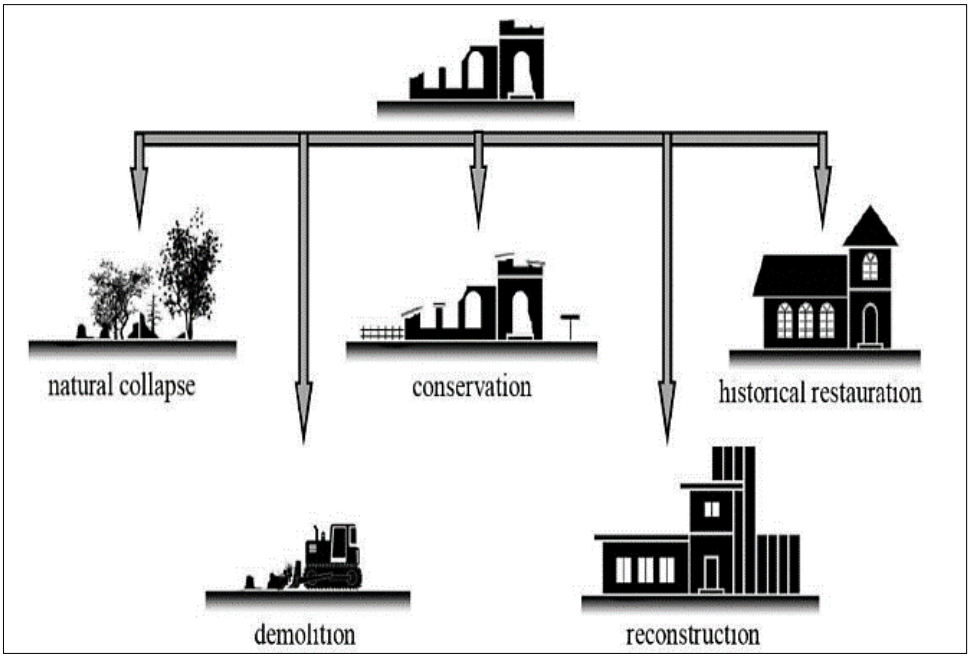

Figure 1: Scenarios of development of ruins.

2.1 General overview of ruins preservation

The preservation of ancient historical sites requires a balance between stabilization and restoration; while full restoration can enhance the external appearance, it is costly and may diminish the authenticity of the ruins. This approach seeks to strike a balance, similar to the reinforced layers in digital history applications. The demarcation of the Roman Empire's boundaries in what is now known as England is exemplified by Hadrian's Wall, which dates back to the 1st century AD. This structure extends 73 miles, punctuated by small forts, watchtowers, and garrisons, and it served as an active military site for 300 years. Milecastle 39, also known as Castle Nick, is one of the most prominent remaining stone structures of the wall [2].

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Figure 2: Milecastle 39.

Holography Technology

There are many modern techniques used in the field of restoration and preservation of antiquities, and they depend on advanced natural sciences and modern tools and equipment. Some of these techniques include the following:

- Virtual modeling and virtual reality: the use of hologram technology so that lasers are used to create three-dimensional images that look like real ones and are used in various fields, especially in the field of architecture and design.
- Using lasers to remove dirt, deposits, and unwanted coatings from stone, metal, wood, and paper surfaces.
- The use of ultrasound to examine cracks and damage in archaeological materials without causing damage to them.
- Using infrared, ultraviolet, and X-ray imaging to detect hidden or counterfeit layers in paintings, manuscripts, and coins.
- The use of chemical and spectral analysis to determine the composition, history, and source of archaeological materials, as well as to detect any added or contaminated materials.

Despite the contribution of these modern technologies used in the field of restoration and preservation and the protection of cultural and archaeological heritage from damage and loss. However, it requires high expertise and respect for the original material of antiquities and is not replaced by traditional techniques except when necessary [(3)].

Definition of Hologram

A hologram is a three-dimensional light field produced through the physical recording of an interference pattern. This pattern involves diffraction, which ultimately creates a virtual 3D image of the original scene.

In simpler terms, holograms are 3D images formed by the interference of light beams reflecting off real, tangible objects. Unlike typical 3D projections, holograms can be viewed with the naked eye without the need for 3D glasses.

The process of creating holograms is known as holography. While the technology has not yet reached the level of cinematic magic, it can produce holograms that capture the depth, parallax, and other characteristics of a real scene. [(4)]. Holograms can be used to show buildings clearly and attractively and to improve communication between designers, customers, and users. Some of the hologram policies in showing buildings are as follows:

- Using holograms to show historical or archaeological buildings so that the visitor or tourist can see how the building was in the past and learn about its history and culture.
- Using holograms to show buildings before they are built so that the client or user can see how the building will look in reality and provide feedback or changes to the design.
- The use of holograms to show futuristic or imaginary buildings so that the artist or designer can create new and unusual scenes and challenge the boundaries between reality and imagination [(3)]..;.l'

Development History of Holographic Projection Technology

Emerging Stage: In 1947, British physicist Dennis Gabor first proposed the concept of holographic imaging while studying microscopes. The idea of holographic projection gradually began to emerge before the public.

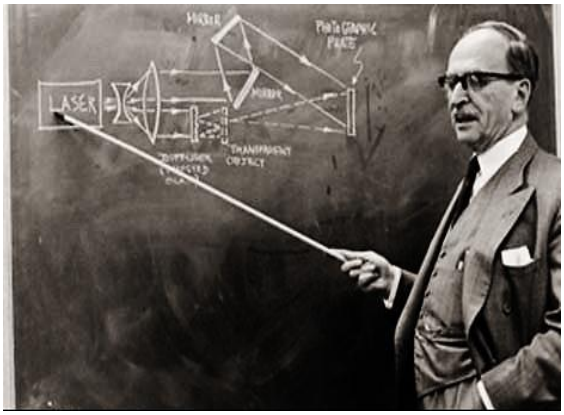

Figure 3: Denis Gabor 1975.

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Exploration Stage: In 1960, the invention of the laser solved the problem of the lack of technology necessary for holographic projection, as the technology reached a certain level of development during this period. In 1962, Soviet scientist Yuri Denisuk captured the first direct optical holographic projection image, capable of recording three-dimensional objects. Leith and Upatniks, staff members of the Radar Laboratory at the University of Michigan, applied the theory of "side view radar" used in the communications industry to holographic imaging based on virtual imaging technology. They discovered off-axis holographic technology, which took virtual imaging to a new level and significantly improved projection performance. In 1969, Benton discovered rainbow holography, which increased the demand for light sources in holographic projection technology.

Bottleneck Stage: In the 1970s and 1980s, holographic projection technology dominated the fields of great interest to scientists at that time. However, most holographic imaging technologies were in the stage of development and consolidation, resulting in few breakthroughs during this period.

Development Stage: With the onset of the 21st century and the rapid advancement of information and material technology, holographic imaging techniques became increasingly diverse. Holographic film technology was developed in 2001, and in 2006, 360-degree ghost imaging technology was widely applied; in 2008, a 3D holographic display screen was developed; in 2014, a 3D holographic projection chip was successfully developed; and in 2017, a 3D imaging fan was developed and put into use [(5)].

How Does Hologram Work?

Holography consists of capturing a light field and subsequently reconstructing it without the original objects present. This process can be likened to sound recording, where the sound generated by a vibrating object is processed in such a way that it can be reproduced later (even when the original vibrating object is not there). To create a hologram, three essential components are required:

- A laser beam directed at the object.
- A recording medium containing the suitable materials.
- A clear environment that allows for the intersection of the light beam. [(4)].

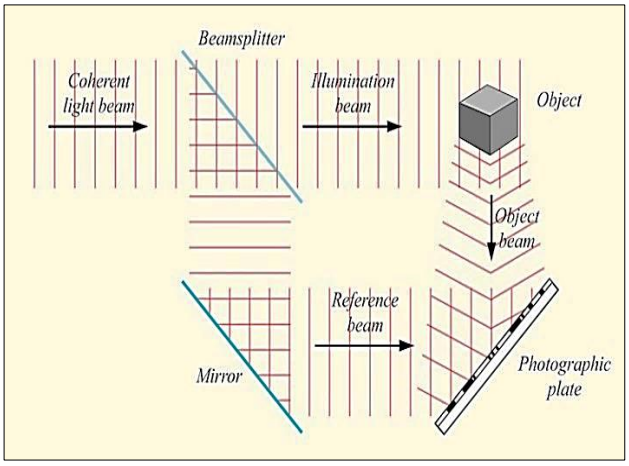

Figure 4: Recording a hologram.

Essential Components for Creating a 3D Hologram:

- **Laser Device**: Produces an argon laser beam or a helium-neon laser that emits red light.
- **Lenses**: Used to focus and direct the laser beams onto the object or imaging plate.
- **Light Splitters**: semi-reflective mirrors that divide the laser beam into two separate parts.
- **Reflecting Mirrors**: Guide the laser beams through the lenses and split the light at designated positions.
- **Hologram Film**: Composed of a layer of photosensitive materials applied to a light-permeable surface, such as a plate of lithium liquid crystals or photopolymers, which are utilized to record the hologram.

How to Obtain a 3D Hologram

To create a three-dimensional stereogram, an object must be present to serve as the target for imaging. Additionally, a laser source is needed to project the beam onto the object that is to be photographed. A recording medium is also required to capture the scattered rays from the object through semi-reflective mirrors, which divide the laser beam into two identical beams. One beam is aimed at the object, reflecting off it onto the recording medium, while the other beam is directed straight to the recording medium to produce the primary stereo image through the hologram.

The hologram (the plate or the recorded interference pattern) contains a complex arrangement of transparent and dark regions. When a light beam similar to the original reference beam is directed at it, the beam passes through the transparent regions while being absorbed by the dark areas to varying degrees. This process generates a composite wave that resembles the original object, creating a similar image in space.

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Thus, obtaining the hologram occurs in two stages: first, where the interference patterns of the light rays are recorded to form the hologram; and second, where the hologram is illuminated in a specific manner so that the incoming beam matches the object wave, resulting in an image that appears as the original object [6].

Principle of Projection Reflection Imaging

Pyramid Holographic Projection

Pyramid holographic projection imaging is generally based on the principle of light reflection, where light signals are reflected onto prisms inside the pyramid-shaped structure. When light encounters the boundary between two different media, it reflects without undergoing refraction. As light passes from a denser medium to a less dense one, the angle of refraction becomes larger than the angle of incidence. If the angle of incidence increases enough, the refracted angle eventually reaches 90 degrees [7].

When these optical signals are combined, they create a spatial configuration resembling the image of a virtual object, as depicted in Figure [5].

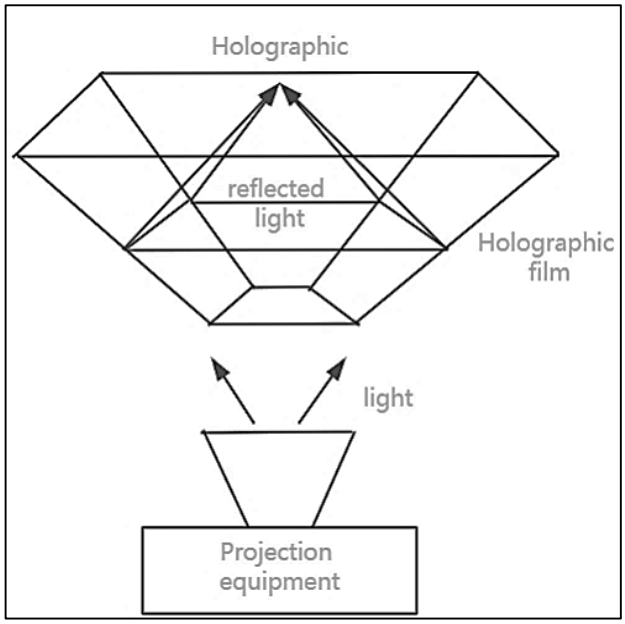

Figure 5: Pyramid holographic projection.

Holographic Film Projection

From the standpoint of imaging principles, holographic film projection enables viewers to see the scenery behind the film while providing sharp image clarity. The quality of the image is exceptionally bright and clear, achieving an impressively ultra-thin form. This projection technique produces a crystal-clear visual experience that immediately captures the audience's curiosity and attention, delivering high-quality visual information without obstructing the presentation of physical exhibits. Unlike three-dimensional imaging using pyramids, holographic film projection is not constrained by venue or design, allowing for widespread creativity and distribution. This flexibility fosters inspiration, imagination, and a sense of technological innovation throughout the environment [8].

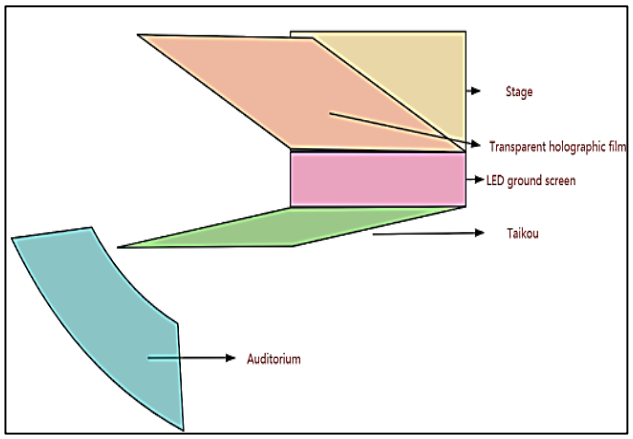

Figure 6: Holographic Film Projection.

Characteristics and Applications of Virtual Holographic Projection

2.2.4.1 Single-Chip Penetration Screen

The single-chip penetration screen is a notable feature of holographic projection. Its precise internal optical structure effectively filters and reduces surrounding light, resulting in exceptionally clear images, particularly with bright picture quality. Additionally, the single-chip screen is remarkably lightweight, which is another distinguishing characteristic.

2.2.4.2 High Transparency

High transparency is another key feature of holographic projection. Unlike traditional projection methods, holography exhibits high brightness and contrast, enabling image quality that exceeds HD standards. Furthermore, it allows for dual-sided imaging, accommodating various objects and presenting them from different angles, even under typical environmental conditions.

2.2.4.3 Simultaneous Presentation of Real Scenes and Images

A unique aspect of holographic projection is its ability to display both real scenes and images simultaneously. This means that it can not only present the content of the actual scene but also integrate images with it, offering a range of aesthetic possibilities. This includes various transparency options, allowing effects such as transparency, translucency, and opacity.

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2.2.4.4 Considerations for Cultural Exhibition Halls

Cultural exhibition halls are typically indoors and require effective light and shadow to enhance the display. Similarly, outdoor exhibitions also depend on light and shadow, often presented in a way that mimics the effects of window displays, akin to shop window advertisements. While external light intensity may fluctuate, holographic projection remains unaffected by these variations. [9].

Advantages of Holographic Projection Technology

- **Novel Form:** Unlike traditional 3D display technologies, holographic images do not necessitate specialized viewing equipment; they can be seen with the naked eye, providing very realistic 3D display effects.
- **Highly Technical:** This technology involves integrating multiple advanced techniques. In practice, it combines various technologies, such as sensing, touch, and voice control, to achieve an optimal blend of visual effects and interactive experiences.
- **Flexible Size:** Holographic projection offers excellent imaging quality, with customizable imaging areas tailored to customer requirements, ranging from a minimum of 20-30 centimeters to over 40 meters. This adaptability makes it suitable for diverse industries and clients, ensuring the best holographic image display for various products.
- **Strong Interactivity:** The display design employs holographic projection technology to turn static objects into dynamic ones, shifting from one-sided displays to interactive experiences for the audience [5].

Applications

As society begins to adopt increasingly advanced technologies, holography has the potential to fundamentally change our perception and experience of architecture. While it's challenging to predict the exact future applications of holographic technology, several existing projects illustrate how holograms and various forms of holography are being utilized to create immersive environments, imaginative scenes, and practical visualizations. These examples go beyond simply using holograms to visualize designs and structures; they employ holography to influence the actual architectural space, significantly transforming the sensory and spatial experience of the environment [10].

2.2.5.1 Ruins as a tourist attraction point:

Heathen's Gate:

At one of Austria's renowned historical sites, a simple line drawing overlaid on a pane of glass breathes life into the crumbling ruins, reanimating the partial building near the Open-Air Museum Petronell. When a viewer aligns the illustration with the structure known as Heidentor (Heathen's Gate), the image compellingly completes itself in an entirely low-tech manner. Located just east of Vienna, Carnuntum dates back to the 1st century A.D., when Roman soldiers expanded an existing town of 50,000 people to establish a military encampment. Between 354 and 361 A.D., a significant triumphal monument was built next to the military camp and city, which was commissioned by Emperor Constantius II, as historical records indicate, to honor his victories. [11].

Figure 7: Heidentor's gate.

Multimedia Light Shows Reviving Ancient Rome at Night:

The Viaggi nei Fori project animates the history of ancient Rome with a multimedia display cast onto the ruins of the Forum of Augustus and the Forum of Caesar. This event runs every evening from June 10 to October 2, 2022. Developed by Piero Angela and Paco Lanciano, the show utilizes light, images, film, and animation to depict life in ancient Rome, with viewers observing from elevated seats along Via dei Fori Imperiali. The presentations build upon the existing marble columns and ruins, employing advanced technology to recreate the forum areas as they appeared during imperial times [12].

Figure 8: 2022 Timetable Forum of Augustus.

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3. SIDI KHREIBISH SITE

Old Benghazi, or what is called "Berniki" (Sidi Khreibish), is the second city after the Hesperides (Sidi Abeed), the first nucleus of settlement. The sources indicate that the wife of Ptolemy III moved her old location in Eusperides to Berenice at the sea. Sidi Akhribish is a neighborhood located in the center of the city of Benghazi. It is bordered to the east by the Al-Sabri neighborhood, to the west by the center of the city, and to the south by the Al-Funduq Al-Baladi Hotel and Al-Jarid Market. This neighborhood was built on the ruins of the city of Berniki, and the area still contains a group of antiquities dating back to that period and its aftermath. There are several old streets branching out within the area formerly known as Torelli, for example, Balah Street, Al-Baja Street, Kweri Street, Sidi Bou Said Street, and Bougoula Street. The neighborhood includes an archaeological area [13].

The area still contains a group of antiquities dating back to that period and its aftermath, despite the theft of many of them [14]. The lighthouse of Sidi Khreibish is located in the neighborhood, which is considered a landmark of the city of Benghazi, on a high hill overlooking the seashore close to the port, as it was established in 1935 AD in the highest area of the city, which is the current cemetery of Sidi Khreibish, which is built over the site of the "Acropos" castle, the Ptolemaic city of Berenice, which was established around 247 B.C.E.

3.1 Brief historical background

Although the site of Benghazi had "been occupied since ancient times, the development of the centre remained slow and erratic until the early decades of this century. The centre was almost certainly founded by Greek settlers from the Jebel at some time before 515 B.C. However, no certain reasons are yet known for the establishment of what was then known as Eusperides, replaced by Berenice. In the third century B.C., the city was renamed in honor of the wife of the Egyptian King Ptolomy III. Eusperides had direct sea communications, and perhaps its effective defensive site developed serious defects because of the gradual silting up of the lagoon on which it was founded. The transfer from the old site was, therefore, inevitable [15].

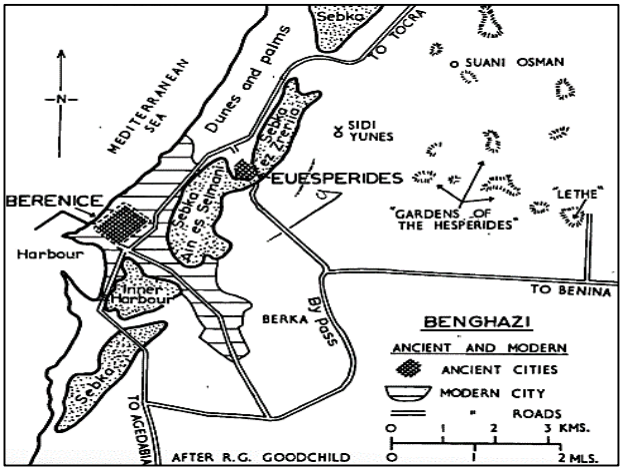

Figure 9: Benghazi: ancient and modern.

Occasional discoveries of mosaic floors and other artifacts confirm the location of Berenice beneath Benghazi and its associated cemeteries. Excavations conducted between 1971 and 1974 in the old Turkish cemetery of Sidi Khrebiesh uncovered remnants of buildings and pottery dating from the Hellenistic period to Byzantine times, along with a section of a late town wall. A stele from the 1st century B.C., discovered in 1972-73, documents civil unrest and pirate attacks. Inscriptions of the 1st century A.D., found previously, mention the separate magistrates of the Jewish community and a synagogue. [16]

Near Benghazi are several sites of legendary interest. The Hesperides, known for their golden apples, were believed to inhabit a lush, sunken garden associated with several natural depressions in the plain located about 10 kilometers east of Benghazi, providing a plausible setting. One of them has an underground pool, which possibly accounts for the location of the river Lethe there. [16]

Benghazi Lighthouse:

In 1992, the architect "Veraza" prepared the design of the water tank and the lighthouse in a classic style derived from architecture in the Islamic era, and its exterior shape is largely the minaret of the Kairouan Mosque in Tunisia." [17]. It contains two tanks, one to supply the city with drinking water, and the second is a tank used to clean the sewage network by supplying it with sea water and then re-pumping it.

The lighthouse is 41 meters high, and it lights up with a white light in a circular pattern every three seconds. A water tank is crowned at the top of the lighthouse lamp, which is located on the upper two floors. Its light can be seen from a distance of 17 nautical miles. [17]. The lighthouse building remained as it was, with its main function being a landmark that expresses the city of Benghazi. Recently, terraces have been added as an

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integral part of the lighthouse design, directing it towards the Mediterranean.

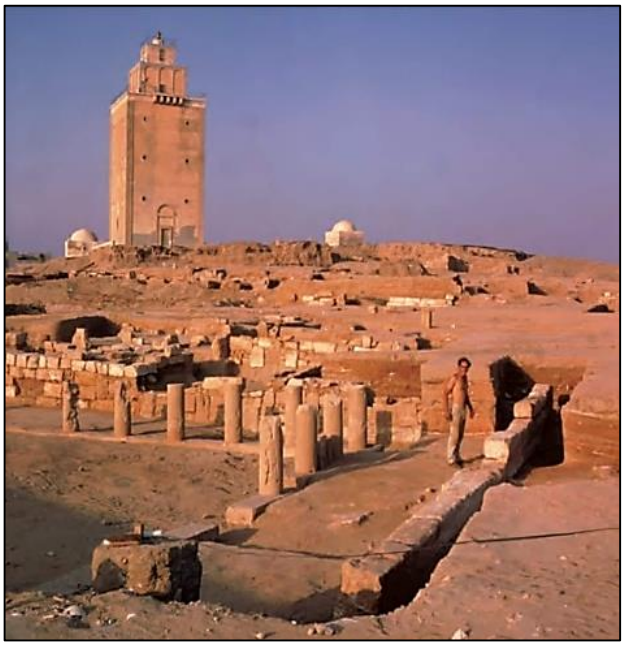

Figure 10: Building the Lighthouse.

3.2 Site analysis

Site analysis refers to the process of studying the physical characteristics and environmental conditions of a site where a proposed building or structure is to be constructed. This analysis is crucial for architects to understand the site's attributes and limitations, including the landscape, topography, orientation, natural or man-made features, availability of utilities, and various other factors that could affect the design and positioning of a building. Site analysis helps architects to develop designs that are harmonious with the surrounding environment and meet the client's needs while considering the site's unique characteristics.

3.2.1 Sidi Akhribish neighborhood

Sidi Akhribish is a neighborhood located in the center of the city of Benghazi. It is bordered to the east by Al-Sabri neighborhood, to the west by the center of the country, and to the south by the Al-Funduq Al-Baladi Hotel and Al-Jarid Market. This neighborhood was built on the ruins of the city of Berenice, and the area still contains a group of antiquities dating back to that period and its aftermath. There are several old streets branching out within the area formerly known as Al-Torelli, including, for example, Bala Street, Al-Baja Street, Kweri Street, Sayed Busaid Street, and Bougoula Street.

3.2.2 Site attributes

The archaeological area is fenced and has two entrances. The antiquities are scattered and not visible from behind the walls. The movement inside is not clear and neglected. There are few modern buildings inside, and they are destroyed. The area still contains a group of antiquities dating back to that period and its aftermath, despite the theft of many of them. The Lighthouse of Sidi Khreibish, which is considered a landmark of the city of Benghazi, is located in the neighborhood on a high hill overlooking the seashore and close to the port.

Figure 11: site plan.

3.2.3 Visual axis

The site is located on a hill, which helps to allow passersby to see, despite the presence of a wall surrounding the site. The field of vision is narrow in the residential neighborhood on the southern and eastern side, while on the seaside there is a wide field of vision. The Lighthouse block is elevated relative to the surrounding buildings. It is considered an important visual attraction in the region, as it also represents the identity of the city.

3.2.4 Skyline and waterfront

Iconic structures that serve as landmarks and symbols of a city. The city's blend of different architectural styles creates a visually captivating and diverse urban landscape. Benghazi city skyline can be seen, and architectural elements are identified as basic elements in the skyline. Where the lighthouse occupies a key element in shaping the waterfront skyline of Benghazi. Other elements include bringing the Benghazi Cathedral and other minarets to life by recreating them in a realistic and interactive manner. Holographic scenes allow viewers to see and engage with the past in an engaging and dynamic way.

3.2.5 Study of Sidi khirebish excavations

Until recently, Berenice was one of the least known of ancient Cyrenaican cities. Most of the site is covered by

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modern Benghazi, whose buildings employed (and thereby destroyed) the old city's extant remains.

A relatively small part of Berenice was, as we now know, safely concealed under the Sidi Khrebish cemetery, in use from the time of the Turkish administration to the 1930s. In the early 1970s, when the municipality of Benghazi proceeded to urbanize the Sidi Khrebish area, the Department of Antiquities at Tripoli and Professor J. B. Ward-Perkins recognized the imminent threat to the hidden remains of Berenice.

The Society for Libyan Studies in London was invited to join the Department of Antiquities in a rescue campaign, which was to become a full-time excavation in 1972–1973. The operation was a major event at the time. At its zenith, it employed over one hundred persons, investigating an area of over 18 000 square meters. It brought to light long-span sequences and an immense wealth of artifactual and immobile find data. [18].

The site excavated by the Department of Antiquities and the Society for Libyan Studies lies within a nineteenth-century Turkish cemetery close to the seafront near the center of Benghazi. It was the clearance of this cemetery by the municipality and the ancient structures thereby revealed which gave rise to the present series of excavations. The site was found to lie on the periphery of the Hellenistic and Roman city of Berenice, and the excavations revealed parts of two different defensive circuits built initially in the Hellenistic period and the mid third century A.D.

Respectively, a grid-plan including courtyard houses and small industrial establishments of various periods, a late Hellenistic shrine (Building X), a large peristyle (Building Ll) belonging to a monumental establishment outside the excavated area (baths?), and on the eastern part of the site a Roman complex of apparently public character (Buildings T and W) cut through by the foundations of a large and very plain Byzantine church (Building G) [19].

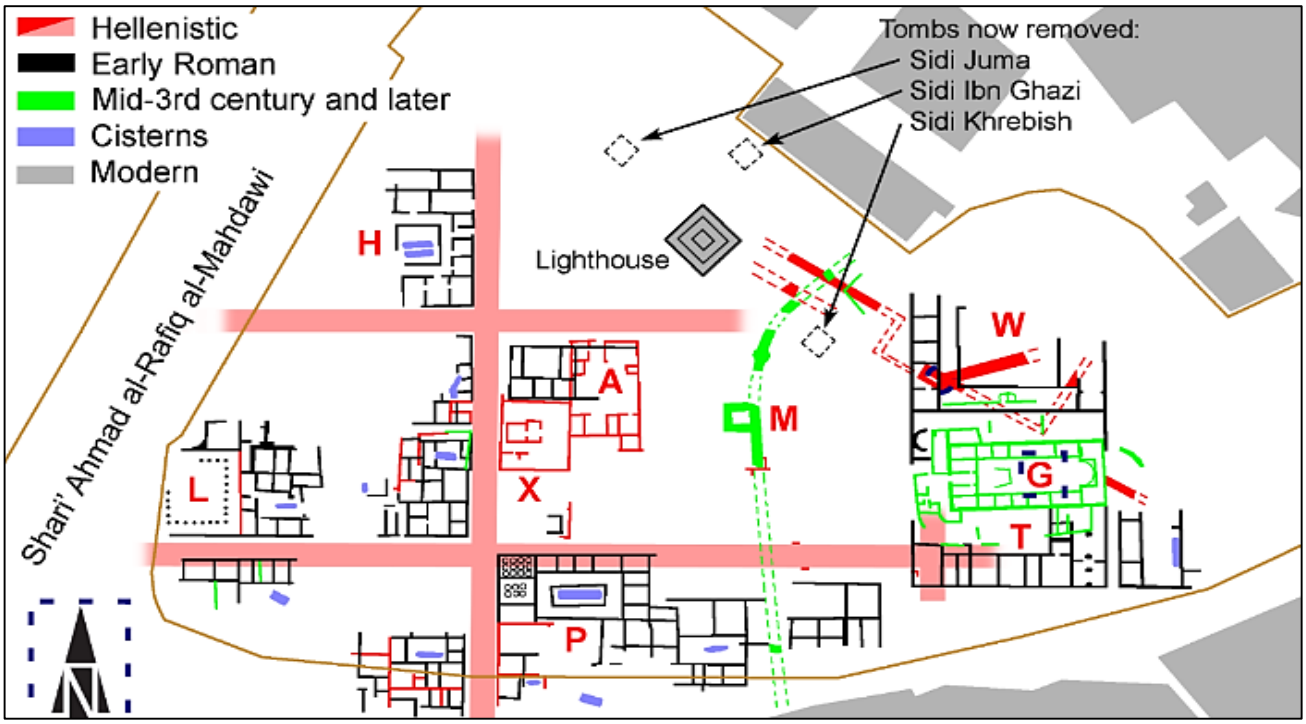

Figure 12: detailed plan of ancient network and buildings.

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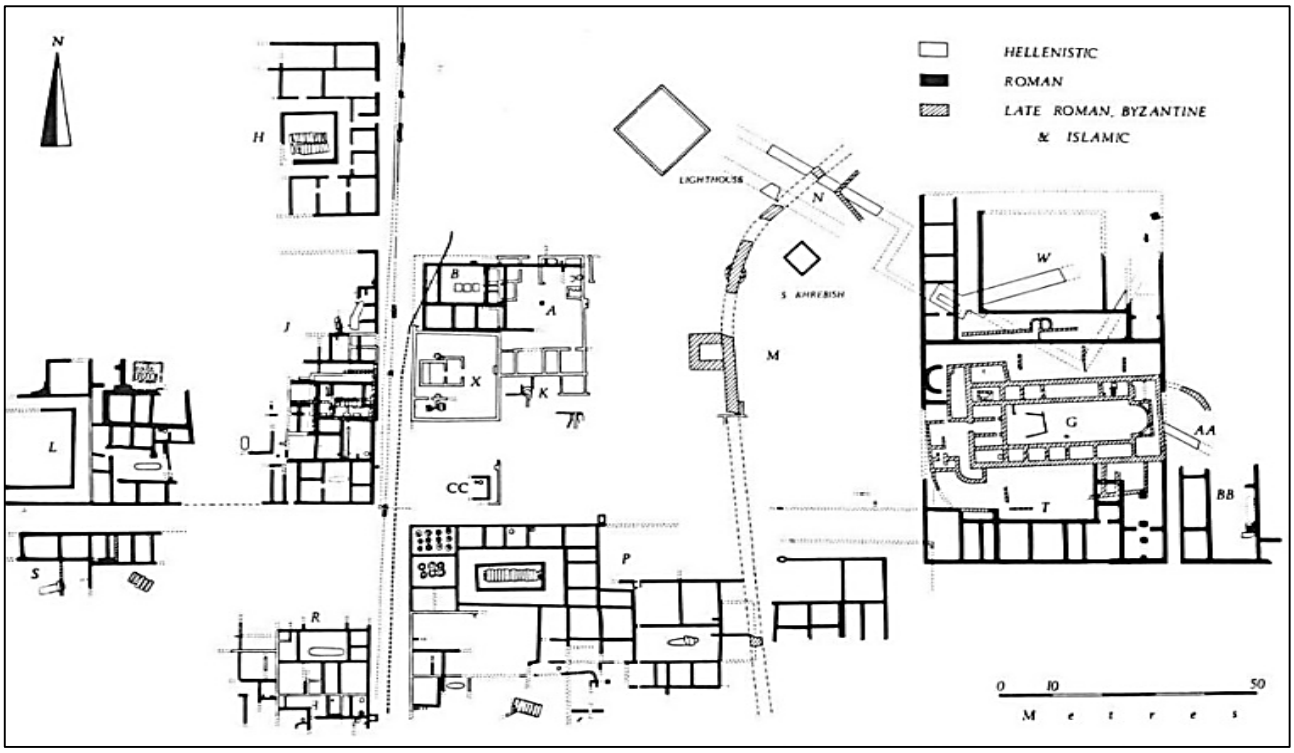

Figure 13: 7 Master Plan of Sidi Khribesh.

3.3 The Importance and Values of Reviving the Ruins of Berenice

- **Historical value:** Heritage is one of the areas of concern for historians. Preserving the architectural heritage of buildings and archaeological sites is promoting the identity of the past, the civilization of the nation, and the continuity of the place. It is said that he who has a past has a present and a future, as some countries promote their future and present with their glorious history.
- The value is social, as it is the basis for preserving the local culture and urban identity, and it enhances the cultural dimension within the community and the sense of belonging and identity.
- A basis for sustainable development: by attracting investment, providing job opportunities, and providing environmental benefits by reducing demolition waste and decreasing the resources required for demolition and reconstruction.
- **The value is aesthetic in its location:** the value includes the characteristics through which the traditional building becomes an important axis in terms of national, cultural or spiritual aspects.
- **Scientific value:** cultural heritage shows the history and life of ancient peoples and shows the diversity and difference between them.
- **Economic value:** The urban heritage and historical areas represent a major source of national income for both internal and external cultural tourism, as a legacy that reflects the history of the region, and cultural tourism is considered one of the fastest growing sectors of international tourism.

4. DISCUSSION AND PROPOSAL STRATEGIES

According to the spatial analysis of the area, a new vision of the place can be created using the hologram technology. That is to create a virtual district where the visitor can have an enjoyable experience walking among the virtual buildings as the most powerful way to revive it.

Using a holographic projection system to reconstruct Sidi Khribish ruins can create immersive experiences for preservation and tourism. Here's a step-by-step approach to how this proposal can be implemented:

4.1 Collect Information:

Gather archives, architectural plans, and archeological discoveries pertaining to the ruins.

Excavation archives as a reference: To start designing a landscape for an archaeological area, it is necessary to search for the original network that existed at that time, where the movement is the same on that network, and for this we searched in excavation research in the area to extract the road network in it and in its light the movement.

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3D scanning: To document the current situation of the ruins, use photogrammetry or 3D laser scanning. This will provide restorers with a detailed model.

Figure 14: Example Of 3D Scanning the Current Satiation of the Ruins.

4.2 Model Creation

3D Modeling: Using the data collected, create a 3D model using tools such as Blender, SketchUp, or Revit. Make sure the model matches the structure's historical development.

Textures and Materials: To increase realism, use textures and materials that correspond with the original construction.

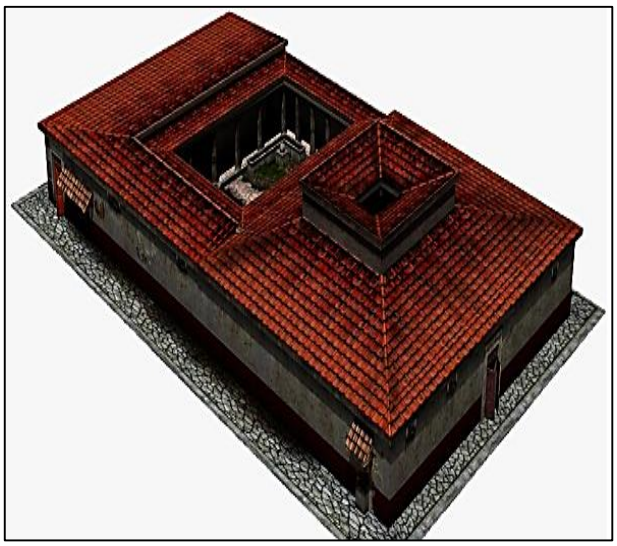

Figure 15: Domus House Roman 3D Model.

4.3 Installing a Holographic Projection System The installation of technology:

Place screens, projectors, or augmented reality devices so that the holograms appear most effectively in the planned settings. In this case, the best view is from the sea (waterfront view) as well as the marine pedestrian paths along the sea.

Figure 16: 3 Holographic projection system display placements.

4.4 Combining Interactivity and Integration The interface design:

Provide an intuitive user interface that enables users to engage with the hologram by enabling them to view it from multiple angles, magnify specific details, and access historical information.

Dynamic elements: Take into consideration adding functions such as audio tours, informational touchpoints, or even augmented reality experiences that allow visitors to view the ruins as they were originally intended to be seen.

Figure 17: View from the seaside, prepared by the researchers.

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4.5 Taking advantage and promotion

Viewers launch: To present the holographic reconstruction to the general audience, organize a launch event or exhibit.

Awareness and education: Work with organizations and schools to integrate the projection system into instructional initiatives.

This approach can create a compelling and educational experience that brings the past to life for visitors.

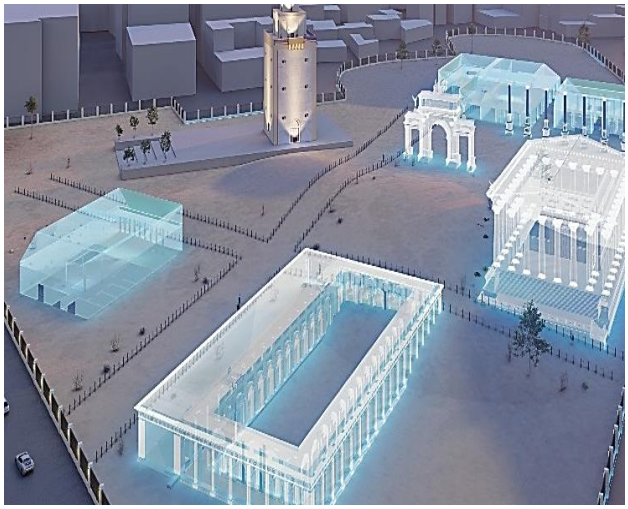

Figure 18: Aerial perspective of holographic projection proposal prepared by the researcher

Limited access: suggesting setting up chains to direct the visitor for movement inside the place where movement is restricted, out of concern for the ruins in the area, to allow wandering inside without disturbing or tampering with it.

5. CONCLUSION

From this study, we conclude that the Sidi Khreibish area in the Old City of Benghazi is a very important archaeological area in terms of its scarcity. However, since its almost complete disappearance, it has lost its importance for the city. Moreover, the Benghazi Lighthouse is an important landmark and a real masterpiece in the architectural heritage. It blends Ottoman and Italian influences to create a unique and iconic structure. Its rich history and cultural significance make it an important landmark for the people of Benghazi, as it stands as a symbol of strength and resilience in the face of adversity. Through extensive architectural conservation and restoration work, the lighthouse will continue to shine brightly for years to come, guiding sailors safely to port and inspiring hope in the hearts of all who see it.

The study attempted to highlight the importance of the archaeological area of Sidi Khreibish once again by using hologram technology to redesign it virtually. Through the submitted proposal, the Greek region and the Roman ruins of the Sidi Khreibish region were highlighted and revived, as well as allowing movement in the region in a limited manner in the original Roman road network as a default reference for the proposal.

It is very important in the field of architectural and urban heritage preservation and revitalization to anticipate a new type of landscape that connects reality and visual imagination and create a new dialogue between the past and the present, where people can move between this specific landscape and cherish the new “free eye” experience.

Also, lighting and lasers can be used on occasions to write and draw on the lighthouse to express the current event in the area. It is also possible to embody a dynamic movement in the area, such as birds, animals, and residents in the area, as if it is a vital area that carries the historical era of the Greek region and Roman ruins, which makes it very interesting.

Figure 19: Proposed waterfront, prepared by researchers.

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Physical and Gamma Ray Attenuation Properties of Bismuth-Lead-Phosphate Glass

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ABSTRACT

In this paper, the physical characteristics and radiation attenuation parameters of five ternary (50-x) PbO-xBi_2O_3-50P_2O_5 glass samples with different compositions were examined. The physical properties investigated were glass density (ρ), molar volume (V_M), molar volume of oxygen (V_O), and oxygen packing density (OPD). An empirical formula was used to determine the glass density theoretically and compared with the experimental density obtained from the Archimedes method. The comparison yielded reasonable results but did not achieve the desired level of accuracy as expected. The findings revealed that both density and molar volume exhibited an increase with higher Bi_2O_3 content. However, the molar volume of oxygen (V_O) and oxygen packing density (OPD) show inconsistent behavior, showing a slight increase in V_O and a decrease in OPD. Furthermore, the essential radiation properties, including the coefficient of linear attenuation (LAC), coefficient of mass attenuation (MAC), half-value layer (HVL), and tenth-value layer (TVL), were determined through experimental and theoretical calculations using the NaI (Tl) detection system and the Phy-X/PSD program, respectively. The results indicated reasonable consistency between the two methods, with the Bi16Pb34P50 sample demonstrating superior radiological properties among the samples. Overall, the study illustrated that the addition of bismuth to phosphate and lead glass improved the glass samples' radiation and physical characteristics.

KEYWORDS: density, lead-phosphate glass, oxygen molar volume, oxygen packing density, physical parameters; mass and linear attenuation coefficient.

1. INTRODUCTION

In the past century, glass has drawn a lot of interest for its potential applications in a variety of fields, including research, industry, medicine, and construction. Its many advantages include high transmittance, durability, water resistance, transparency, high homogeneity, and acceptable mechanical and chemical stability [1]. These features exhibited by glass provided it with simple applications and processing. One of the important applications for glass is in the area of shielding and radiation protection. Protection from radiation is needed since radiation is present in many fields like energy generation, medical diagnosis and treatment, and others. These advantages of radiation come with costs and hazards to the environment and health.

To avoid these risks, protection measures are required to lessen the high-energy gamma photons that are radiated from radioactive sources [2]. Traditionally, concrete and lead are primarily used for such protection, shielding, and radiation reduction measures. Concrete was the preferred material due to its high density, easy formability, structural strength and low cost [3]. However, concrete has several disadvantages, namely: cracking, space consumption, opacity to visible light, aggregate expansion, moisture, and a progressive decrease in mechanical strength and density [4]. On the other hand, lead is one of the most commonly used materials for radiation shielding and protection [5]. Nevertheless, the opacity and potential health risks associated with lead toxicity have prompted researchers to seek safer, more environmentally friendly alternatives for radiation shielding. Glass, with its diverse properties, emerges as a promising candidate. By offering superior radiation protection while minimizing environmental concerns, glass could provide a viable solution to the challenges posed by lead-based materials. Borate, silicate, and phosphate glasses are among the most significant types.

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Phosphate glass, in particular, exhibits unique properties like high absorption, low glass transition temperature, and minimal optical scattering. While ionizing radiation cannot be completely eliminated, its levels can be reduced [6]. HVL and TVL are commonly measured parameters in shielding calculations where they determine the required material thickness to attenuate gamma radiation intensity to half and tenth of its original amounts, respectively, and are usually stated in mm or cm distance units [7]. The present paper investigates the effect of the addition bismuth oxide on lead phosphate glass with different percentages. The different physical properties, namely: glass density, molar volume (V_M), oxygen molar volume (V_o) and oxygen packing density (OPD), are evaluated. In addition, the radiation shielding specifications for TVL, MAC, HVL, and LAC are also determined. The attenuation coefficient was evaluated in two ways: experimentally using the thallium-activated sodium iodide, NaI (Tl), detection system, and theoretically using the Phy-X/PSD program, at gamma energies of 0.662, 1.173 and 1.33 MeV.

2. Experiment Methods

2.1. Glass Preparation and Density Determination

Five glass samples with the composition (50-x) PbO-xBi_2O_3-50P_2O_5, where x = 0, 4, 8, 12, and 16 mol%, were prepared using the "melt-quenching" technique. Glass sample densities were measured using the Archimedes method with xylene serving as the immersion solvent. The experimental density was calculated using the following relationship [8]: (1)

Where w_a and w_X represent the sample weight in air and xylene, respectively, and ρ_x denotes the density of xylene (ρ_x = 0.861 g cm^{-3}). The details of the preparation method and the glass density measurement were reported in our previous work [9]. The produced glass samples and their chemical compositions are presented in Table 1 [9].

Table 1: Glass compositions and their photos for prepared samples [9].

Sample code	Chemical composition (mol %)	Prepared glasses
Bi0Pb50P50	50PbO-0Bi_2O_3-50P_2O_5	
Bi4Pb46P50	46PbO-4Bi_2O_3-50P_2O_5	
Bi8Pb42P50	42PbO-8Bi_2O_3-50P_2O_5	
Bi12Pb38P50	38PbO-12Bi_2O_3-50P_2O_5	
Bi16Pb34P50	34PbO-16Bi_2O_3-50P_2O_5	

2.2. Physical Parameters Related to the Glass Density

The V_M is calculated using the following formula [10]:

$$V_M = \frac{\sum M_i x_i}{\rho_{exp}} \quad (2)$$

Where M_i is the molecular weight of the glass sample and ρ_{exp} is the experimentally evaluated glass sample density.

The oxygen molar volume, V_o (the volume of glass that contains one mole of oxygen) is calculated by the formula [11]:

$$V_o = \frac{V_M}{\sum X_i n_i} \quad (3)$$

Where n_i number of oxygen atoms in each component oxide.

The OPD, which provides information about the tightness of glass network, is determined by [12]:

$$OPD = 1000\ C\ (\frac{\rho_{exp}}{M}) \quad (4)$$

Where C represents the number of oxygen atoms.

2.3. Measurement of Linear Attention Coefficient

In this work, sodium iodide (NaI) detection system was used to determine LAC experimentally. The basic gamma ray detection system, which is shown in Figure 1 and used for spectral measurements, consists of a "1.5x1.5" crystal of Thallium-activated sodium iodide

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scintillation detector, NaI (Tl), model no. (PM-9266B) and serial no. (WA00012638), a multichannel analyzer MCA, a high-voltage power supply, and a CASSY sensor. The detector assembly was inserted into a 15-mm-thick cylindrical lead shield to reduce background and unwanted radiation that might come from sources in the lab or from other sources such as natural radionuclides and cosmic rays [13]. Collimated gamma photons from point sources ^{137}Cs (0.662 MeV) and ^{60}Co (1.173, 1.33 MeV) were used in the measurements, and the glass samples were placed between the source and the NaI detector, as shown in Figure 1. Counts of the incident and attenuated intensities of gamma ray energies for each glass sample were recorded for 20 min. The measurements were repeated three times with and without the glass samples for better statistics. The net counts under the photo peaks were obtained after background subtraction and Gaussian fitting of the spectral peaks.

The measured LAC of all glasses was acquired by the Beer-Lambert relation [13]:

$$I = I_0 e^{-(LAC)x} \qquad (5)$$

Where I_0 is the intensity of the incident radiation on the glass sample, I is the intensity of attenuated radiation, and x is the glass sample thickness.

Fig. 1: NaI detection system used in the research.

2.4. Calculation of Mass Attenuation Coefficient (MAC)

MAC values of glass samples were calculated from the determined LAC values in the previous section using the following formula [14]:

$$MAC = \frac{LAC}{\rho_{exp}} \qquad (6)$$

Where ρ_{exp} (g cm^{-3}) is the experimentally measured density of glass samples.

2.5. Determination of Half Value Layer (HVL)

The formula below was utilized to determine HVL values [14]:

$$HVL = \frac{0.693}{LAC} \qquad (7)$$

2.6. Determination of Tenth Value Layer (TVL)

TVL values were calculated using the following formula [14]:

$$TVL = \frac{2.30}{LAC} \qquad (8)$$

3. THEORETICAL STUDY

3.1. Empirical Density

The empirical densities of the glass samples (ρ_{emp}) were found theoretically using the following formula [15]:

$$\rho_{emp} = 0.53 \frac{\sum M_i X_i}{\sum V_i X_i} \qquad (9)$$

Where M_i is the molecular weight of the glass components, X_i is the mole fraction for each component, and V_i is the packing density parameter. For an oxide M_XO_Y, the V_i parameter can be determined by:

$$V_i = \frac{4}{3}\pi NA\,(X.r_M^3 + Y.r_O^3) \qquad (10)$$

Where r_M and r_O are the ionic radii of metal and oxygen, N_A is the Avogadro number, and X and Y are the number of metal and oxygen atoms, respectively.

3.2. Theoretical Calculations of Radiation Parameters

The radiation parameters LAC, MAC, HVL, and TVL were established theoretically by Phy-X/PSD software [16]. ^{137}Cs, and ^{60}Co gamma radioactive sources were selected for this program.

4. Results and discussion

4.1. Outcomes of Physical Characteristics

Glass density (ρ), V_M, V_O, and OPD, are the most important physical properties that were studied in this current work. Density measurement is a convenient way to sense any structural difference in the glassy system, since density is affected by changes in atomic coordination numbers and the size of the ionic radius in the glass lattice. When experimental density (ρ_{exp}) and theoretical density (ρ_{emp}) were determined, it was observed that they increase linearly with increasing Bi_2O_3 concentration, as shown in Table 2 and Figures 2 and 3 with a deviation (RD%) ranging from 9.02 to 13.72%. This deviation is not closely agreed upon but is reasonable compared to previous published results for different glass compositions calculated by several methods [17][18] [19].This may be due to the effect of bismuth and lead on the structural composition of the glass samples compared to other oxide. This may also be attributed to Inaba and Fujino who has neglected to include lead and bismuth data with the phosphate glass when calculating the theoretical density. As for the increase in density with increasing Bi_2O_3, Bi_2O_3 (M = 465.959 g mol^{-1}) was replaced by PbO (M = 223.199 g mol^{-1}) in the composition, which resulted in obtaining

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denser glass samples. Values of molar volume have increased from 37.48 cm^3 mol^{-1} to 43.68 cm^3 mol^{-1} as the Bi_2O_3 content of the glass matrix increased, as shown in Figure 4. This suggests a potential expansion of the vitreous network and a more open vitreous structure in the glassy matrix. In general, molar volume of any glassy matrix increases with increasing number of oxygen atoms and the size of ionic radii [17].

Table 2: Physical Parameters of the glass system xBi_2O_3–(50 – x)PbO–$50P_2O_5$

Sample code	ρ_{exp} [9]	ρ_{emp}	RD%	M	V_M [9]	V_O	OPD
	(g/cm^3)	(g/cm^3)		(mol/g)	(cm^3/mol)	(cm^3/mol)	(mol/L)
S1	4.87	4.20	13.72	182.57	37.48	12.49	80.02
S2	4.89	4.31	11.90	192.28	39.28	12.75	78.40
S3	4.97	4.42	11.13	201.99	40.64	12.86	77.75
S4	5.03	4.52	10.15	211.70	42.11	12.99	76.93
S5	5.07	4.61	9.02	221.41	43.68	13.16	76.00

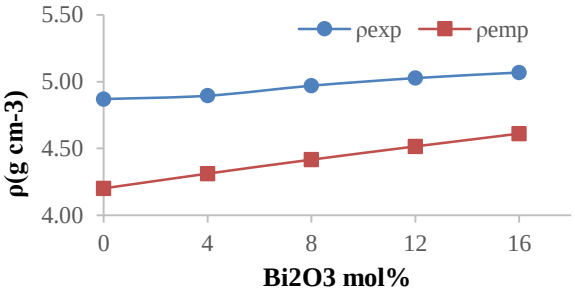

Fig 2: The experimental and empirical densities as a function of Bi_2O_3 mol% content.

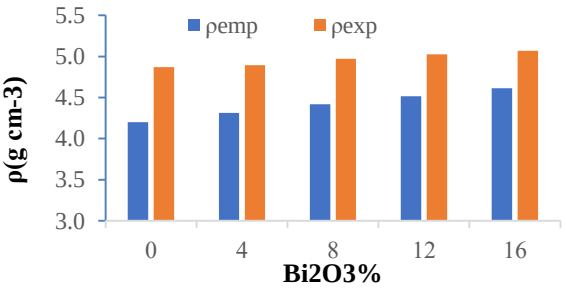

Fig 3: A histogram of the experimental and the empirical densities.

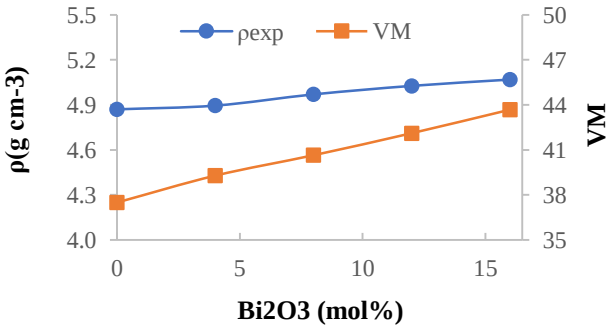

Fig 4: Variation of ρ_{exp} and V_M with Bi_2O_3 mol% content.

The relationship between the OPD and the V_o greatly affects the physical properties of the glass; through the oxygen packing density, the rigidity of OPD in the glass network is known. There is an inverse relationship between OPD and V_o and this inverse general behavior is experimentally confirmed by the results shown in Table 2 and Figure 5. This behavior indicates a bond decrease in the glass matrix as the glass structure becomes tighter and more rigid [20].

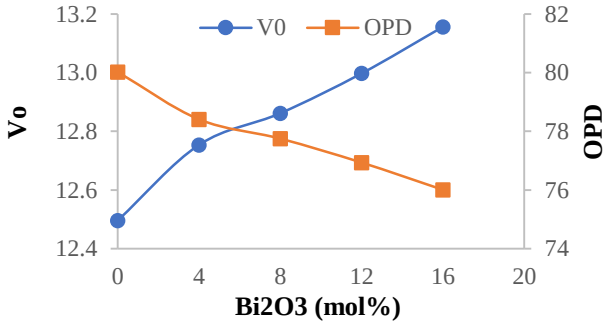

Figure 5: Variation of V_O and OPD with Bi_2O_3 mol% content.

4.2 Radiation Properties

LAC and MAC are critical factors in evaluating a material's ability to attenuate gamma radiation. LAC determines how well a material reduces radiation intensity per unit thickness, while MAC measures the reduction in intensity per unit mass [21]. The LAC and MAC for the glass samples were determined experimentally and theoretically, experimentally using a sodium iodine detection system and theoretically using Phy-X/PSD program at the specified energies of 0.662, 1.17, and 1.33 MeV. The results are shown in Tables 3 and 4. Ahigh degree of concordance was observed between the two methods, indicating that tabulation-

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based electronic programs are reliable tools for determining attenuation coefficients. For the gamma energies 0.662 MeV, 1.17 MeV and 1.33 MeV used, the highest LAC and MAC values of to 0.478 cm^{-1} and 0.0944 cm^2/g respectively, were found at the 0.662 MeV energy, and in the sample, Bi16Pb34P50, containing 16 mol% of Bi_2O_3. Moreover, the lowest LAC and MAC values of 0.436 cm^{-1} and 0.0896 cm^2/g, respectively, were found at value at 1.33 MeV energy, and in the sample, Bi0Pb50P50, containing 0 mol% of Bi_2O_3 as shown in Figures 6, 7, 9, and 10. The LAC and MAC values increased with increasing Bi_2O_3 concentration at each of the gamma energies 0.662, 1.17 and 1.33 MeV, as shown in Figures 8 and 11.

Table 3: Comparison of MAC values calculated experimentally and values by the Phy-X code of the glass system xBi_2O_3– (50 – x) PbO–$50P_2O_5$

MAC (cm^2/g)								
	0.662 MeV			1.173 MeV			1.33 MeV	
EXP	Phy-x	RD%	EXP	Phy-x	RD%	EXP	Phy-x	RD%
0.0896	0.0956	6.26	0.0541	0.0602	10.18	0.0528	0.0554	4.64
0.0910	0.0963	5.57	0.0549	0.0603	8.98	0.0530	0.0555	4.56
0.0907	0.0970	6.46	0.0589	0.0604	2.60	0.0535	0.0556	3.82
0.0928	0.0976	4.85	0.0638	0.0606	-5.29	0.0574	0.0557	-3.18
0.0944	0.0981	3.83	0.0638	0.0607	-5.25	0.0594	0.0557	-6.61

Table 4: Comparison between the LAC values calculated experimentally and values obtained by the Phy-X code of the glass system xBi_2O_3– (50 – x) PbO–$50P_2O_5$

MAC (cm2/g)								
	0.662 MeV			1.173 MeV			1.33 MeV	
EXP	Phy-x	RD%	EXP	Phy-x	RD%	EXP	Phy-x	RD%
0.436	0.466	6.26	0.263	0.293	10.18	0.257	0.270	4.64
0.445	0.471	5.57	0.269	0.295	8.98	0.259	0.272	4.56
0.451	0.482	6.46	0.293	0.300	2.60	0.266	0.276	3.82
0.467	0.490	4.85	0.321	0.304	-5.29	0.289	0.280	-3.18
0.478	0.497	3.83	0.324	0.307	-5.25	0.301	0.283	-6.61

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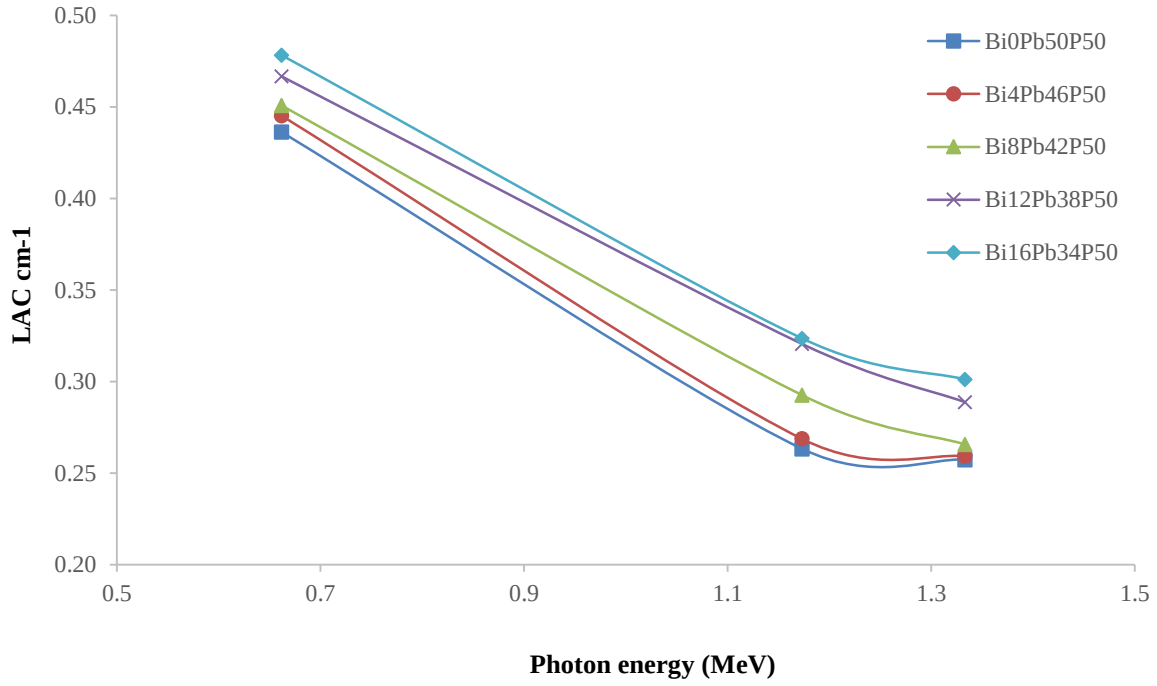

Fig 6: The relationship between linear attenuation coefficient (cm^{-1}) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses (experimentally).

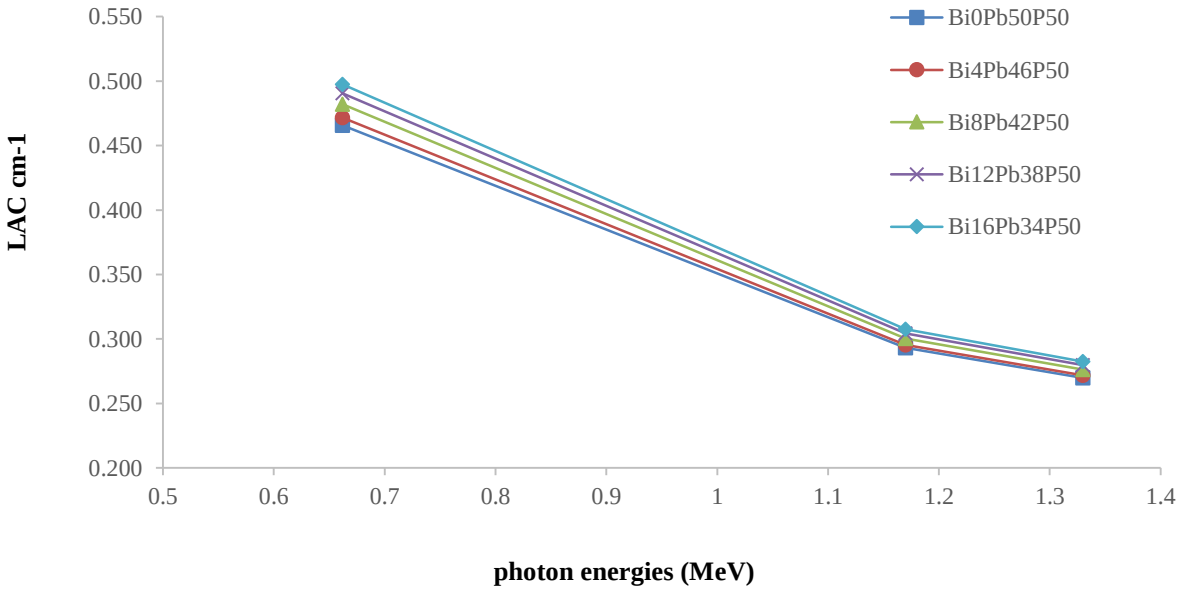

Fig 7: The relationship between linear attenuation coefficient (cm^{-1}) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses (theoretically).

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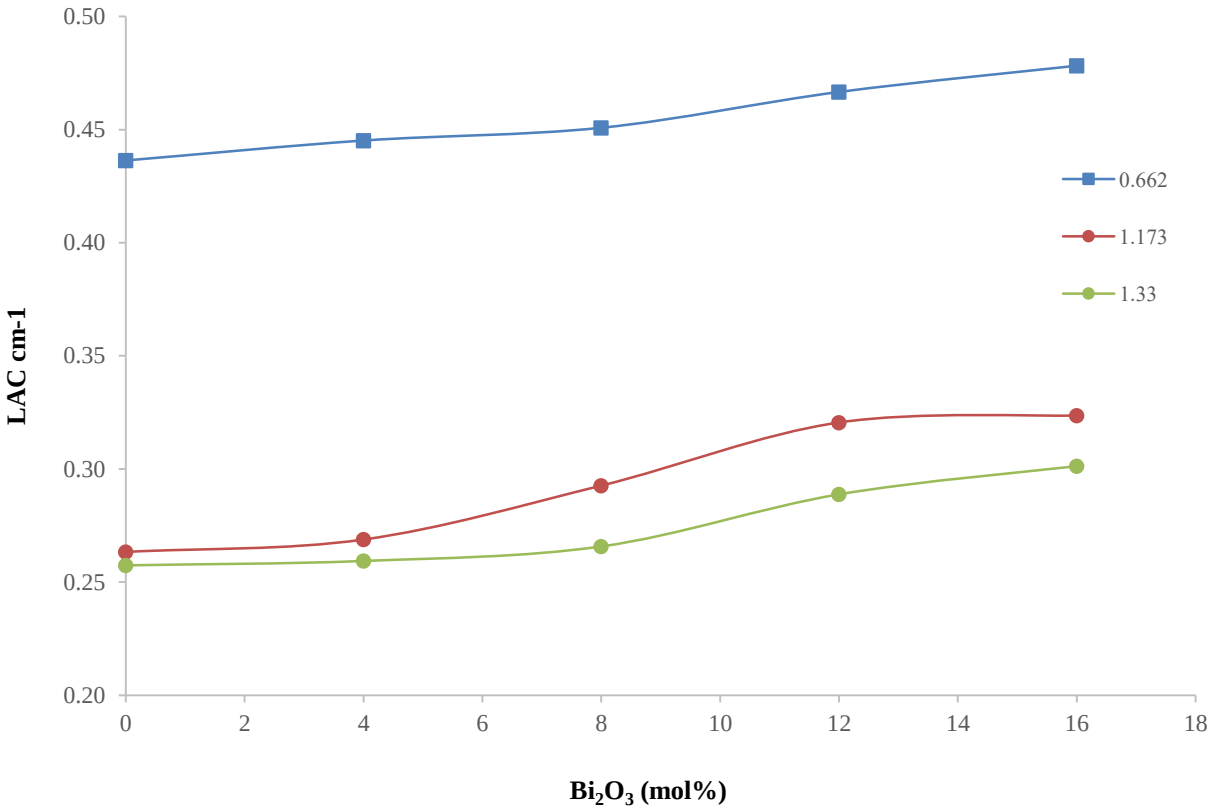

Fig 8: The relationship between linear attenuation coefficient (cm^{-1}) and Bi_2O_3 (mol%) content for Bi_2O_3-PbO-P_2O_5 glasses at different photon energies (experimentally).

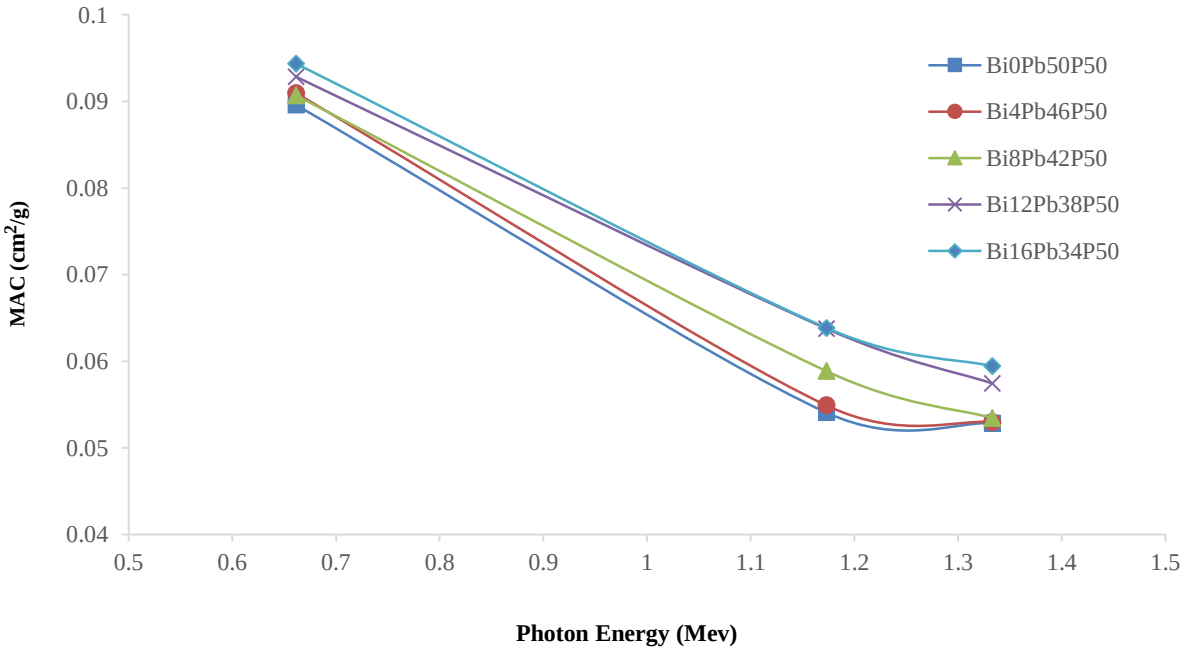

Fig 9: The relationship between mass attenuation coefficient (cm^2/g) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses (experimentally).

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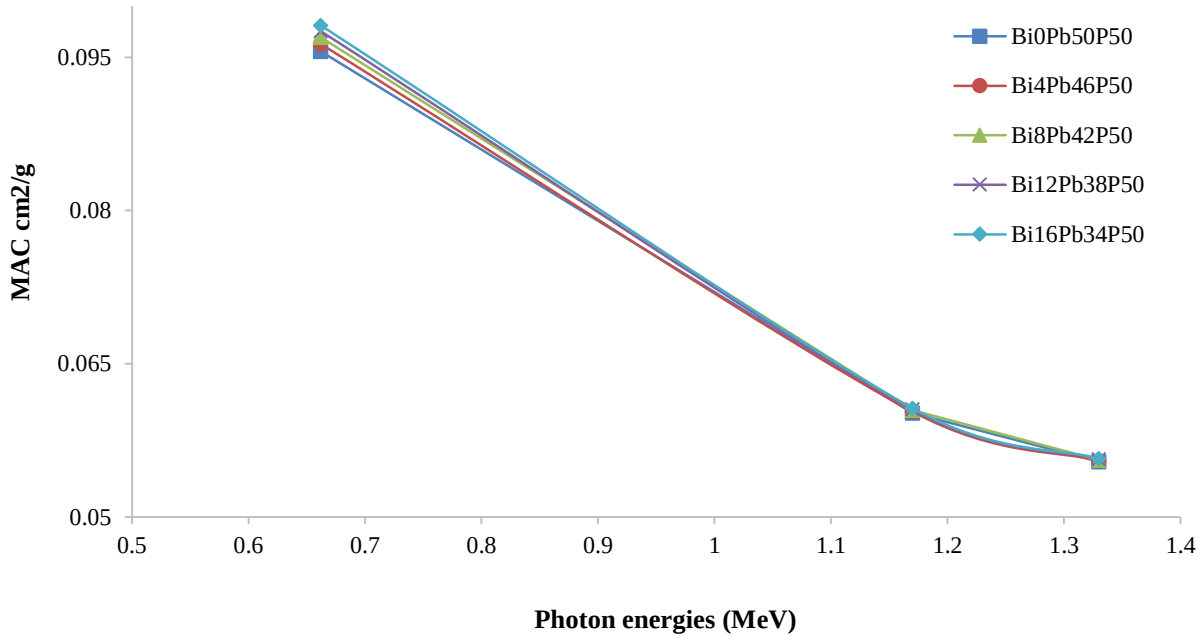

Fig 10: The relationship between mass attenuation coefficient (cm^2/g) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses (theoretically).

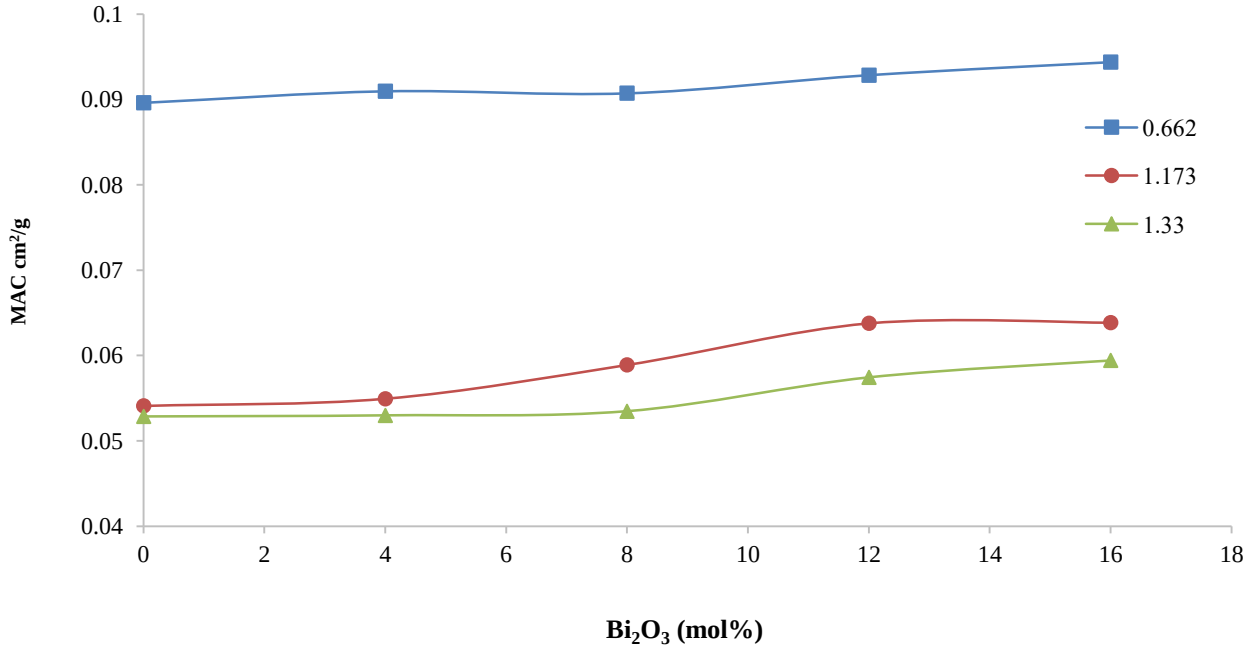

Fig 11: The relationship between mass attenuation coefficient (cm^2/g) and Bi_2O_3 (mol%) content for Bi_2O_3-PbO-P_2O_5 glasses at different photon energies (experimentally).

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Half-Value Layer (HVL) and Tenth-Value Layer (TVL) are crucial metrics for understanding the radiation shielding capabilities of glass. HVL indicates the thickness of material required to reduce radiation intensity by half, while TVL represents the thickness needed to reduce it by a factor of ten [19]. In the context of the prepared glass samples, the decrease in the HVL percentage indicates a decrease in the thickness required to reduce the radiation capacity by half, and this decrease appeared in the results shown in Table 5 and Figures 12 and 14, which represented HVL against energy and Figure 16, which represented HVL against concentration, and the best and the lowest thickness of the prepared glass samples was Bi16Pb34P50 sample. The highest HVL thickness was for the sample Bi0Pb50P50. At all specified energies, TVL values were in complete agreement with the maximum and the minimum HVL thickness of the samples, as shown in Table and Figures 13 and 15. In other words, the addition of Bi_2O_3 and the reduction of PbO greatly enhance the shielding ability of the glasses and significantly reduce the necessary sample thickness, which is both practical and economical, as shown in Figure 17

Table 5: Comparison between the HVL values calculated experimentally and values obtained by the Phy-X code of the glass system xBi_2O_3– (50 – x) PbO–$50P_2O_5$

HVL (cm)								
	0.662 MeV			1.173 MeV			1.33 MeV	
EXP	Phy-x	RD%	EXP	Phy-x	RD%	EXP	Phy-x	RD%
1.588	1.489	6.26	2.632	2.364	10.18	2.693	2.568	4.64
1.557	1.470	5.57	2.579	2.347	8.98	2.673	2.551	4.56
1.537	1.438	6.46	2.369	2.307	2.60	2.608	2.509	3.82
1.485	1.413	4.85	2.162	2.277	-5.29	2.401	2.477	-3.18
1.449	1.394	3.83	2.142	2.254	-5.25	2.301	2.453	-6.61

Table 6: Comparison between the TVL values calculated experimentally and values obtained by the Phy-X code of the glass system xBi_2O_3– (50 – x) PbO–$50P_2O_5$

TVL (cm)								
	0.662 MeV			1.173 MeV			1.33 MeV	
EXP	Phy-x	RD%	EXP	Phy-x	RD%	EXP	Phy-x	RD%
5.277	4.946	6.26	8.744	7.854	10.18	8.947	8.532	4.64
5.172	4.884	5.57	8.566	7.797	8.98	8.880	8.474	4.56
5.107	4.777	6.46	7.868	7.664	2.60	8.665	8.334	3.82
4.934	4.694	4.85	7.184	7.564	-5.29	7.974	8.228	-3.18
4.814	4.630	3.83	7.116	7.489	-5.25	7.645	8.150	-6.61

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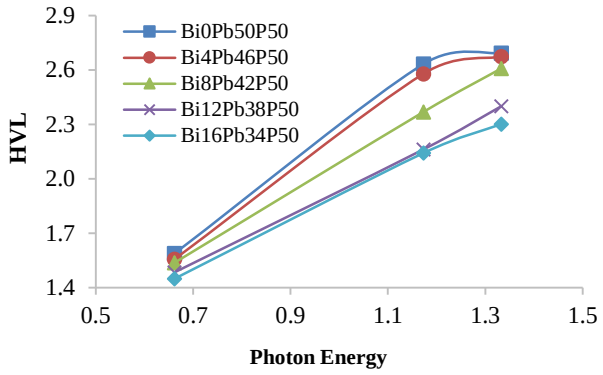

Fig 12: The relationship between half-value layer (cm) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses at different photon energies (experimentally).

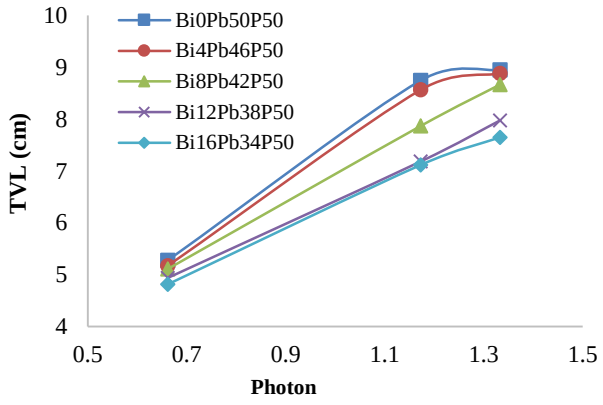

Fig 13: The relationship between tenth value layer (cm) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses at different photon energies (experimentally).

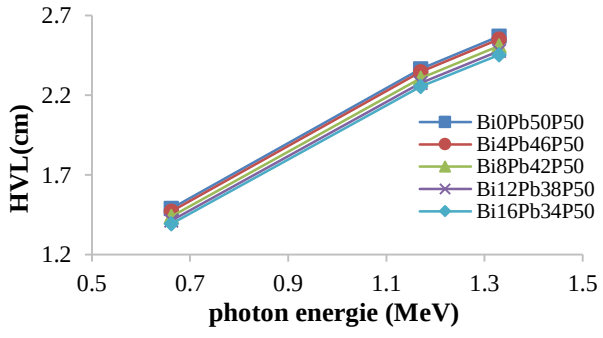

Fig 14: The relationship between half-value layer (cm) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses at different photon energies (theoretically).

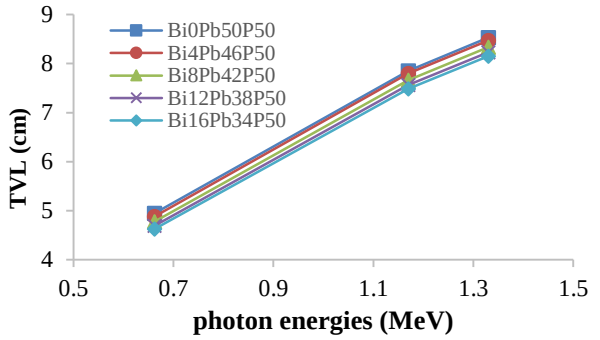

Fig 15: The relationship between tenth value layer (cm) and photon energy for Bi_2O_3-PbO-P_2O_5 glasses at different photon energies (theoretically).

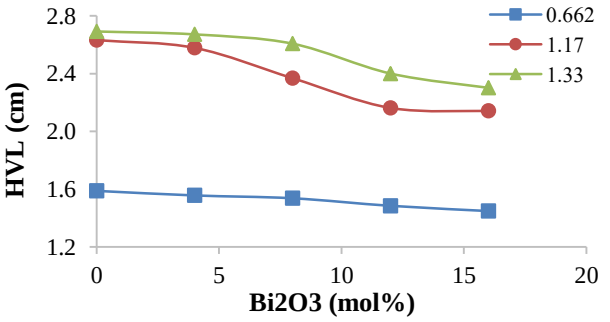

Fig 16: The relationship between half-value layer (cm) and Bi_2O_3 (mol%) content for Bi_2O_3-PbO-P_2O_5 glasses (experimentally).

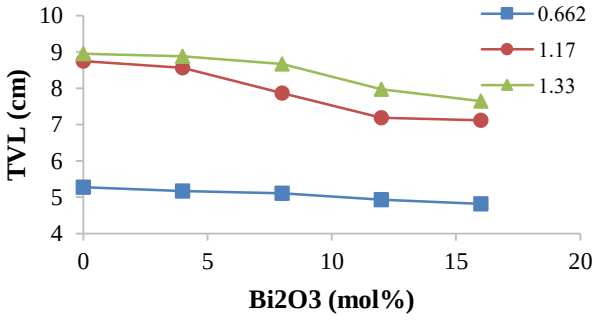

Fig 17: The relationship between tenth value layer (cm) and Bi_2O_3 (mol%) content for Bi_2O_3-PbO-P_2O_5 glasses (experimentally).

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5. CONCLUSION

The goal of this research was to investigate the physical characteristics of phosphate, lead, and bismuth glasses, focusing on how these properties vary with changes in concentration. The comparison of theoretical and experimental methods for estimating the density of glass samples produced a satisfactory result. The results showed that as Bi_2O_3 levels increased, so did density and molar volume, indicating that the glassy networks expanded and the glassy structure became more open within the glassy matrix. The response of oxygen molar volume (V_O) and OPD was contradictory; there was a slight increase in V_O, but this was offset by a decrease in OPD. This means that as the matrix's connections decrease, the glass structure becomes more compact. The LAC was also measured experimentally with three gamma energies: 0.662, 1.117, and 1.33 MeV from radioactive point sources ^{137}Cs and ^{60}Co and a NaI(Tl) scintillation detection system. LAC and MAC then calculated theoretically, along with HVL and TVL by the Phy-X/PSD program at the same energies, and the experimental and theoretical findings were contrasted, and there was good agreement between the two results. LAC and MAC results indicated that the inclusion of Bi_2O_3 increased glass sample radiation attenuation capacity. Similarly, the best results in HVL and TVL were obtained in the sample Bi16Pb34P50, which contained the highest concentration of Bi_2O_3.

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Soaking and Cooking Techniques: A Study on Nutritional Enhancement of Common Beans (*Phaseolus vulgaris L.*) in Libyan Cuisine

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ABSTRACT

This study investigates the effect of soaking duration, cooking time, and the type of water used on the mineral and nutritional content of common beans (*Phaseolus vulgaris L.*) available in the Libyan market. Common beans are a significant source of essential minerals, making them a staple food in Libya. The research involved preparing beans through various methods: uncooked (control), unsoaked, boiled in desalinated water, and soaked for 12 hours in four different types of water (distilled, desalinated, artificial river, and well water) before boiling. Samples were measured using a flame atomic absorption spectrophotometer. The results demonstrated that soaking beans significantly reduced cooking time and enhanced the retention of vital minerals. The concentrations of minerals (mg/100 ml) in the cooked beans were as follows: sodium (Na) ranged from 2.8 to 49.3, calcium (Ca) from 8.4 to 20.8, potassium (K) from 189.0 to 742.8, zinc (Zn) from 1.1 to 2.1, barium (Ba) from 159.1 to 300.9, and iron (Fe) from 1.2 to 37.7, depending on the soaking and cooking conditions. Additionally, the type of water used for soaking and cooking influenced the mineral content, with artificial river and well water yielding higher concentrations of beneficial nutrients such as Na ranged from 400 to 628 mg/100 ml and Ca ranged from 50 to 73 mg/100 ml. The measured concentration of heavy metals in the samples is low and falls within the normal range according to the Libyan food specifications. This research contributes to the understanding of how traditional cooking practices can be improved for better health outcomes. The findings highlight the importance of proper soaking and cooking techniques in maximizing the nutritional value of common beans, providing practical recommendations for consumers and food preparers.

KEYWORDS: Common Beans, Cooking Time, Cooking Water Type, Minerals, Nutrients.

1. INTRODUCTION

Common beans (*Phaseolus vulgaris L.)* are one of the most widely consumed globally, especially in Africa [(1)], recognized for their rich nutritional profile and significant role in the human diet. It belongs to the order Fabales, Family Fabaceae, Genus Phaseolus L. and Species *Phaseolus vulgaris L.* [(2,3)]. In Libya, common beans are a staple food, providing a crucial source of nutrition for the population. It is an excellent source of vegetable protein, dietary fiber, complex carbohydrates, vitamins, and essential minerals, making them a vital component of food security and nutrition, particularly in developing countries [(4-7)]. Therefore, beans could improve health and also decrease the risk of developing certain diseases, including diabetes, obesity and heart disease [(6)].

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Despite their nutritional benefits, the preparation methods of beans can significantly influence their health-promoting properties.

Traditional cooking practices often involve soaking and boiling, which can affect the retention of nutrients and the presence of anti-nutritional factors. Soaking beans before cooking has been shown to reduce cooking time and enhance the bioavailability of minerals by leaching out certain anti-nutritional compounds such as phytic acid and tannins [(8,9)]. Furthermore, the type of water used for soaking and cooking can also impact the mineral content of the beans, as different water sources may contain varying levels of essential nutrients. This study aims to investigate the effects of soaking duration, cooking time, and the type of water used on the mineral and nutritional content of common beans available in the Libyan market. By studying these elements, the research aims to find the best ways to prepare beans in order to maximize their nutritional advantages; thus, this study will provide valuable insights for consumers, nutritionists, and food scientists, emphasizing the

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importance of proper preparation techniques in enhancing the health benefits of legumes in the diet.

2. The EXPERIMENT

2.1. Materials and methods:

In this study, all chemicals were used as received without further purification. Common beans (*Phaseolus vulgaris L.)* from an Egyptian source were purchased on 28 August 2023 from Sunbulah National Food Industries Company, one of the wholesale stores located south of the capital city, Tripoli, which is known for selling food to all commercial food stores in Libya. After purchasing the grains, they were transported to the laboratories of the Libyan Advanced Center for Chemical Analysis in Tripoli. Four types of water, namely distilled, desalinated, artificial river and well water were used for soaking and cooking as well. In addition, appropriate and relevant equipment, such as hotplates, pots and beakers with the same specifications, were used for soaking and cooking to control extraneous variables.

2.2. Preparation of the samples

The preparation of the samples in this study involved several systematic steps (Fig. 1.) to ensure the proper handling and cooking of common beans (*Phaseolus vulgaris L.*). Here's a detailed description of the sample preparation process:

1. ***Sorting*:** The common beans were manually sorted to remove any undesirable elements, including bad beans, stones, damaged seeds, and immature seeds. This step ensured that only high-quality beans were used for the study.
2. ***Grouping:*** The sorted beans were divided into six distinct groups for the experiment:

- **Group 1:** Raw sample (control sample) - these beans were not soaked or cooked and were used for comparison.
- **Group 2:** Unsoaked beans - these beans were boiled in desalinated water for three different cooking times (30, 60, and 90 minutes).
- **Group 3:** Beans soaked for 12 hours in distilled water, then boiled for one minute, and subsequently divided into three parts for cooking in distilled water at three different times (30, 60, and 90 minutes).
- **Group 4:** Beans soaked for 12 hours in desalinated water, boiled for one minute, and then divided into three parts for cooking in desalinated water at three different times (30, 60, and 90 minutes).
- **Group 5:** Beans soaked for 12 hours in artificial river water, boiled for one minute, and divided into three parts for cooking in the same water at three different times (30, 60, and 90 minutes).
- **Group 6:** Beans soaked for 12 hours in well water, boiled for one minute, and divided into three parts for cooking in the same water at three different times (30, 60, and 90 minutes).

3. ***Soaking:*** The beans in Groups 3 to 6 were soaked overnight for approximately 12 hours in their respective types of water (distilled, desalinated, artificial river, and well water). This soaking process is crucial for enhancing the nutritional quality and reducing cooking time (10,11).
4. **Boiling:** After soaking, all beans were briefly boiled for one minute in the soaking water before being washed. This step helps to eliminate some of the anti-nutritional factors present in the beans.
5. ***Cooking:*** The beans were then cooked in clean water (the same type used for soaking) for the specified times according to their group assignments. This cooking process was conducted in triplicates to ensure consistency and reliability of the results.
6. ***Chemical Digestion:*** After cooking, all boiled samples, including the control sample, were dried overnight at 60 °C. They were then subjected to a chemical digestion process according to (12-14). Briefly, 25 ml of concentrated nitric acid was added to 5 g of each sample and boiled on a hot plate at 100 °C until all the dark fumes rose, then 10 ml of 30% perchloric acid was added and boiled until the solution concentrated and changed color. 3 ml of concentrated nitric acid was added to increase the digestion process, then the solution was desalinated in a volumetric flask using Whatman filter paper grade 0.42.

This systematic preparation of samples allowed for a comprehensive analysis of the effects of soaking and cooking methods on the nutritional content of common beans, ensuring that the results were valid and applicable.

Nutrient minerals {Ferrous (Fe) , Calcium (Ca), Sodium (Na) and Potassium (K)} were measured using a flame photometer, while heavy metals {Zinc (Zn), Chrome (Cr), Lead (Pb), Cadmium (Cd) and Barium (Ba)} were measured using a flame atomic absorption spectrophotometer.

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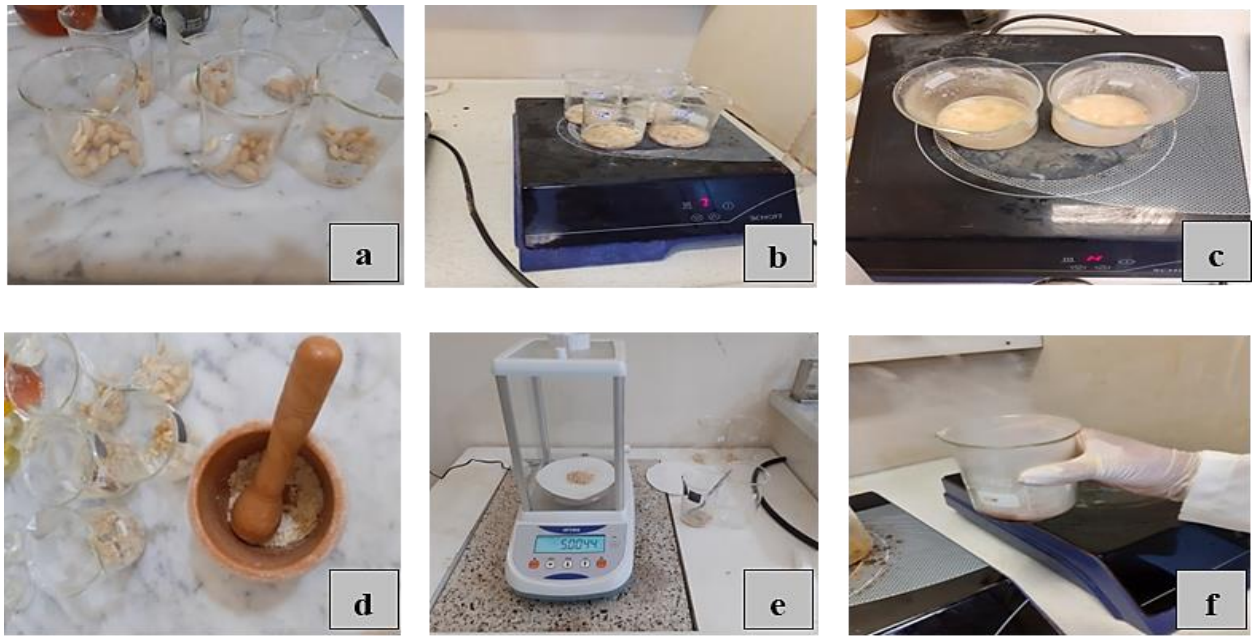

Fig. 1. (a) Soaking the beans. (b,c) cooking process. (d) grinding the samples. (e) weighing the samples and (f) chemical digestion process.

2.3. Statistical analysis

The data was analyzed using statistical software (SPSS) to determine the significance of the effects of soaking and cooking times on mineral content. Applying appropriate statistical tests (such as ANOVA and t-tests) to compare the means of mineral concentrations across different groups. The software calculates the p-value, which indicates the probability of observing the data.

3. RESULTS AND DISCUSSION

The result highlights the significant impact of soaking and the type of water used on the cooking and nutritional quality of common beans (*Phaseolus vulgaris L.*). Soaking beans for 12 hours not only reduce cooking time but also enhances the retention of beneficial minerals and reduces anti-nutritional factors, leading to a more nutritious product.

Table 1. Concentrations of based minerals (mg/100ml) at different cooking time and water types.

Samples	Type of water	Cooking time (min)	Na	K	Ca	Ba	Fe	Zn
			mg/100ml					
Raw beans	Direct chemical digestion		10.6±3.0	477.9±27.4	9.1±0.1	376.0±8.1	4.8±0.2	1.6±0.6
Cooked without soaked beans (CWS)	Desalination	60	42.0±4.1	314.7±6.6	9.8±0.5	276.9±15.8	2.8±1.2	1.7±0.8
		90	49.3±4.5	298.1±31.7	17.2±2.8	255.4±18.0	2.6±1.5	1.1±0.1
		120	44.4±1.7	189.0±10.7	8.4±0.5	170.0±6.8	2.6±0.7	1.7±0.7
Soaked and cooked beans	Distilled	60	4.5±0.1	649.1±19.2	12.5±0.7	246.1±5.9	3.8±2.2	1.7±0.4
		90	3.3±0.5	659.5±58.9	13.4±1.6	252.6±33.4	5.6±0.7	1.9±0.3
		120	2.8±0.2	656.3±19.9	13.6±2.3	300.9±49.0	25.2±0.1	1.6±0.1
	Desalinated	60	29.6±3.6	742.8±90.3	20.8±2.8	297.7±38.7	6.3±5.9	1.9±0.1
		90	28.4±0.9	701.9±56.9	20.0±4.2	270.0±29.2	4.9±2.9	1.5±0.1
		120	36.1±1.1	619.2±77.0	19.9±0.1	235.8±35.8	16.2±9.0	1.7±0.1
	Artificial river	60	441.8±47.4	573.3±19.6	52.0±6.3	128.4±25.6	37.7±7.4	2.1±0.2
		90	498.0±35.6	560.7±77.1	59.5±5.7	170.8±24.8	1.2±0.7	1.8±0.2
		120	628.4±5.8	666.5±72.5	73.5±4.0	214.5±0.4	2.7±0.8	1.8±0.1
	Well	60	400.2±40.8	614.7±11.6	50.1±2.7	212.0±1.9	2.7±0.8	2.1±0.4
		90	443.9±54.9	697.5±12.6	60.7±2.6	219.7±21.3	1.7±0.6	1.8±0.1
		120	575.2±9.5	573.2±19.9	72.6±1.9	159.1±69.7	3.0±1.7	2.0±0.1

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3.1 Effect of soaking process on cooking time

Soaking beans before cooking is beneficial as it reduces cooking time, enhances nutrient retention, and minimizes anti-nutritional factors, leading to a more nutritious and digestible final product. Ferreira et al. [15] reported similar findings. Cooking beans without soaking typically requires a longer cooking time compared to beans that have been soaked. Soaking beans for several hours (e.g., 12 hours) helps to soften the beans, which reduces the overall cooking time and improves the retention of essential minerals. Similar results were reported by Mamiro et al. [16]. Soaking beans before cooking can significantly increase the concentration level of K and Ca ($P < 0.05$). However, the concentration level of Na, Ba and Zn is not affected by soaking process ($P > 0.05$). These results is agree with those of the majority of previous studies. During soaking, some anti-nutritional factors, such as phytic acid and tannins, leach into the soaking water, which can improve the bioavailability of minerals like iron and zinc in the cooked beans [16].

3.2 Impact of water type on mineral content

The results found that the type of water used for soaking and cooking common beans significantly affected the mineral concentrations in the cooked beans. Yulianti et al. [10] reported similar findings, indicating that water with higher mineral content could enhance the nutritional profile of legumes. The following are the main differences reported in mineral concentrations based on the type of water used (Fig. 2).

1. ***Distilled Water:*** This type of water is free from impurities and minerals, which may help in preserving the natural mineral content of the beans while allowing for effective leaching of anti-nutritional factors. Beans soaked and cooked in distilled water showed the lowest level of Na and Ca retention (Table 1).
2. ***Desalinated Water:*** Similar to distilled water, it may not contribute additional minerals, but it can help in maintaining the natural mineral content of the beans while allowing for some leaching of anti-nutritional factors.
3. ***Artificial River Water:*** This type of water likely contains various minerals and organic matter, which can enhance the mineral content of the beans. The study indicated that beans cooked in artificial river water had increased concentrations of certain minerals, such as Na, Ca, and Fe, compared to those cooked in distilled or desalinated water. Shaltami et al. and Omoikhoje et al. [17,18] also found that the type of water used for cooking legumes significantly influenced mineral retention. Their study showed that mineral-rich waters enhanced the mineral content of cooked legumes.
4. ***Well Water:*** The mineral content of well water can vary widely based on the geological characteristics of the area. Beans cooked in well water may show increased concentrations of specific minerals, depending on the mineral composition of the well water used [17].

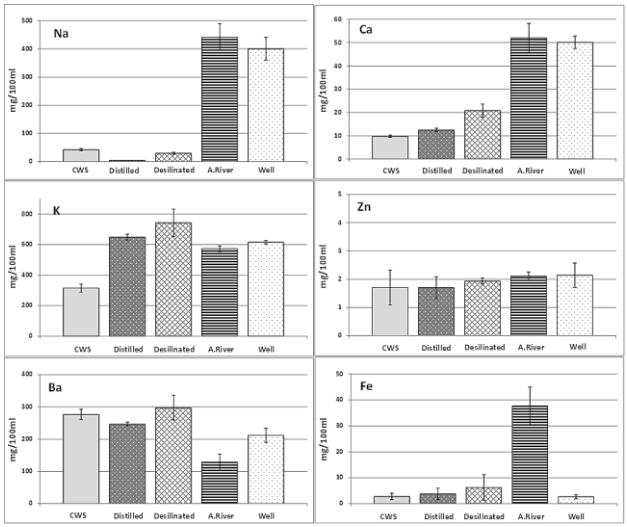

Fig. 2. Concentrations of essential minerals in common beans cooked in different types of water (cooking time at 60 min). CWS = cooking without soaking.

Overall, the results indicated that beans cooked in artificial river water and well water generally had higher concentrations of essential minerals compared to those cooked in distilled or desalinated water. This suggests that the mineral content of the cooking water can significantly influence the nutritional profile of the cooked beans [17]; this result was similar to the results of Feitosa et al. [19].

The type of water used for soaking and cooking plays a crucial role in determining the mineral content and overall quality of the cooked beans. Beans soaked and cooked in mineral-rich waters, such as artificial river water and well water, exhibited higher concentrations of essential minerals compared to those cooked in distilled or desalinated water. This suggests that the mineral composition of the cooking water can significantly enhance the nutritional profile of the beans.

Additionally, the study indicates that the texture and flavor of the cooked beans can vary based on the type of water used, with mineral-rich waters potentially contributing to a more desirable sensory experience. Overall, the findings underscore the importance of both soaking practices and the choice of cooking water in optimizing the nutritional and culinary qualities of common beans, which are a vital source of protein and nutrients in the diet, particularly in regions like Libya.

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Furthermore, the study analyzed the mineral content in different types of water used for soaking and cooking common beans. The concentrations of specific minerals (in mg/100 ml) in various water types were as follows (Table 2).

Table 2. Concentrations of some minerals in different types of water used (mg/L).

Type of water	Na	K	Ca	Ba	Li
Distilled	0.00	0.00	0.00	0.00	0.00
Desalinated	2.90	0.01	1.70	0.65	0.01
Artificial river	25.7	0.83	8.78	0.05	0.01
Well	25.3	1.20	9.23	0.05	0.04

The results indicated that well water and artificial river water, which are sources of groundwater, contained higher concentrations of Na and Ca (25 and 9 mg/L, respectively) compared to desalinated water (2.9 and 1.7 mg/L, respectively). This is attributed to the presence of dissolved salts in groundwater, which includes essential minerals like sodium, potassium, calcium, and magnesium.

3.3 Effect of type of water on cooking time

The type of water used for soaking and cooking beans has a significant effect on cooking time. Beans soaked and cooked in distilled water may require a standard cooking time, but the lack of additional minerals in the water can lead to a more straightforward cooking process without any enhancements in cooking efficiency. Similar to distilled water, desalinated water does not contribute extra minerals, and the cooking time may be comparable to that of beans soaked in distilled water. However, the overall cooking time may still be slightly reduced due to the soaking process. Beans soaked and cooked in artificial river water may have a reduction in cooking time compared to those soaked in distilled or desalinated water. The presence of minerals and organic matter in artificial river water can facilitate a more efficient cooking process, potentially leading to quicker softening of the beans. The mineral content of well water can vary, and this variability can affect cooking time. Depending on the specific mineral composition, beans cooked in well water may either cook faster or slower than those cooked in other types of water. Overall, the results suggest that beans soaked and cooked in artificial river water and well water may have reduced cooking times compared to those soaked in distilled or desalinated water (Table 1). The mineral content and characteristics of the water used play a crucial role in determining the efficiency of the cooking process [20, 21].

3.4 Comparison of nutritional content of uncooked (control) and cooked samples

This comparison highlights the importance of cooking methods and times in determining the nutritional quality of common beans, emphasizing the need for optimal cooking practices to maximize nutrient retention. The duration of cooking significantly influenced nutrient concentrations; cooking for 60 minutes generally increased sodium and calcium concentrations while decreasing potassium, iron, and zinc levels. This suggests that while some nutrients become more available through cooking, others may be lost in the process. However, with 90 minutes often yielding the highest levels of certain nutrients like sodium and calcium, while longer cooking times led to decreased retention of potassium, iron, and zinc, similar findings were reported by Stephen [22].

3.5 Heavy metals content

Heavy metals may negatively affect the nutritional quality of common beans. They can accumulate in plant tissue, therefore reducing their usability as a healthy food. Heavy metals such as lead, cadmium, and mercury can affect the absorption of essential nutrients from the soil and may lead to an imbalance in the mineral content within legume plants, leading to a lower level of good nutrients such as iron and zinc. These metals may inhibit the growth and production capacity of plants. High concentrations of heavy metals can also cause toxicity to plants, leading to cell death and tissue deterioration. The results indicated the following concentrations (mg/100 ml) for various heavy metals in raw common beans (Table 3).

Table 3. Heavy metal composition (mg/100 ml) of raw common bean seeds.

Minerals	Pb	Cd	Cu	Cr
Raw beans	0.03±0.02	< 0.001	0.01±0.01	1.19±0.08

The findings suggest that the concentration of heavy metals in the samples is low and falls within the normal range according to the Libyan food specifications. This aligns with results from previous studies, indicating that the beans are safe for consumption regarding heavy metal content.

Additionally, the study noted that the concentration of heavy metals in the water used for soaking and cooking was also lower than the detection limit, particularly in distilled and desalinated drinking water, which is designed to remove such contaminants.

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4. CONCLUSION

The conclusion of the study emphasizes the critical role of soaking and the type of water used in enhancing the cooking and nutritional quality of common beans (*Phaseolus vulgaris L.*). Soaking beans for 12 hours significantly reduce cooking time and improves the retention of essential minerals while also minimizing anti-nutritional factors. The type of water used for soaking and cooking has substantial effect on the mineral content and overall quality of the cooked beans. Mineral-rich waters, such as artificial river water and well water, contribute to higher concentrations of beneficial nutrients compared to distilled or desalinated water. The study also highlights that the texture and flavor of cooked beans can vary based on the water used, suggesting that using mineral-rich water may improve the sensory qualities of the beans. Finally, adopting proper soaking techniques and selecting appropriate cooking water are essential practices for maximizing the health benefits and culinary qualities of common beans. These insights can guide dietary practices and cooking methods, particularly in regions where beans are a staple food.

5. RECOMMENDATIONS

The study recommends the following practices to enhance the nutritional quality and culinary qualities of common beans (*Phaseolus vulgaris L.*):

1. **Soaking Duration:** Soaking beans for 12 hours is advised as it significantly reduces cooking time and improves the retention of essential minerals while minimizing anti-nutritional factors.
2. **Type of Water:** The type of water used for soaking and cooking has a substantial impact on the mineral content of the beans. It is recommended to use mineral-rich waters, such as artificial river water and well water, as they contribute to higher concentrations of beneficial nutrients compared to distilled or desalinated water.
3. **Cooking Techniques:** Proper soaking techniques and the selection of appropriate cooking water are essential practices for maximizing the health benefits and culinary qualities of common beans.
4. **Sensory Qualities:** The study highlights that the texture and flavor of cooked beans can vary based on the water used, suggesting that using mineral-rich water may improve the sensory qualities of the beans.

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Evaluation of the Recycling Conditions Through Injection Molding Using Fuzzy Logic Approach

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ABSTRACT

Recycling plastic products is still essential and crucial in every country around the globe due to its positive benefits on the environment and the economy. There are several mixing procedures for recycling, and it is crucial to understand how these mixtures affect the quality of products by standards and specifications. Consequently, it is helpful to apply analysis and prediction techniques to find out scientifically. Artificial intelligence "AI" techniques are widely used in many manufacturing engineering fields such as recycling operations. This is because of the many advantages that artificial intelligence techniques offer, including the ability to reduce human errors, save time, provide digital support, and make objective decisions. This study intends to employ the fuzzy logic method as one of the "AI" techniques for predicting a significant property that customers frequently need based on their quality levels and standards. This study employed the injection molding process to forecast the values of a mechanical characteristic, specifically tensile strength, under specific operating conditions based on data from the authors' earlier work. This investigation was conducted using two distinct mixing plans. The first mixed all the raw materials, while the second mixed 50% of the raw materials with 50% of the recycled materials. The fuzzy logic results were acquired, and the mean absolute percentage error for the two plans was calculated. Additionally, the outcomes of the current study, which employed the fuzzy logic approach, were contrasted with those of the earlier study, which utilized the response surface methodology approach. Furthermore, the results showed that the response surface technique approach is more accurate than the fuzzy logic since it has the lowest mean absolute percentage error.

KEYWORDS: Injection molding, fuzzy, recycling, prediction.

1. INTRODUCTION

Due to the expanding amounts of plastics used in various products, plastic reprocessing is one of the manufacturing sectors with the greatest growth rate. This is due to its lightweight, low cost, and reprocessing ability. Thermoplastics constitute 85% of consumed plastics in the world [1]. For this reason, the reprocessing of thermoplastics and the usability of reprocessed materials are gaining significance due to environmental and economic reasons. The well-known commercial and public term for reprocessed plastic material is recycling. Recycling may be defined as any activity involving reclamation, recovery, or reuse of materials (e.g., waste, post-consumer materials, plastic disposal in landfill sites, etc.); in other words, any method of extracting value in the form of energy or material from waste generated at any time in the life cycle of a product [2].

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One of the most common recycling techniques is to blend virgin and recycled polymers to produce materials with satisfactory characteristics. This practice is widespread in an industry where plastic scraps are ground and reintroduced into the processing apparatus and the virgin material. The main problem related to this practice is choosing the right amount of recycled polymer to be blended with the virgin polymer to obtain materials that do not show significant variation from the virgin component [2].

The recycling of homogeneous polymers is a relatively easy challenge only when their structure is preserved, and no significant degradation occurs either during the lifetime or during the processing operations. Indeed, the degradation phenomena, causing a decrease in molecular weight, formation of branching, and other chemical groups, etc., give rise as a consequence of these structural and morphological changes to the remarkable worsening of all physical properties [2]. Scrap and rejects generated during processing can be largely reprocessed almost 100%. It is well known today that the complete reuse of waste from products such as runners, sprues, and short shots is possible without significant loss in quality [3]. Furthermore,

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recycled materials require sorting, filtering, cleaning, drying, and other processes (Fig.1), which can raise manufacturing costs [4].

Investigating the reprocessing ability of polymeric materials is a significant issue, particularly in the area of glass fiber-reinforced compounds, as the fiber during the reprocessing could influence different properties, such as mechanical and rheological properties as presented in previous studies [5]. Predicting the amount of recycled material to add to raw material is necessary for various reasons, including the environment and product quality.

Numerous studies have employed the fuzzy logic method, but some examined the impact of specific process parameters [6-7]. Other studies focused on predicting errors and failures in injection molding [8–10]. Additionally, some researchers examined the prediction of injection molding flow length [11]. Furthermore, the prediction of warpage and shrinkage in injection molding was examined [12–14]. Some researchers have extensively examined another crucial material property regarding tensile strength [15–17]. Additionally, the fuzzy logic approach and the response surface methodology method were compared in the context of the injection molding process [18–19].

This study uses the fuzzy logic approach to predict the mechanical qualities of injection-molded parts in terms of tensile strength utilizing recycled material. The data for this study came from previous research [20] that employed response surface methods to predict outcomes. This study's second goal is to compare this study's findings with previous research findings.

Fig. 1. Plastic recycling overview.

2. PLAN OF THE STUDY

Based on the previous study [20], the reprocessing operations started by introducing 10 Kg of raw material. The first plan products were granulated (including runners and sprues). The second plan was performed by blending 50% of regrind material from plan I with 50% of raw material as shown in Fig.2 [20].

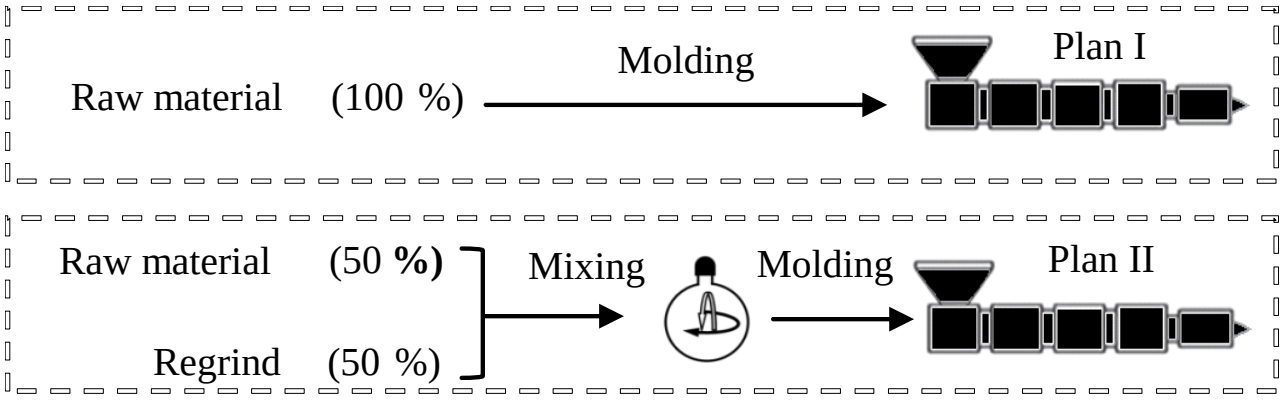

Fig. 2. Processes Scenario [20].

3. MATERIAL AND METHOD

3.1 Materials Selection

Based on the original work [20], the material used in this study was long glass fiber (GF) reinforced polypropylene (PP-20 wt.%) homopolymer; grade Polyform FPP 21 GFM HI supplied from A. Schulman Inc.

3.2 Machine's Facilities, and Conditions

The injection molding machine used in this study was a 100-ton clamp force FANUC Robocat S-2000i-100A all-electric drive with a screw diameter of 32 mm, and L/D of 22:1. The injected test part was an ASTM D638 tensile bar specimen with a gauge length of 90 mm, width of 10 mm and thickness of 4mm. Based on the original work [20], The molding conditions settings (factors) used were: melt temperatures (°C), screw speed (rpm), holding pressure (bar), holding time (sec),

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and injection rate (mm/sec). The property objected to in this study (response) is a tensile strength at yield. Table1 shows the levels considered for each reactor [20].

Table 1. The Levels of Factors [20].

Factor	Units	Low level	High level
Melting temperature (A)	ºC	230	270
Screw rotational speed (B)	Rpm	50	300
Holding pressure (C)	MPa	50	250
Holding time (D)	Sec	15	35
Injection rate (E)	$mm.sec^{-1}$	50	300

3.3 Fuzzy Logic Modeling

Fuzzy logic is a multi-reasoning logical concept where the evaluation is based on true/false, yes/no, high/low, etc. In fuzzy-logic modeling, reasoning is defined in terms of human linguistics, which is the common reasoning for the decision-making of situational problems. The linguistic variables are defined as extremely small, very small, small, medium, less high, high, very high, extremely high, and very extremely high, etc. In fuzzy logic, the Mamdani modeling system mainly consists of data definition, fuzzification, implication, aggregation, and defuzzification. The data definition defined all the input and output data to be considered for the selected model. The fuzzification and implication of the users developed the membership functions in terms of human linguistic variables to generate the fuzzy rules. The if-then rule describes the fuzzy rules in the Mamdani model. Next, the aggregation process mixes up all output rules and the defuzzification process converts the aggregation output to a single predicted value. In the current study, the triangular membership functions used for the input process parameters are melting temperature (°C), screw rotational speed (rpm), holding pressure (MPa), Holding time (sec), the injection rate ($mm.sec^{-1}$) to predict tensile strength. The membership function for each input variable was divided into three levels (low, medium, and high), and the output variable was divided into six levels (extremely low, very low, low, medium, high, and very high). The fuzzy logic controller was Median type and contained a rule base. This base comprises groups of rules; each output was defined by forty-six rules.

As previously explained, Fig. 3 represents the software's screen capture which illustrates the inputs and outputs of the study for model building. The inputs (also known as parameters or factors) that are indicated by the letters A, B, C, D, and E, as shown in Fig. 3. They are the melting temperature, the screw rotational speed, the holding pressure, the holding time, and the injection rate. However, the output (also known as the response) is the tensile strength in the Mamdani model.

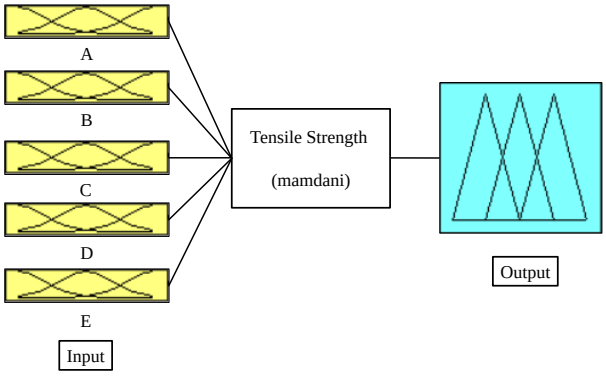

Fig. 3. Input-Output Parameters of the Fuzzy Logic Control Model.

4. RESULTS AND DISCUSSION

The scenario in plan I is to use 100% raw material (0% recycled material). The criteria of comparison between the actual values (original work-RSM) and the predicted values (fuzzy logic) is the mean absolute percentage of error (MAPE). Table 2 shows the actual and predicted values for Plan I.

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Table 2. The actual and predicted values for plan I.

Run no.	Parameters					Tensile strength (MPa)		MAPE
	Melt Temperature (°C)	Screw speed (RPM)	Holding pressure (MPa)	Holding time (sec)	Injection rate (mm/sec)	Actual	Predicted	
1	230	50	150	25	175	38.7	38.8	0.23
2	270	50	150	25	175	38.2	38.8	1.65
3	230	300	150	25	175	39.1	39.8	1.71
4	270	300	150	25	175	40.2	40.6	1.11
5	250	175	50	15	175	37.4	37.8	0.94
6	250	175	250	15	175	38.8	38.8	0.12
7	250	175	50	35	175	37.2	37.8	1.62
8	250	175	250	35	175	39.4	39.8	0.96
9	250	50	150	25	50	37.4	37.8	0.94
10	250	300	150	25	50	38.3	38.8	1.18
11	250	50	150	25	300	38.6	38.8	0.54
12	250	300	150	25	300	39.5	39.8	0.70
13	230	175	50	25	175	35.7	36	0.84
14	270	175	50	25	175	39.6	39.8	0.45
15	230	175	250	25	175	40.9	40.6	0.71
16	270	175	250	25	175	38.0	38.8	2.00
17	250	175	150	15	50	37.9	37.8	0.23
18	250	175	150	35	50	37.6	37.8	0.52
19	250	175	150	15	300	39.0	39.8	1.94
20	250	175	150	35	300	38.8	38.8	0.08
21	250	50	50	25	175	37.2	37.8	1.71
22	250	300	50	25	175	38.2	38.8	1.57
23	250	50	250	25	175	38.8	38.8	0.02
24	250	300	250	25	175	39.1	39.8	1.71
25	230	175	150	15	175	39.0	38.8	0.41
26	270	175	150	15	175	38.9	38.8	0.15
27	230	175	150	35	175	39.2	38.3	2.25
28	270	175	150	35	175	39.6	39.8	0.58
29	250	175	50	25	50	36.6	36.7	0.16
30	250	175	250	25	50	37.7	37.8	0.26
31	250	175	50	25	300	38.2	38.8	1.70
32	250	175	250	25	300	40.0	40.6	1.46
33	230	175	150	25	50	38.3	38.8	1.37
34	270	175	150	25	50	37.9	37.8	0.39
35	230	175	150	25	300	39.5	39.8	0.69
36	270	175	150	25	300	39.4	38.3	2.85
37	250	50	150	15	175	38.6	39.8	3.22
38	250	300	150	15	175	39.2	39.8	1.48
39	250	50	150	35	175	39.1	38.8	0.88
40	250	300	150	35	175	38.5	38.8	0.74
41	250	175	150	25	175	38.8	39.3	1.24
42	250	175	150	25	175	39.1	39.3	0.64
43	250	175	150	25	175	38.6	39.3	1.72
44	250	175	150	25	175	39.4	39.3	0.20
45	250	175	150	25	175	39.0	39.3	0.68
46	250	175	150	25	175	39.2	39.3	0.15

Figure 4 illustrates the high dependability of the model by comparing the actual and predicted values of fuzzy logic for plan I. This can be confirmed by

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calculating the percentage of error which is 1.02%. Here, it can be said that the percentage of error is accepted because it falls within the acceptable range of engineering error where the maximum acceptance limit does not exceed 10%. Therefore, this indicates the validity of this model using the fuzzy logic method for plan I. Physically, the results of plan I, which uses 100% of the raw material, can be interpreted as this material being considered a virgin material, it has not been used or recycled before. This means that it has not been exposed before to mechanical or thermal stresses resulting from the injection molding machine during its manufacture or the effect of the shear force resulting from the grinding machine. More precisely, this may mean that the material used in this work is a composite material containing a percentage of glass fibers. The primary function of these fibers is to enhance and strengthen the mechanical properties represented in this work by tensile strength. The material did not have a critical reduction in the lengths of its fibers, so there was no significant variation in the tensile strength values. Thus, this could justify the behavior of the data shown in Fig. 4.

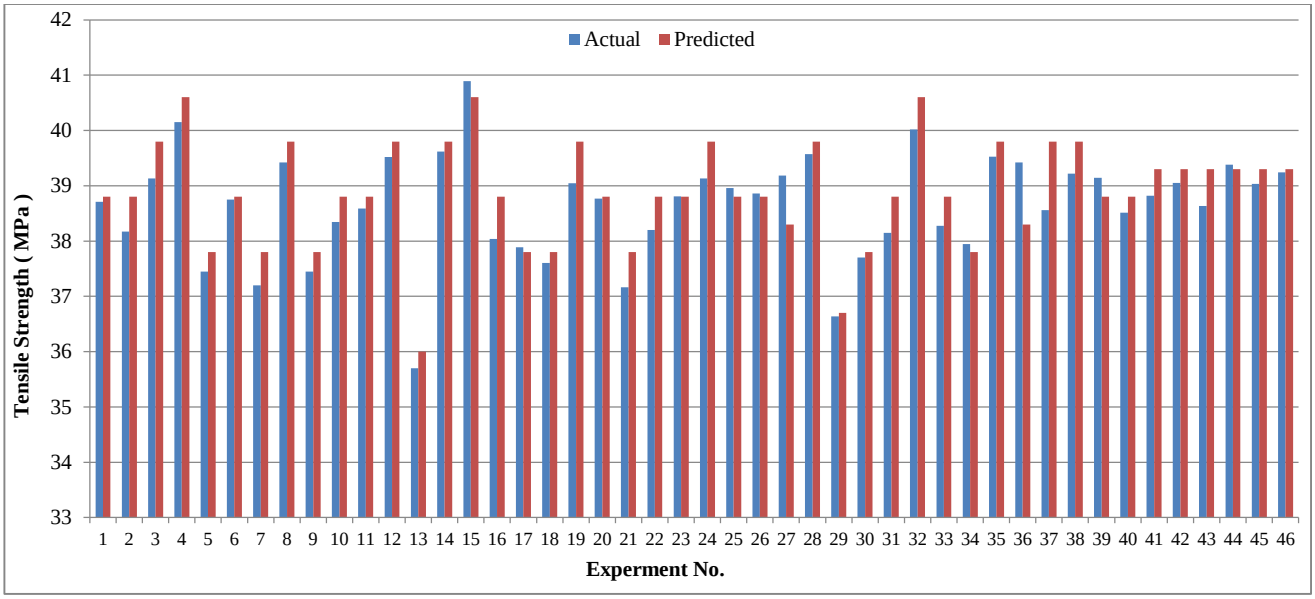

Fig. 4. Actual Vs. Predicted Values for Plan I.

The scenario in plan II is to use 50% raw material and 50% recycled material. Table 3 shows the actual and predicted values for plan II.

Table 3. The actual and predicted values for Plan II.

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Run no.	Parameters					Tensile strength		MAPE
	Melt Temperature (°C)	Screw speed (RPM)	Holding pressure (MPa)	Holding time (sec)	Injection rate (mm/sec)	Actual	Predicted	
1	230	25	250	175	42	42.02	175	0.05
2	270	35	150	175	41	41.82	175	1.96
3	250	35	150	175	42	42.95	300	2.21
4	250	15	150	175	42	42.56	300	1.32
5	230	25	150	175	39.9	40.98	50	2.64
6	250	15	250	175	42	42.18	175	0.43
7	230	25	150	50	42	42.15	175	0.36
8	250	25	250	175	42.8	43.9	300	2.51
9	250	15	150	300	41	41.7	175	1.68
10	250	35	150	300	41	41.78	175	1.87
11	250	25	150	175	41.5	41.89	175	0.93
12	270	25	150	50	41	41.71	175	1.70
13	230	25	50	175	38.8	39.67	175	2.19
14	250	35	250	175	41	41.82	175	1.96
15	270	25	250	175	42	40.08	175	4.79
16	230	25	150	300	41	41.8	175	1.91
17	270	25	150	175	42	42.48	175	1.13
18	250	25	150	175	41	41.47	300	1.13
19	250	25	150	50	42	42.43	175	1.01
20	250	25	250	300	41	41.98	300	2.33
21	250	35	50	175	38.8	39.18	175	0.97
22	250	25	150	175	41	41.42	175	1.01
23	250	25	50	175	41	41.5	300	1.20
24	250	15	50	175	39.9	40.4	175	1.24
25	270	25	150	300	41	41.46	175	1.11
26	270	25	150	175	38.8	39.59	50	2.00
27	250	25	250	50	41	41.73	175	1.75
28	250	25	50	50	38.8	39.61	175	2.04
29	230	15	150	175	41	41.61	175	1.47
30	250	25	250	175	38.8	40.88	50	5.09
31	230	25	150	175	42	42.33	300	0.78
32	250	25	150	175	41	41.79	175	1.89
33	250	25	50	300	39.9	40.4	175	1.24
34	250	35	150	175	38.8	39.8	50	2.51
35	230	35	150	175	41	41.98	175	2.33
36	270	25	50	175	39.9	40.43	175	1.31
37	250	25	150	50	38.8	39.7	50	2.27
38	250	15	150	50	39.9	40.91	175	2.47
39	250	25	150	175	41	41.28	175	0.68
40	250	25	150	175	42	42.38	175	0.90
41	250	25	150	300	39.9	40.68	50	1.92
42	270	15	150	175	41	41.23	175	0.56
43	250	35	150	50	41	41.83	175	1.98
44	250	15	150	175	39.9	40.11	50	0.52
45	250	25	150	300	42	42.62	300	1.45
46	250	25	50	175	38.1	37.75	50	0.93

Figure 5 illustrates the high dependability of the model by comparing the actual and predicted values of fuzzy logic for plan II. This could be confirmed by calculating the error (%) of 3.02% which falls in the

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accepted range of the engineering error. In this plan, the error (%) is higher than its value for plan I of 1.02%. This could be justified as the material used in this plan is 50% raw material mixed with 50% recycled material. In other words, the material employed in this study is not only recycled but also a composite material that contains glass fibers. This means that it has already been subjected to mechanical stresses produced by the injection machine or granulating machine. This indicates that these repeated stresses may have caused the glass fibers to shorten, which possibly caused an increase in the variation of the tensile strength values and slightly increased the error (%). This may justify the behavior of the data as seen in Fig. 5. By comparing the error (%) between Plan I (100% of the raw material) and Plan II (a mixture of 50% raw material with 50% recycled material), it was found that the error (%) in Plan II is 3.02% higher than its counterpart in Plan I of 1.02%, as mentioned previously. Even though the material was subjected to previous stresses since the material used is recycled, the variation in the tensile strength values in Plan II is still acceptable. This can be explained by the fact that the settings of the injection molding machine as shown in Table 1 (specifically the screw rotational speed and the injection rate, which possibly cause the glass fibers to break and reduce their lengths) were chosen experimentally to reduce their negative effect on the tensile strength values [20].

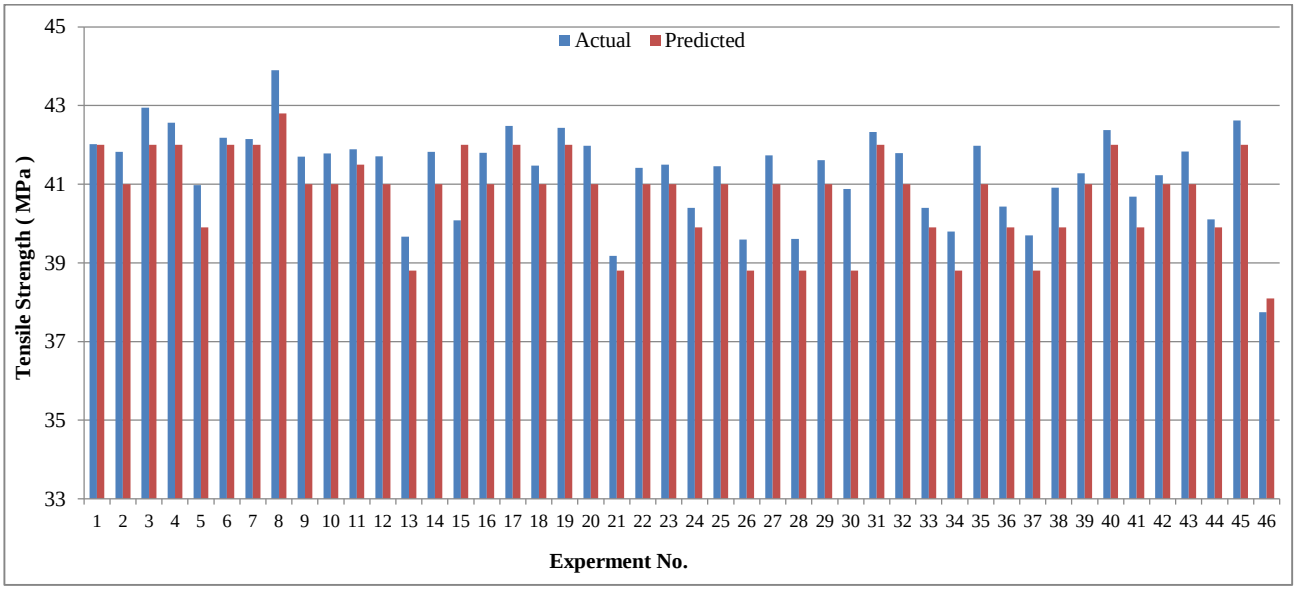

Fig. 5. Actual Vs. Predicted Values for Plan II.

Based on the result obtained from the original work [20], it has been found that the mean absolute percentage of error by using RSM is 0.52%, and 0.74% for plan I and plan II respectively. Using Fuzzy Logic, these values were found to be 1.02% for Plan I and 3.05% for Plan II. However, when comparing the two methods, it was found that the mean absolute percentage of error increased twice in the first plan (from 0.52% to 1.02%). When applying Fuzzy Logic as opposed to RSM, this proportion similarly rises in the second plan at a pace of four times (from 0.74% to 3.05%). This indicates that the RSM is more accurate because it has the lowest MAPE of the two plans.

5. CONCLUSIONS

This study used a Fuzzy Logic technique to predict the mechanical qualities of injection-molded parts in terms of tensile strength utilizing recycled material. The data for this study obtained previous research [20], which employed Response Surface Method "RSM" to predict outcomes. The second goal of this work is to make a possible comparison between the findings of this study and the previous research.

The following points can be concluded:

- At plan I (100% raw material) the mean absolute percentage error for RSM and fuzzy logic were found 0.52%, and 1.02%, respectively.
- At plan II (50% raw material + 50% regrind) the MAPE for RSM and Fuzzy logic, were found to be 0.74%, and 3.05%, respectively.
- RSM is more accurate because it has the lowest MAPE of the two plans.

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Preliminary Study on the Use of Chemical Pesticides in Beir Bullerjam's Farms, Suluq, Libya

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ABSTRACT

Pesticides in Libya have increased recently in the agriculture sector to control pests, consequently improving field and horticultural crop productivity. The present study was undertaken to assess the current pesticide utilization among farmers in different farms across Beir Bullerjam's area. Data were collected from farmers using a structured questionnaire containing the following (socio-demographic details, awareness and knowledge, and farmer practices). Our results show that all farmers were male (100%), their farming experience was 13 years, and their average age was 46 years old. Not surprisingly, farmers did not know the modes or the compositions of pesticides being used and relied mainly on pesticide commercial retailers' knowledge. The most commonly used pesticides were: insecticides, herbicides, acaricides, and fungicides (47%), (34%), (18%), and (2%) respectively. Moreover, their trade names were: Oscar wp® 50, Roundup, Gramoxyone (herbicides), AQ Dorsban*4, Permethrin, Cyberkill 25, Mospy-one 20% sp, Fl-oil, Voliam Targo (insecticides), Vertimec (acaricide), and Strike (fungicide), and they were regularly utilized by farmers in this survey. We found that farmers reuse the same pesticides over years which may result in pesticide resistance of the targeted pest. Additionally, heavy use of insecticides by farmers could harm bee populations negatively in the region or decrease the natural enemies of pests. Farmer's awareness and attitudes towards pesticide use must be improved through agriculture extension agents or workshops for better food, healthy people, and ecosystems.

KEYWORDS: pesticides, insecticides, fungicides, survey, Libya.

1. INTRODUCTION

Pesticide is defined by the U.S. Environmental Protection Agency as "any *substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest* [1]. The heavily indiscriminate use of pesticides has deleteriously impacted human health, with chronic diseases such as cancer, aging, Parkinson, and asthma as a consequence of their long-term exposure [2,3]. In addition, pesticide utilization, even at low doses, can contaminate the environment by killing beneficial insects (e.g. abnormal behavior effects on *Apis* spp.), birds, polluting the groundwater, and the air [4]. Annually, around 2 billion kilograms of pesticides are used [5]. According to McDougall's analysis [6], pesticide marketing values were $50 billion worth from 2008 to 2012.

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The agriculture sector contributes roughly 3-4 % to Libya's Gross Domestic Product (GDP), yet Libyans involved in the agricultural production were significantly huge (20%) [7; 8]. Regrettably, there is no authentic or governmental data on how much and what types Libya imports of pesticides.

To the best of the author's knowledge, no scientific study has been conducted on pesticide attitudes and use patterns among farmers in Beir Bullerjam's area. Thus, the main aims of the current survey were performed: 1) to assess farmers use and knowledge of pesticides; 2) to determine if farmers wear personal protective equipment while applying; and 3) to determine the common pesticide types that are utilized by farmers.

2. MATERIAL AND METHODS

2.1 Study area description:

Beir Bullerjam's farms were located between latitude 31.67 and altitude 20.32 (Fig. 1). These farms are famously known for producing grapes, olives, figs, different vegetables for local consumption, wheat, and

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barley. The willingness of farmers to participate in this survey was an important factor in choosing the farm.

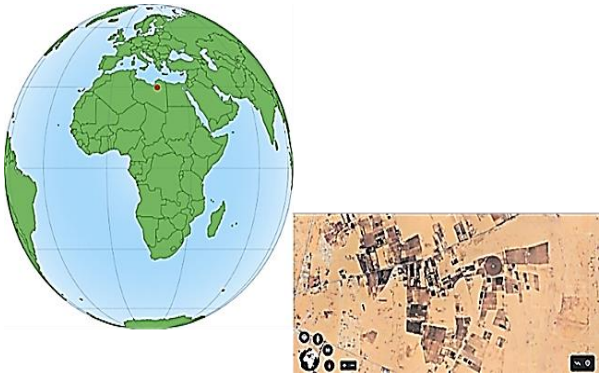

Fig. 1. Survey location.

2.2 Data collection:

Data were collected from farmers by means of a standardized questionnaire (appendix) to obtain information on gender, education level, pesticide type, following pesticide label information, etc. The questionnaire was adopted from [9] and modified to fit our survey. The questionnaire was divided into three sections: section one deals with sociodemographic; section two deals with awareness and knowledge; and section three deals with farmer practices. Approximately, there are 30-40 small-sized (1-4 hectares) to middle-sized (50 hectares) farms in the area under our survey. These farms were owned by individuals and were irrigated by groundwater. Out of 20 filled-out questionnaires, we only chose 16 as they were completely filled out by respondents. In addition, there was no local Agriculture Farmers Association, in which they could help us in distributing and filling out more questionnaires. We firmly believe this number is relatively small, but it would give a better idea regarding the farmers attitudes, knowledge, and use of pesticides.

2.3 Data analysis

Data were presented in graphs and analyzed using descriptive statistics (mean and chi-square test). R programming and JMP SAS (2009) software were exploited in this survey [10].

3. RESULTS AND DISCUSSION

3.1 Farmer social conditions and practices

All farmers were males (100%), and their age mean was 46 years old. Interestingly, the majority of farmers have higher education levels, as shown in Fig 2. However, all farmers had no formal training or license in preparing or applying pesticides; instead, they depended entirely on pesticide retailers or read themselves the information label attached to the product. Interestingly, there was no significant effect of farmers' education levels on whether or not to follow pesticide instruction (p = 0.791). Our result matches Oztas et al. [11] who found in a similar survey that all farmers were male. Likewise, Bakhtawer and Afsheen [9] conducted a similar survey and reported males were the predominate agriculture workforce (93%). Farmers working hours mean were three hours per day, with few exceptions above seven hours.

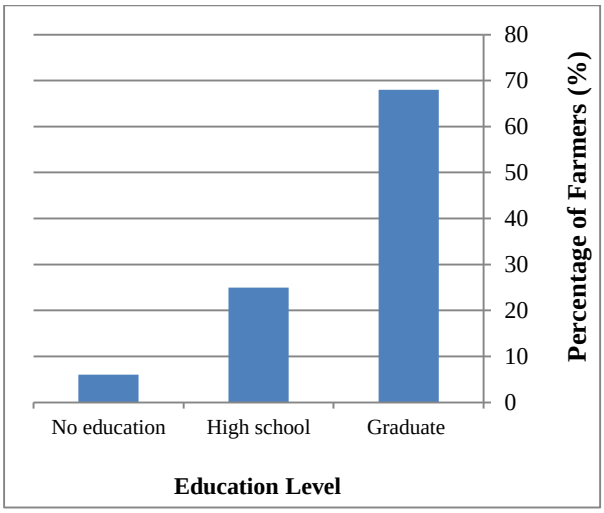

Fig. 2. Farmers education level

In this survey, most farmers wore hand gloves and face mask during pesticide application. Nonetheless, other personal protective equipment (PPE) such as coveralls and goggles were often neglected when spraying pesticides. Reasons for not wearing PPE include: farmers felt uncomfortable wearing PPE, being expensive, and ignorance of their adverse effects on their health. In accordance with our result, Egyptian farmers demonstrated a misuse of pesticide PPE [12]. Similarly, Damalas et al. [13] conducted a study on pesticide use among Greek farmers and showed that farmers unheeded the paramount of wearing PPE and their dire effect on their health, and their findings were in agreement with our results. Another study performed on Filipino farmers use of PPE during pesticide application showed farmers underestimate the value of PPE [14]. In the Palis survey, respondents believed pesticides entered the human body only through inhalation or ingestion, and no dermal absorption can occur.

The surveyed data showed that farming experience was high (13 years old). However, there is no relation between farming experience and emptied pesticide discarding (p = 0.562). It seems farmers were keen on burning the emptied containers over the other methods (Fig. 3).

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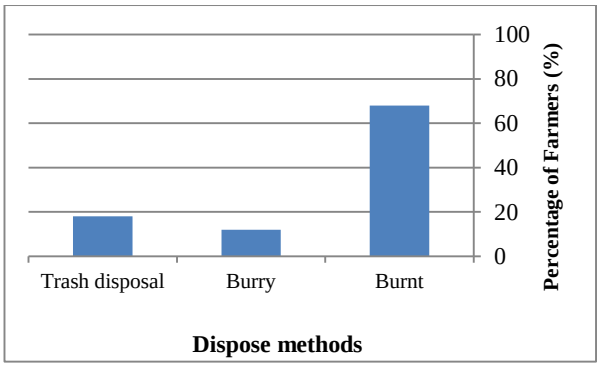

Fig. 3. The means of methods using for deposing empty pesticide containers.

Most farmers in this study preferred to apply pesticides in the early morning, followed by evening and afternoon (Fig. 4). Farmers preferred the morning because the wind was not strong, the sun was not blazing, and there was balanced humidity. According to Puspitasari's work [15], the majority of farmers chose to spray pesticides in the morning.

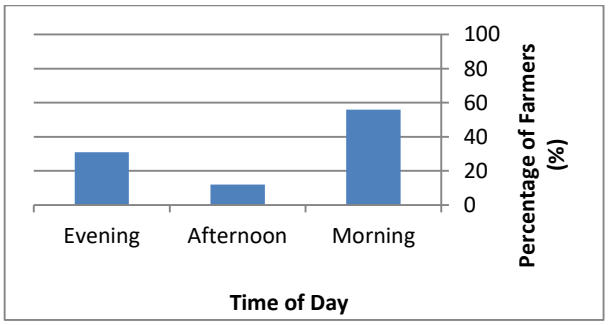

Fig. 4. Times of applying pesticides.

3.2 Types of pesticides

Four kinds of pesticides were reported in this survey. These pesticides were listed in the following: insecticides, herbicides, acaricides, and fungicides (fig. 5). Farmers apparently applied more insecticides and herbicides in comparison with the others.

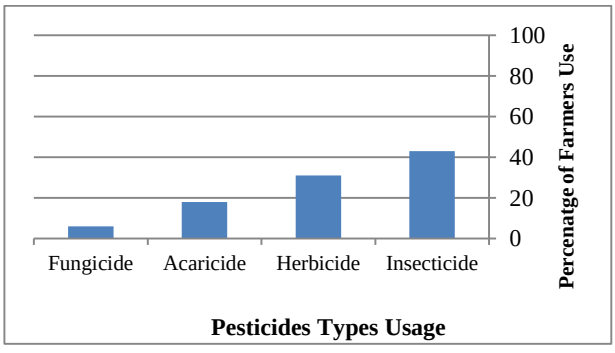

Fig. 5. Percentages of pesticides types that utilizing by farmers.

The type of pesticides being applied by farmers was not affected by farmers' education level ($p = 0.679$).

Our survey found three kinds of herbicides that farmers sprayed. The herbicides were Oscar wp® 50, Roundup, and Gramoxyone (Fig. 6). Their active ingredients were tribenuron-methyl (TBM), glyphosate, and paraquat (PQ), respectively. TBM belongs to the sulfonylurea group, and it has been shown that this herbicide had a negative effect on the liver tissue of zebrafish (*Danio rerio*) [16]. PQ is a highly toxic compound to humans; even a small dosage can be lethal and cause mortality [17]. Some countries, e.g., Central America, have banned or restricted its use [18]. Both Oscar and Roundup were frequently sold in pesticide shops in Sirte, Libya [19].

Our results showed five types of insecticides., viz., AQ Dorsban, Permethrin, Cyberkill 25, Mospy-one 20% SP, and Voliam Targo (Fig. 6). The active ingredients were chlorpyriphos (CP), pyrethroid, cypermethrin, acetamiprid, and both chlorantraniliprole and abamectin, respectively. Long-term exposure to CP can cause endocrine disruption in humans [20]. It has been shown that dermal absorption of pyrethroid is associated with chronic diseases such as cardiovascular and Parkinson [21]. In a study conducted on farmers in the Aljebal Alakhtar region, Libyans who were exposed to pesticides had higher levels of total protein, albumin, globulin, total bilirubin, total cholesterol, triglycerides, urea, and creatinine compared with people who were not exposed to pesticides [22]. This study was so alarming specifically to Libyan farmers, and let this be our take-home message.

Both acaricide and fungicide were represented by Vertimec and Strike, respectively (Fig. 6). Vertimec's active ingredient was abamectin, whereas the active ingredient in Strike was triadimefon and trifloxystrobin.

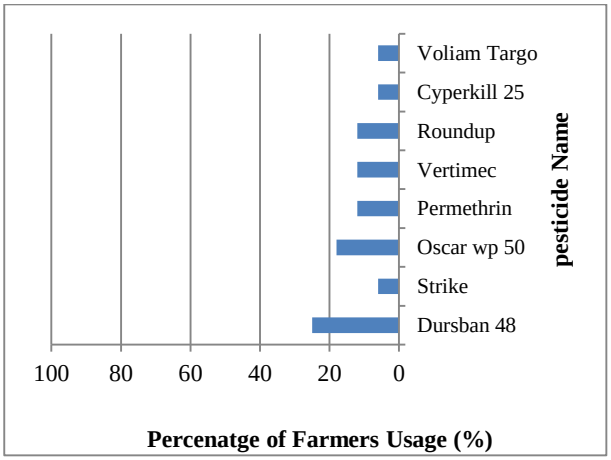

Fig. 6. Percentage of farmers using pesticides by brand name.

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4. CONCLUSION

The survey indicated that farmers had no formal training on pesticide knowledge and mode of action. Personal protective equipment (PPE) was neglected by most farmers. Farmers reuse the same type of pesticides over years, and that ultimately leads the pest to evolve resistance towards pesticides. Some pesticides in this survey were highly toxic to bees. There is a necessity to educate and enhance farmers knowledge and perceptions about the detrimental effects of pesticides on their health in the long term.

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Practical Design of a Home Appliance Control System Using Audio Signals

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ABSTRACT

In this paper, the design of a system that controls home appliances using voice commands is considered. This system may be utilized by people with special needs and the elderly. By using just their voice, they can control the lighting of their room, and turn on or off their television, air conditioner, or fan with safety and security and without needing someone else's assistance. This may be achieved by passing their voice commands to a microcontroller, (Arduino), through a device that uses voice or speech recognition technology. Herein, the system is designed at the lowest possible costs. Two basic ways are discussed to build this system, a wired system that does not depend on wireless technologies and the other depends on Bluetooth technology. Each of them has advantages and disadvantages. The hardware parts utilized in the design process are the Arduino Uno, Relay Module, and voice recognition module. The latter could be replaced by a Bluetooth module and a smartphone with an application that uses voice or speech recognition technology. The proposed wired system proved to be advantageous in terms of privacy, security and reliability. A comparison between the two systems is concluded at the end of this paper.

KEYWORDS: Speech Recognition Technology, Recognition Module V2, Home Appliances, Arduino Uno, Bluetooth.

1. INTRODUCTION

The demography of the world population shows a trend in which the number of elderly people is increasing rapidly in recent years as a result of the increase in the average lifespan [1]. In addition, the number of amputees in the world specifically in Libya has increased due to the wars in recent years. There are no accurate statistics for the number of local amputees, but the last statistic was in 2018, and the number of amputees was approximately 120,000 according to the Ministry of Social Affairs. This increase in the number of elderly, amputees, and people with special needs is the main purpose of the proposed system.

There are numerous studies on the subject of household appliance control using voice recognition techniques [2]-[8].

In [2], the authors suggested a control system, which is composed of three parts, Arduino Uno, Ethernet controller, and a relay module. A similar system was proposed in [3], but the ATMEGA2560 microcontroller is used instead of Arduino. The system in [4] utilized the Android platform as a control system, which may take advantage of the features that are already available in smartphones.

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Therein, the fast Fourier transform method is applied to the received voice to match it with the previously stored ones. If there is a match, the microcontroller will execute the command accordingly.

The system proposed in [5] is composed of a microcontroller and a voice recognition system. The system is utilized to control the light, fan, water pump, and safety deposit box. The average rate of successful commands is about 65%, with the minimum rate is about 58% and the maximum is around 85%. Therefore, some commands need to be repeated.

In [6], the authors proposed a system that is composed of a microphone to be used as a sound sensor to control various devices such as fans, lamps, laptops, and TVs. The voice signal is transferred to a digital signal, which is the input to the Arduino microcontroller to be processed and yield the proper control signal to the actuator. To make the system more reliable, a converter-battery set was utilized to store energy and reuse it in an emergency. Several tests were performed on the proposed system to evaluate the system's performance and sensitivity to surrounding noise.

In [7] and [8], similar systems were proposed as tools to aid visually impaired people in handling some of their daily activities, such as controlling password-protected safety box which is used to store their personal belongings.

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The system proposed in this study is composed of a microcontroller (Arduino) device connected to a voice recognition module, which captures an audio signal and compares it with the stored voice signal in the recognition module. This is in the case of the first design, and as for the second design, which depends on Bluetooth technology, the spoken word is compared to a word stored on the Arduino board. The two systems rely on two different technologies that are similar at the same time, namely, voice recognition technology and speech recognition technology. Speech recognition and voice recognition are not quite the same thing. Speech recognition recognizes only the words (WHAT was spoken). Voice recognition, on the other hand, recognizes only the voice and identifies an individual user's voice (WHO is speaking) [9].

Arduino-c-software is used as a monitoring and control section. In addition, an access port program is used to record the voice of the person speaking. Another program is utilized which is the Android voice controller. These are the main three programs used in this system.

The contributions of this study are as follows: first, this study proposes a comparison between two systems, wired and wireless systems. On one hand, the wired system is less susceptible to noise, protects someone's security and privacy, and consumes less energy. The wireless system, on the other hand, is more flexible and can easily cover a larger area. A comparison that highlights the difference between the two systems is presented at the end of this paper. Secondly, this system provides a great service for society since it may be manufactured locally, thus it can be customized for each specific disability case based on its need. In addition, there are no extra costs required such as international shipping costs.

2. HISTORY AND BACKGROUND

A. History of Voice Recognition Technology

Voice recognition technology has become very popular in recent years and the great development of this technology is evident. However, this technology is not very recent as it has its roots go back to the 1950's. A review of the beginnings of this technology is in the following points [10]:

- In 1952 Audrey was invented by Bell Laboratories which could only understand numbers.
- In 1962, the shoebox technology was able to understand 16 words in English.
- In 1990, the first speech recognition software in the world was released by the company Dragon.
- In 2001, Google invented an application called Google Voice Search.
- In 2010, Google introduced personalized recognition on Android devices, which can recognize 230 billion English words, and Apple's Siri was invented too.

B. What is the voice recognition

Vocal communication between humans may be explained as follows: the sound starts from the vocal cords and then travels to the air through the mouth, air is the medium that transmits sound. Then the signal is received by the ear in order to be sent to the brain. It follows that the information is interpreted and translated. In the same principle, communication is made between humans and machines.

This process can be summarized in the following steps: The first step, the person's voice begins as vibrations in the throat and then is transmitted to air. This causes pressure changes in the air (waveform). Then the audio input unit (microphone) converts the pressure changes into electrical voltage changes (an analog signal). The next step, the analog signal is converted to digital by using an A/D converter and is stored in memory [11]. The final step is the processing of the digital signal by a speech recognizer in order to be used in a specific program. The program contains the input template and matches this template with the actual input. The block diagram of the process is shown in Fig.1.

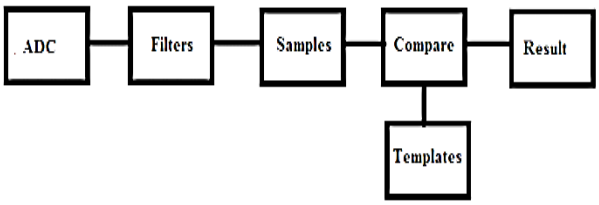

Fig. 1. Block diagram of the speech recognition process.

C. Different between voice and speech recognition

The difference between voice and speed recognition may be summarized in the following points:

- Voice recognition is a technique that focuses its attention on who is the speaker. Voice recognition has two types, one that does not depend on the text (**Text Independent**), which is who is the speaker regardless of what he is speaking, and another type that depends on text **(Text Dependent)**, that the text cares about who and what he is speaking [12].
- Speech Recognition is a technique that focuses its attention on what you speak (speech). It also has two types, one that does not depend on the speaker

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(Speaker Independent), meaning that the word is important only regardless of who spoke, and the second type depends on the speaker **(Speaker Dependent)** and is interested in the word and who is the speaker at the same time [13].

However, one may consider both as one technology that differs as follows:

1. Recognizes WHO is speaking (voice recognition Text-independent).
2. Recognize WHAT was spoken (speech recognition Speaker independent).
3. Recognize WHO is speaking and WHAT was spoken at the same time (voice recognition Text-Dependent or speech recognition Speaker independent).

D. Smart home

In smart homes, all home devices together are connected as a big network and controlled by remote control, smartphones, or microphones as depicted in Fig. 2. There are several benefits of smart homes, such as convenience, entertainment, safety, security, energy savings, and healthcare for elderly and disabled people[11].

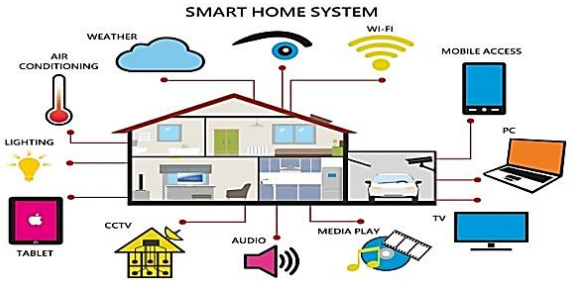

Fig. 2. Smart home.

3. SYSTEM COMPONENT

The following devices are utilized to configure the wired system.

A. Arduino Uno

The Arduino board is an open-source board founded by the Arduino company in Italy that can be programmed easily using the Arduino IDE which is based on the C language. There are several types of this product, and one of which is commonly used, is the Arduino Uno, depicted in Fig.3. Arduino Uno is a very suitable board for starting projects as it is inexpensive. It contains several components, the most important of which is the microcontroller, which contains the CPU, RAM of 2KB (this is runtime memory), and Flash memory of 32 KB. The program loaded from the Arduino IDE is stored in the flash memory. It contains 14 digital input/output pins, 6 of which can be used as PWM outputs. In order to operate them, a DC source equal to 5 V is required.

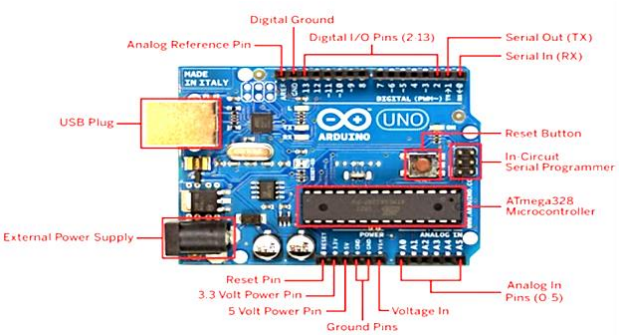

Fig. 3. Arduino UNO.

B. Voice recognition module v2

The module, depicted in Fig.4, could recognize the speaker's voice. It receives voice commands and compares them with pre-stored voice commands. The Access Port program is utilized to store voice commands. This module (v2) can store up to 15 pieces of voice. It stores 15 voice commands in three groups, and each group contains 5 voice commands. When storing voice commands, they are recorded in each group separately. This module is characterized by a high accuracy of 99% so that it can identify even the person who is speaking. It works at a voltage of 4.5-5.5 V. There is a new version of this module that can store up to 80 voice commands.

Fig. 4. Voice recognition module.

C. Relay module 4× 4

A relay is an electrically operated switch that can be turned on or off. It can be used to control various appliances with large current and yet it can be controlled directly by a microcontroller. It works at a voltage of 5 volts, similar to the Arduino. The module illustrated in Fig. 5 has four channels, each channel needs a 15-20 mA driver current.

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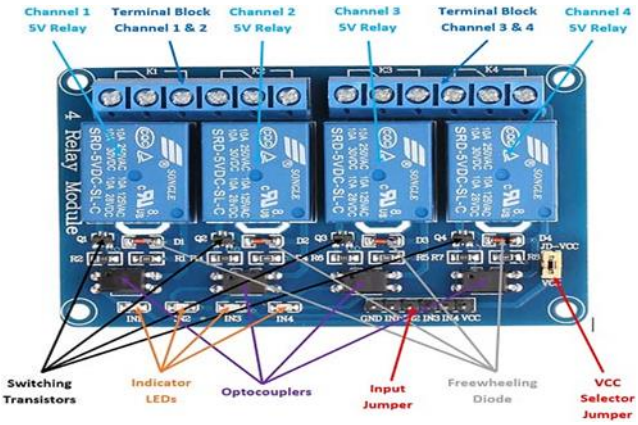

Fig. 5. Relay module 4×4.

D. USB and ttl driver

As shown in Fig. 6, USB and ttl driver is the mediator that is used to download the sounds that are generated to control the devices. It is used to connect VRV2 to the computer.

Fig. 6. USB and ttl driver.

It may be worth mentioning that this system could be converted into a wireless system only by replacing the voice recognition module with a Bluetooth module and linking it to a smartphone with a voice recognition application installed on it.

E. Bluetooth module

It is the device that is used to connect the Arduino board to the smartphone which contains any application that uses speech recognition technology such as Android Voice Controller.

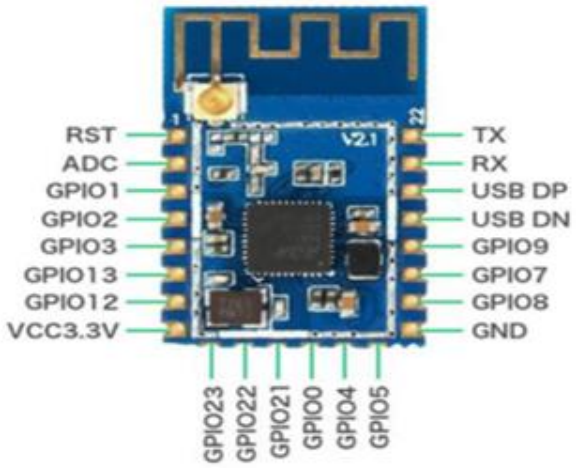

Fig. 7. Bluetooth module.

4. METHODOLOGY AND RESULT

A. Wired System based on voice recognition module

The speech input from the microphone is given to the voice recognition module where the speech signal is compared with the previously stored trained voice samples. Upon successful recognition of voice command, the Arduino microcontroller actuates the corresponding electrical device like turning on lights or adjusting bed elevation using the relay module. In Fig.8, the block diagram sets the principle of the system's work.

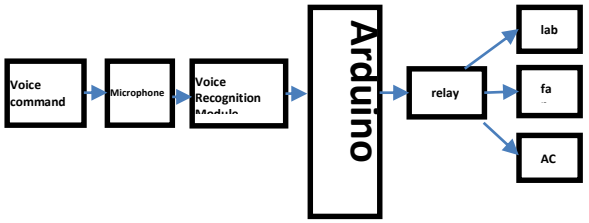

Fig. 8. Block diagram of the proposed system.

The working principle of the system is as follows:

First, we connect the voice recognition device to the computer (connection is shown in Fig.9).

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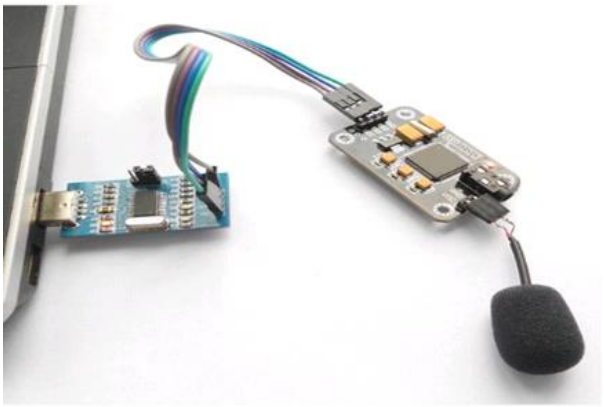

Fig. 9. Voice recognition system.

Then the voices are recorded and stored on it, with the help of the (Access Port) program as demonstrated in Fig.10. In order to connect the voice recognition device to the computer, the USB and ttl driver are used. The maximum number of voice commands that can be recorded is 15 voices.

Fig. 10. Access port window.

To set the stage for this case study, the voice commands with their descriptions are presented in Table 1. Herein, only five commands are used as a demonstration to evaluate the performance of the system.

Table 1. System Commands

Command number	Command words	Description
Commomd1	On	To turn on the lighting
Commomd2	TV on	To turn on the TV
Commomd3	Charger	To turn on the charger
Commomd4	Off	To turn off the lights and the charger
Commomd5	TV off	Turn off the TV

Secondly, we define the Arduino device to the computer, and through the Arduino C program, all the codes for the project can be written and then sent to the Arduino microcontroller.

Finally, we connect the Arduino to the voice recognition model and the relays which are used to connect home devices to the Arduino. The hardware connection of this system is shown in Fig. 11.

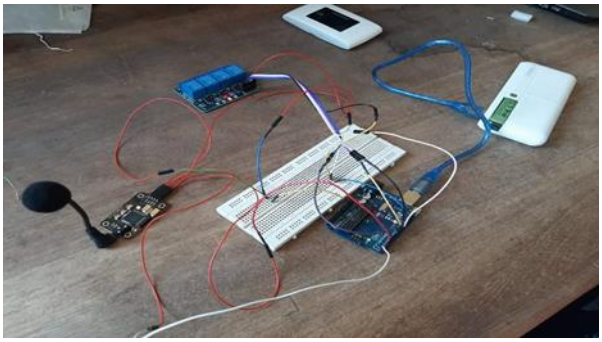

Fig. 11. Connection of the system.

B. Wireless system using bluetooth module

The composition of this system is the same as the installation of the previous system with the difference is in replacing the voice recognition module with the Bluetooth module. The block diagram in Fig.12 illustrates the wireless system.

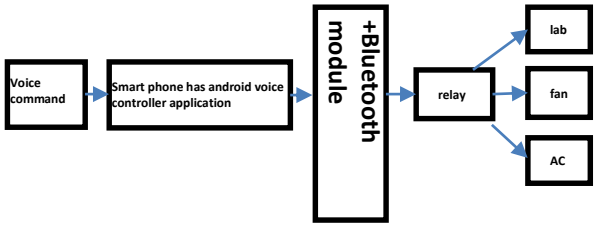

Fig. 12. Block diagram of the system.

The working principle of the system is as follows:

First, the code for the system is written using the Arduino IDE, and it is sent to the Arduino board as in the first system. Secondly, the Arduino, Bluetooth module l and the relay are connected to each other and the relay is used to connect home devices to the Arduino. The connection of the Arduino with Bluetooth module is shown in Fig.13.

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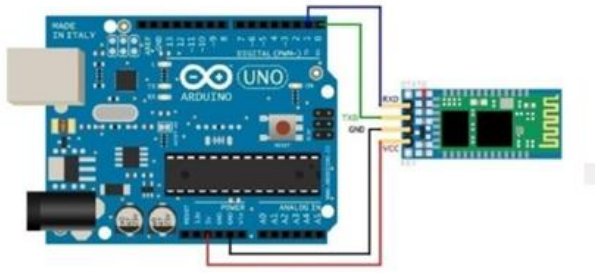

Fig. 13. Connection of the arduino with Bluetooth module.

Finally, the application that uses voice recognition technology is downloaded from the App Store, such as the **Android Voice Controller** application. Then it is connected to the Bluetooth module that is connected to the Arduino board application.

5. RESULTS

This system has been tested in terms of accuracy, speed of response, and the effect of distance from the system on its response, and the evaluation of the system performance with the results are presented in the following subsections.

A. System Accuracy

In this section, we will test the accuracy of the system, as mentioned earlier is approximately 95%. Table 2 illustrates the voice commands which are tested five times for each command. As shown, '0' indicates that the system has not responded to the command while '1' indicates that the system has responded to the command.

Table 2. Wired System Accuracy

Commands	Successful Responses					Total Responses	Accuracy
	1	2	3	4	5		
ON	1	1	1	1	1	5	100%
TV ON	1	1	1	1	1	5	100%
CHARGER	1	1	1	1	1	5	100%
OFF	1	1	1	1	1	5	100%
TV OFF	1	1	0	1	1	4	80%

Here we measured the response at a fixed distance of one meter, we calculated the accuracy for each voice command, and it is as shown in the table. If we want to calculate the system accuracy for all commands we get an average accuracy of 96%, which is close to the previously mentioned value.

One may argue that this is a random process that is affected by surrounding circumstances. For instance, if we measure the response in a noisy environment, the accuracy rate is estimated to be about 60%. However, in our experiment, the accuracy is found to be as low as 44% as shown in Table 3.

Table 3. System Accuracy, Noisy Environment

Commands	Successful Responses					Total Responses	Accuracy
	1	2	3	4	5		
ON	1	1	0	0	0	2	40%
TV ON	1	0	0	1	1	3	60%
CHARGER	0	1	0	0	1	2	40%
OFF	0	0	0	1	1	2	40%
TV OFF	1	0	0	0	1	2	40%

B. The effect of distance on the system

The system is tested at three different distances which are measured between the system and the source of the voice command which are 'one' meter and 'two' and 'three' meters.

We notice that the system's response to commands decreases if the distance between the speaker and the system is increased. That means, increasing the distance has a negative effect on the accuracy of the response. As depicted in Table 4, the further the distance, the lower the accuracy which is intuitively should be the case.

The system's average accuracy for all commands at a one-meter distance is about 96%. The system's average accuracy for all commands at a two-meter distance gives an accuracy of 72%. Finally, the system average accuracy for all commands at a three-meter distance is about 48%.

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Table 4. System Accuracy At Different Meter Distances.

Voice commands	At 1 Meter Distance		At 2 Meter Distance		At 3 Meter Distance	
	Total Responses	Accuracy	Total Responses	Accuracy	Total Responses	Accuracy
ON	5	100%	4	80%	3	60%
TV ON	5	100%	4	80%	2	40%
CHARGER	5	100%	3	60%	2	40%
OFF	5	100%	4	80%	3	60%
TV OFF	4	80%	3	60%	2	40%

C. System speed response

Here, we will test the speed of the response to the voice command. After issuing the command, the response time is recorded as displayed in Table 5.

Table 5. Time Response Of Commands.

Voice commands	Response Time (seconds)					Average Response Time (seconds)
	1	2	3	4	5	
ON	0.47	0.48	0.41	0.54	0.41	0.462
TV ON	0.47	0.53	0.48	0.54	0.34	0.472
CHARGER	0.41	0.60	0.47	0.43	0.54	0.49
OFF	0.40	0.54	0.48	0.47	0.54	0.486
TV OFF	0.41	0.60	0.51	0.35	0.35	0.44

Finally, the comparison between the wired technology and the Bluetooth technology is presented in Table 6.

Table 6. Comparisons Of Wired Technology and Bluetooth Technology

Technology / Comparisons	Wired technology	Bluetooth technology
Range of the distance that can be covered	3 meter Suitable for smart room	More than 10 mete Suitable for smart home
The ability to exchange the voice recognition model for mobile phone	We cannot exchange the a voice recognition model for mobile phone	We can exchange the a voice recognition model for mobile phone
Usability by the elderly	More Suitable	Suitable
Usability by amputees	More Suitable	Suitable if we use VRV2or VRV3. Is not suitable if we use mobile phone.
Number of commands	15 commands if we use VRV2,If we use VRV3 are 80 commands	15 commands if we use VRV2, If we use VRV3 are 80 commands. Infinite number if we use mobile
Accuracy	Very High accuracy	Very High accuracy if we use VRV2. High when we use mobile
Flexibility and simplicity of the system	Simple and flexible if we use it for smart rooms, but if we use it for all home, it can increase the complexity.	Simple and flexible for smart home

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It can be shown from the results that the response is within 0.35 to 0.6 seconds. That means that the system has a relatively rapid response to voice command. These tests are conducted on the wired system, which prove to be much more accurate than wireless technology for this specific case study.

6. CONCLSION

This paper discusses two systems that have a high response speed and high efficiency, yet they are relatively simple systems and reasonably inexpensive. The cost of the first system is only 300 L.D, and you only need an extra 20 L.D to convert your system into a wireless system (the second system).

The first system has a high accuracy at ideal conditions approximately 95%-99%. This accuracy is achieved using the voice recognition module. The proposed system can distinguish between people's voices, because it uses voice recognition technology. For the second system, the application used in it uses speech recognition technology that only needs the correct word to execute the command. One advantage of the second system is that it is not required to be close to the system to execute commands. On the other hand, you need a distance of less than three meters for the first system to respond. In terms of security, however, the first is better because the voice is considered as a fingerprint for a specific person.

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Genetic Stability Assessment of Three Tomato Hybrids (*Lycopersicon esculentum*) grown in the Libyan Green Mountains Using SRAP and RAPD Techniques

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ABSTRACT

The genetic diversity of F1 tomato hybrid (Nada, Mona, and Dania) grown in Libyan Green Mountain (LGM) was investigated using SRAP and RAPD molecular marker techniques while the coefficient of variation C.V was used to investigate F1 seed purity. The coefficient of variation C.V., in the three cultivars Nada, Mona and Dania are 31.88, 51.66 and 44.18, respectively, indicating the homogeneity of Nada cultivar over Dania and Mona. The SRAP marker provided a total number of 29 amplified DNA bands with an average of 9.67 bands per primer, 26 of which were polymorphic (67% polymorphism), while the RAPD marker provided a total of 73 bands with an average of 14.6 bands per primer; all of them were 100% polymorphic. The genetic diversity for the three studied cultivars was 0.31, whereas Nada cultivar was the most homogeneous recording a genetic diversity of 0.24 compared with Mona 0.25 and Dania 0.28 Dania. Principal coordinate analysis (PcoA) divided tomato F1 hybrid samples into two main groups, the first (A) includes all the plants of a Nada hybrid cultivar, while group (B) consists of overlapping of Dania and Mona cultivars, reflecting the genetic relatedness.

KEYWORDS: Tomato hybrid, *Solanum Lycopersicon*, Genetic diversity, Genetic Stability, Seed purity.

1. INTRODUCTION

Tomato (*Solanum lycopersicum L.*) is a highly valuable vegetable crop cultivated globally for both fresh consumption and processed products. It is a rich source of essential nutrients, particularly vitamins A and C, along with a variety of antioxidants.[1] Additionally, it holds substantial economic importance for producers and breeding industries across numerous countries.[2] Currently, approximately 7,500 cultivated tomato varieties exist worldwide, displaying considerable variation in size, shape, colour, and taste.[3] Traditional breeding methods face challenges like long breeding cycles, limited genetic diversity, and unpredictable results. These factors slow down the efficient development of new crop varieties with enhanced yields.[4] The strategic use of molecular markers in crop improvement programs enhances selection accuracy and shortens the breeding cycle enabling the faster development of new cultivars with desirable traits.[5]

The genetic purity of hybrid seed cultivars is very important in the process of producing hybrid seeds to meet the desires of the farmer, preserve his rights, and protect him from commercial fraud.[6]

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The contamination in the seeds may occur as a result of mixing with seeds resulting from the self-pollinating of the parents instead of pollinating him with the father to be crossed, due to negligence in the process of castration and removal of the anthers, or it may be due to the arrival of strange pollen grains to the line to be crossed with one of the well-known parents, Sometimes cheating is done intentionally by mixing the seeds of the first generation F1 as a result of their high price with seeds of the second generation F2.[7]

The purity of seeds in hybrid cultivars is confirmed by means of a test called (GOT) field Grow Out Test by planting replicates from the two parents involved in the composition of the hybrid cultivar with replicates of the hybrid cultivar. Morphological traits are studied and evaluated based on the similarity discrimination test and genetic stability (DUS), Distinctness, Uniformity and Stability. However, this method takes a long time and requires great effort and good experience.[8] The discovery of molecular biology techniques and the development of Molecular marker techniques identifying the genetic fingerprint of the parents of the hybrids and comparing them with the hybrid cultivar. In addition to the comparison within the hybrid cultivar for the identification of homology and genetic homogeneity.[8]

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Among the markers that were used in the genetic purity test and the study of genetic stability of the hybrid cultivar are the techniques of RAPD as well as the SRAP technique, which was used in the test of the purity of tomato hybrids,[9] as well as in genetic stability and purity of tobacco hybrids.[8] A commonly utilized approach involves molecular markers, such as RAPD, which offer high-resolution insights into the genetic variation within tomato populations.[2] RAPD markers demonstrated effectiveness in distinguishing the studied lines by calculating the average Polymorphism Information Content (PIC) values.[10] The SRAP technique was used to study the genetic diversity of heat-tolerant tomato plants,[11] as well used to reveal the genetic relationship of tomato strains in Spain,[12], in addition, the technique was used to study the molecular variance of some quantitative traits in tomato fruit in F2 second generation plants.[13] This study aims to assess the purity and homogeneity of the F1 hybrid tomato plants grown in Libyan Green Mountain (LGM) (Fig. 1), which can be used to identify commercial fraud and determine the degree of homogeneity and purity of F1 hybrids.

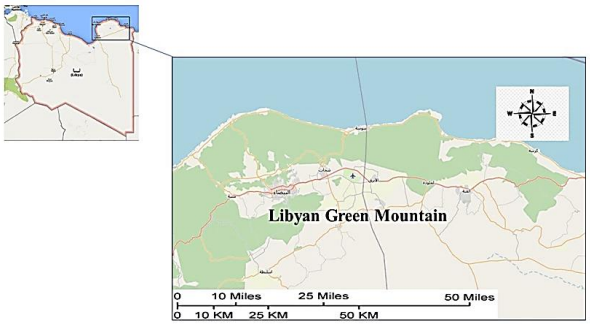

Figure 1 The Green Mountain region in Libya served as the site for the sampling studies conducted in this research.

2. MATERIAL AND METHODS

Thirty-three random samples of whole plants, including their fruits, were collected in late summer from the Libyan Green Mountain (LGM), an area characterized by a Mediterranean climate featuring warm to hot summer conditions and mild to cool winters. The samples included three F1 hybrid cultivars: Nada, Mona, and Dania (Fig 2).

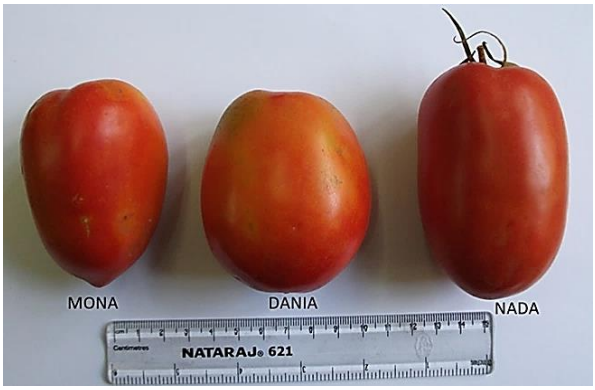

Figure 2: The F1 hybrid tomato varieties under investigation are Nada, Dania, and Mona.

The hybrids were sourced from TAJURI Agricultural Development Company located in Tripoli, Libya. for the study of morphological characteristics, eleven replicates were considered for each cultivar (Table 2). The data were analysed using ASSISTAT version 7.7 (2016), and mean comparisons were performed using Tukey's test ($p \leq 0.05$). Fresh, healthy leaves were washed with tap water followed by distilled water. Subsequently, the samples were disinfected using 70% ethyl alcohol. Finally, the samples were stored in plastic bags and placed in a freezer until DNA extraction.

One gram of each leaf sample was finely chopped and ground into a powder using washed, distilled, sterilized sand. Subsequently, an extraction solution was added following the CTAB extraction method. The isolated DNA was quantified and assessed by loading 2 µL onto a 0.85% agarose gel, which was run at 100 V for 30 minutes. The gels were then stained with ethidium bromide and visualized under ultraviolet light.

DNA amplification was conducted using a Px2 thermal cycler (Thermo) with eight primers, comprising three SRAP and five RAPD primers (Table 1)

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Table 1. Sequences and melting temperature (Tm) of SRAP and RAPD primers

No.	Marker	Primer	Primer sequences (5'–3')	CG%	Optimal Tm °C
1	SRAP	me2	5' TGA GTC CAA ACC CGA GC – 3'	58.82	54.8
		em5	5' – GAC TGC GTA CGA ATT TGA – 3'	44.44	51.6
2	SRAP	me2	5' TGA GTC CAA ACC CGA GC – 3'	58.82	54.8
		em3	5' GAC TGC GTA CGA ATT TGC – 3'	50	53.9
3	SRAP	me13	5' – TGA GTC CAA ACC GGT TG – 3'	52.94	52.4
		em8	5' – GAC TGC GTA CGA ATT AAC– 3'	44.44	51.6
4	RAPD	OPA10	5' - GTG ATC GCA G – 3'	60	32
5	RAPD	OPC02	5' - GTG AGG CGT C – 3'	70	34
6	RAPD	OPC10	5' – TGT CTG GGT G – 3'	60	32
7	RAPD	OPC11	5' – GTG ATC GCA G – 3'	60	32
8	RAPD	OPD20	5' – ACC CGG TCA C – 3'	70	34

The conditions for the SRAP technique were as follows: initial denaturation at 94 °C for 5 minutes, followed by 5 cycles consisting of denaturation at 94 °C for 60 seconds, primer annealing at 35 °C for 60 seconds, and extension at 72 °C for 1 minute. This was followed by an additional 35 cycles of denaturation at 94 °C for 60 seconds, primer annealing at 47 °C for 60 seconds, and extension at 72 °C for 2 minutes, with a final extension at 72 °C for 10 minutes. For the RAPD technique, the protocol included an initial denaturation at 94 °C for 3 minutes, followed by 40 cycles of denaturation at 94 °C for 45 seconds, primer annealing at the respective temperatures, and extension at 72 °C for 1 minute, concluding with a final extension at 72 °C for 5 minutes. Five microliters of the amplified DNA fragments, including a loading dye, were loaded onto a 1.5% agarose gel, which was run at 30 V for 180 minutes in 1X TAE buffer (30 mM). The gels were stained with ethidium bromide and visualized using a UV trans-illuminator.

SRAP (Sequence-Related Amplified Polymorphism) and RAPD (Random Amplification of Polymorphic DNA) bands were scored as present (1) or absent (0) to generate a binary data matrix. They were computed in PAST software V 1.91[14] to identify the relationships between the hybrids using Principal coordinate analysis (PcoA) through the hamming similarity index while analysis of molecular variance (AMOVA) assessment of genetic variation within and among populations was conducted using the GenAlex 6.5 software.[15]

3. RESULTS AND DISCUSSION

The statistical analysis presented in (Table 2) indicated significant variability in the fresh weight of both ripe and green fruits serving as a measure of plant productivity as determined by Tukey's test. The Nada hybrid exhibited the highest fresh fruit weight averaging 5609 grams per plant. In contrast, the Dania and Mona cultivars produced average weights of 3209 grams and 2421 grams, respectively, with no significant difference between these two cultivars. These variations in fruit weight may be attributed to the plants' responses to environmental factors and their genetic backgrounds.

Table 2 Productivity Traits and Coefficient of Variation CV of Nada, Mona and Dania F1 Hybrid Cultivars.

	NADA	CV	DANIA	CV	MONA	CV
Fresh fruit weight by gram	5609^{a}	31.88	3209^{b}	44.18	2421^{b}	51.66
Number of fruits	85^{a}	29.8	95.5^{a}	37.12	42.5^{b}	54.4
Fruit weight by gram	105.9^{a}	9.6	83.18^{b}	20.5	93.5^{b}	14.3
Fruit size by mm3	111.3^{a}	11.3	84.7^{b}	26.7	81.8^{b}	17.3
Number of locules	3.36^{a}	15.52	2.61^{b}	18.72	2.67^{b}	17.71
Fruit rigidity by Durometers	7.2^{a}	11.45	5.01^{c}	18.92	6.76^{b}	12.94

Each value represents the mean of eleven replicates (plants). Means followed by the same letter in each line are not significantly different by Tukey's test ($p \leq 0.05$).

The level of homogeneity within each cultivar serves as an indicator of the genetic purity of the hybrid cultivar. This homogeneity can be assessed using dispersion criteria. Given the differences in mean values of homogeneity among the cultivars, alternative measures of dispersion, such as standard deviation could not be employed. Nevertheless, the dispersion criteria were found to be consistent with the coefficient of variation.

The coefficients of variation for the three cultivars Nada, Mona, and Dania were 31.88, 51.66, and 44.18,

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respectively (Table 2). These results indicate that the Nada cultivar demonstrates the greatest homogeneity exhibiting the smallest differences across all production traits (Table 2). In contrast, the Dania and Mona cultivars displayed notable dispersion and heterogeneity suggesting potential impurity. For comparison, a coefficient of variation of 14.3% for tomato fruit weight has been reported in Pakistan[16] indicating that hybrid cultivars can be differentiated based on vegetative vigor and homogeneity reflecting similar genetic backgrounds. When the coefficient of variation exceeds 30%, it typically indicates a high degree of heterogeneity with large genetic dispersion and minimal homogeneity among average values.[17,18] Furthermore, the coefficients of variation among genotypes significantly impact phenotypic traits, particularly productive traits such as fruit weight, in contrast to non-productive traits.[19]

In this study, the SRAP primers yielded 29 amplified DNA bands averaging 9.67 bands per primer with 26 of these being polymorphic resulting in a polymorphism rate of 67%. Conversely, a combination of the me2em3 and me13em8 primers achieved complete polymorphism (100%) while the me2em5 primer exhibited no polymorphism. The SRAP profiles of the amplified products from each primer are presented in (Table 3). The primer me2em3 produced the highest number of bands, totalling 14, whereas the primer me2em5 generated the fewest, with only three bands (Table 3). This number of bands surpasses that reported in a related study, which documented an average of 6 bands per primer among 15 tomato genotypes in Turkish breeding programs.[11]

Table 3. Amplified DNA bands and polymorphism percentage of SRAP and RAPD primers.

Marker	Primer	No of bands.	Polymorphic bands.	% Polymorphic	Genetic Diversity
SRAP	me2em3	14	14	100%	0.298501
SRAP	me2em5	3	0	0%	0
SRAP	me13em8	12	12	100%	0.308854
Average		9.67	8.7	67%	0.20
RAPD	OPA10	8	8	100%	0.314453
RAPD	OPC02	12	12	100%	0.309671
RAPD	OPC10	16	16	100%	0.413966
RAPD	OPC11	25	25	100%	0.339753
RAPD	OPD20	12	12	100%	0.263889
Average		73	14.6	100%	0.33
Both markers					**0.31757**

In a study involving 26 combinations of SRAP primers applied to local tomato cultivars in Spain,[12] a total of 384 bands were identified, resulting in an average of 14.77 bands per primer combination with a minimum of 4 bands and a maximum of 49. This variation in band number can be attributed to the diverse genetic compositions of the plants as well as the specific primers utilized. In the present study, the SRAP primer me2em3 (Fig. 3) produced profiles for 14 genotypes exhibiting a range of molecular weights with the heaviest band at approximately 1500 bp and the lightest at 250 bp found in the third sample of the Nada cultivar. Notably, the primers failed to amplify DNA in the first and second samples of the Nada cultivar. The same me2em3 primer combination previously applied to local tomato cultivars in Spain yielded only 4 bands,[12] while another analysis reported 10 bands with 70% polymorphism across different tomato cultivars.[20]

The SRAP primer me2em5 identified 3 genotypes with molecular weights ranging from 450 bp to 900 bp, while the primer me13em 8 detected 12 genotypes with molecular weights spanning from 50 bp to 1400 bp. Additionally, molecular weights between 500 bp and 1050 bp were recorded for the me2em3 primer.[11] In this study, the RAPD markers generated a total of 73 bands yielding an average of 14.6 bands per primer, all exhibiting 100% polymorphism. The RAPD profiles of the amplified products for each primer are detailed in (Table 4). In a separate study, an average of 9.7 fragments was identified using 16 RAPD primers across three tomato cultivars,[21] whereas another analysis employing 27 RAPD primers on 19 tomato cultivars reported a total of 442 RAPD bands, with an average of 16.4 bands per primer.[22]

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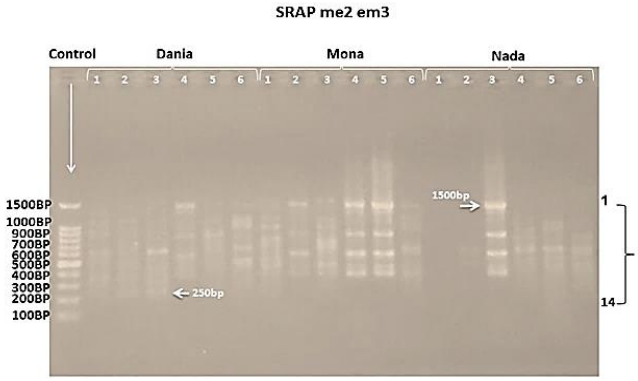

Figure 3: Banding patterns of F1 tomatoes hybrid obtained with me2 and em3 SRAP primers.

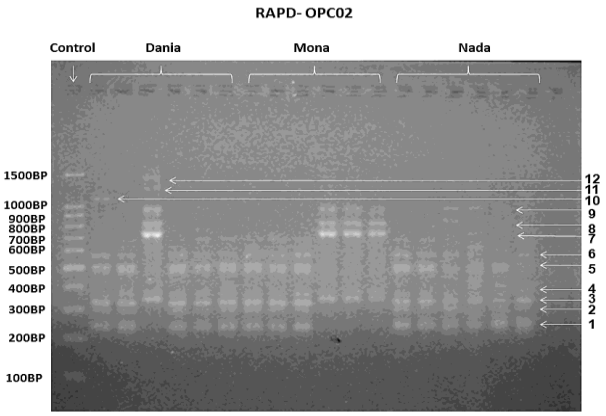

Figure 4: Banding patterns of F1 tomatoes hybrid obtained with OPC02 RAPD primers.

A maximum of 25 bands were amplified using the primer OPC11, while the primer OPA10 yielded a minimum of 8 bands. Additionally, the primers OPC02 and OPD20 each generated only 12 bands (Fig. 4). In previous research, the same primer was applied to various tomato cultivars and resulted in only 3 bands[23] of which two were polymorphic and one was non-polymorphic. Similarly, 7 bands were produced with the primer OPC11 in tomato cultivars from Korea; however, none of these bands exhibited polymorphism.[24]

All DNA fragments presented in (Table 3) were identified as sources of genetic variation among F1 hybrids of tomato cultivars exhibiting a polymorphism rate of 100%. In a study involving 24 tomato cultivars cultivated in India and examined with 11 RAPD primers, an average of 89.39% polymorphic bands was observed.[25] Conversely, an analysis of genetic relationships among eight tomato cultivars in Egypt, utilizing 7 RAPD primers, revealed an average of 11.57 bands per primer with 66.48% of these being polymorphic.[26] Additionally, a separate study identified an average of 4.14 bands per primer across 27 tomato cultivars in India with 63.81% showing polymorphism.[27]

The RAPD primer OPC10 produced the largest band, measuring 1600 bp, while the smallest band, at 200 bp, was generated by both the OPC10 and OPC11 primers. The primer OPC02 identified 12 genotypes with varying molecular weights (Fig. 4). The maximum molecular weight recorded was approximately 1400 bp corresponding to the third sample of the Dania cultivar, while the minimum was 250 bp, associated with 14 different samples across all cultivars. In a separate study, the same primer evaluated 11 tomato cultivars in Bangladesh yielding 41 bands with sizes ranging from 750 to 2000 bp.[28] Additionally, the same primer produced only 11 bands among 24 tomato cultivars in India.[25] These variations can be attributed to genetic differences among the cultivars studied resulting in distinct variations at the DNA level.

3.1. Genetic stability assessment using RAPD and SRAP:

The F1 hybrid tomato cultivars were distinguished by their high quality, productivity, early ripening, uniformity of fruit, and disease resistance. However, the production of F1 seeds presents significant challenges, as it demands highly skilled labour and precise knowledge of production techniques. The evaluation of hybrids typically takes into account factors, such as the characteristics of the parent plants, the male-to-female ratio, the precision of emasculation, and the compatibility of pollination. Additionally, any plants that do not meet the standards of the parental lines must be eliminated, as they are required to be completely identical and pure (100%). Inaccurate execution or omission of any essential procedures may result in the generation of impure or pseudo-hybrid genotypes.[29] The genetic diversity among the three studied cultivars was measured at 0.31, indicating low genetic diversity. Nevertheless, this value for genetic stability was consistent with the observed genetic diversity (0.31), in comparison to a previous study involving 25 hybrid cultivars from Italy.[30]

Among the cultivars, the Nada cultivar exhibited the highest homogeneity in genetic diversity at 0.24, followed by Mona at 0.25, and Dania at 0.28. Dania displayed the lowest homogeneity due to its higher genetic diversity, which may be linked to seed purity issues. A genetic diversity index of 0.41 was reported for 335 tomato strains collected from 25 Asian countries, evaluated using SSR markers,[31] although fourteen genotype pes of tomato cultivars in Azerbaijan tested using 6 RAPD primers, the genetic diversity rate was 0.61,[32] it may be due to samples are collected from different countries, environments, and sources compared with our study. Understanding the genetic

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distance among diverse cultivars is crucial for plant breeders, as it facilitates the selection of suitable parent plants for developing new genetic combinations

Principal coordinate analysis (PcoA) divided tomato F1 hybrid samples into two main groups, the first includes all the plants of a Nada hybrid cultivar, which appear as group A, while the samples of the cultivar Dania and Mona overlapped with each other in group B (Fig. 5). It is an indicator that reflects the genetic affinity between the plants of the two cultivars Dania and Mona, which may be caused by the closeness of the parents used in the crossbreeding process. It also indicates greater homogeneity in the cultivar Nada compared to the other two cultivars.

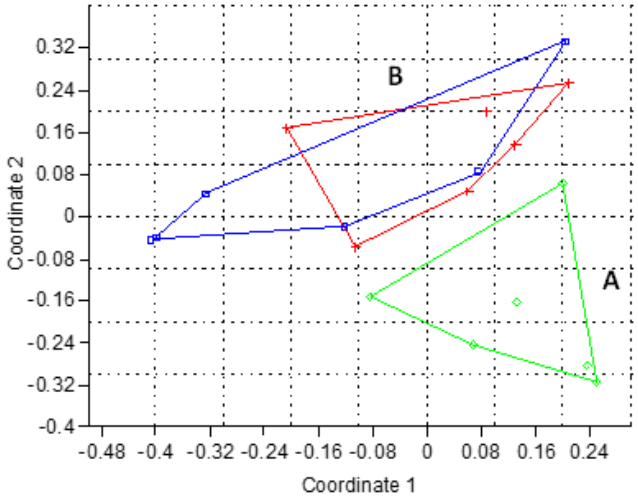

Figure 5: Scatter plot of Principal Coordinate Analysis (PCoA) of RAPD and SRAP markers divided tomato F1 hybrid into two main groups A: (Nada hybrid) and B: (Dania and Mona hybrids).

This finding coincided with the study on different genotypes of tomato in Sudan using 16 primers of the RAPD marker, where closely related strains were grouped into separate groups.[21]

Analysis of molecular variance (AMOVA) shows that only 16% of the variance was between the three different cultivars, while 84% of the genetic variance is attributed to differences within the cultivars (Fig. 6). This is an indication the lack of genetic purity, which may be caused by either error in the emasculation process, which caused self-pollination of mothers, or it may be contaminated with pollen from other cultivars.

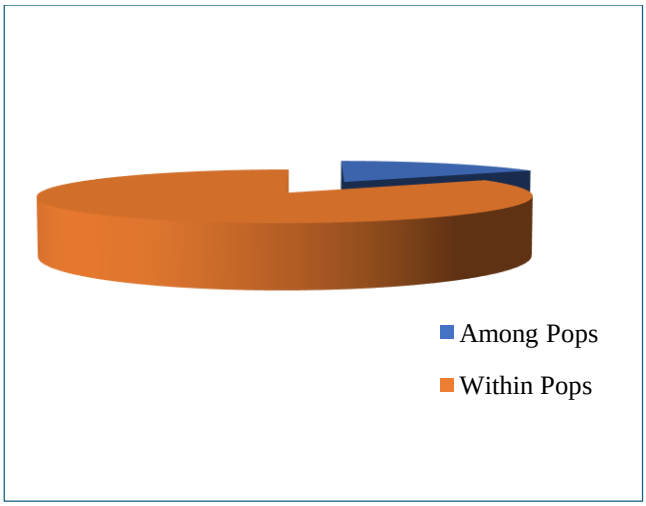

Figure 6: Analysis of molecular variance (AMOVA) of the three F1 hybrid tomato cultivars.

The DNA molecular marker was used to test seed genetic purity of two commercial F1 hybrid cultivars 'Hezuo 903' and 'Sufen No. 8' showed that eight of the 210 F1 plants in 'Hezuo 903' and 13 of 210 in 'Sufen No. 8' were false hybrids.[10]

4. CONCLUSION

This study is considered one of the first studies to identify the common genotypes of tomato F1 hybrids in (LGM) using DNA molecular markers, which could have strong implications for the breeding programs to develop and improve tomatoes as a commercially important crop and will be useful for future programs on genetic improvement of tomato cultivars. The genetic stability for the studied tomato cultivars was appropriate, the cultivar Nada is the most homogeneous through phenotypic and genetic results, while the Mona cultivar is the least homogeneous, which may be attributed to the lack of purity of seeds. This result was proved by the Principal coordinate analysis (PcoA) test, which separated the most homogeneous cultivar into one group, while the rest of the cultivars were in the second group. This adulteration of the seeds may be due to errors in the production process, or it may be deliberate by some fraudsters, which requires the state to enact deterrent laws for that matter.

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Optimizing Quality Control: A Comprehensive Analysis of Computer Vision Methods for Assessing Vegetables and Fruits

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ABSTRACT

Efficient quality control in the agriculture sector, particularly regarding the inspection of vegetables and fruits, stands as a critical necessity in today's health-focused industry. Conventional fruit grading methods, ill-suited for large-scale production, demand an automated, non-invasive, and economically feasible substitute. Computer vision emerges as a promising avenue, leveraging image analysis and machine learning algorithms to evaluate the quality of produce. The convergence of computer vision and image processing technologies in contemporary agriculture has brought about a substantial transformation in quality assessment methodologies. This paper conducts an in-depth exploration of the amalgamation of computer vision and image processing techniques for the evaluation of agricultural produce quality. Through a comprehensive review, this scientific analysis investigates the integration of computer vision and image processing techniques in agricultural quality assessment. It scrutinizes key studies, their practical implementations, outcomes, and the research voids they reveal. Technological progressions within the agricultural domain have the potential to amplify productivity and curtail the circulation of flawed or substandard products. Moreover, this study deliberates on the forthcoming trends in computer vision technology applications, accentuating their prospective influence on the vegetables and fruits industry.

KEYWORDS: Computer Vision**,** Classification Mechanisms, Fruits; Image Processing, Quality Assessment, Vegetables.

1. INTRODUCTION

In recent years, there has been a growing interest in the application of computer vision techniques for the quality and safety inspection of vegetables and fruits. This is driven by the increasing demand for high-quality produce and the need to ensure food safety for consumers. Researchers have explored various methodologies to evaluate the quality attributes of vegetables and fruits using computer vision, making it a promising field of study.

One area of research focuses on the evaluation of vegetable and fruit quality using computer vision. Conventional imaging techniques have been utilized for non-destructive evaluation of quality attributes in both fresh and packaged vegetables and fruits. These techniques enable accurate assessment of the quality of produce, helping to ensure consumer satisfaction and reduce post-harvest losses [1, 2]. Another area of interest is the sorting and grading of vegetables and fruits using computer vision and image processing techniques [3, 4].

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By automating the sorting and grading processes, computer vision systems can improve efficiency and productivity in the agricultural industry. For example, shape-based vegetable and fruit recognition and classification systems have been developed to streamline the sorting and grading of vegetables and fruits [4].

Classification of vegetables and fruits based on image processing techniques has also been explored [5]. By analyzing the visual features of produce, CV can accurately classify fruits and vegetables, aiding in inventory management and marketing decisions [5].

Additionally, fractal analysis has been proposed as an approach for fruit and vegetable classification, further enhancing the accuracy of classification systems [6].

CV techniques have also been employed for volume and mass estimation of fruits and vegetables. These methods enable automated and accurate estimation of yield and quality control, providing valuable information for farmers and producers [7].

In recent years, the use of conditional Generative Adversarial Network (GAN) data augmentation has been investigated for fruit quality and defect image

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classification. This technique enhances the accuracy of classification systems by generating synthetic data to augment the training set, improving the capability to detect defects in fruits [8]. Using image processing techniques and machine learning algorithms to classify fruits and vegetables. By analyzing different visual attributes such as size, shape, color and texture, the authors aim to develop a comprehensive classification system that can accurately distinguish between different product types.

Transfer learning has also been applied to vegetable and fruit quality assessment, leveraging pre-trained models to achieve accurate classification and quality assessment. This approach allows for the utilization of existing knowledge and models, reducing the need for extensive training and enhancing the efficiency of the assessment process [10]. The vegetables and fruits industry plays a pivotal role in providing nutritious and fresh produce to meet the growing demand for healthy food. Ensuring the quality and safety of vegetables and fruits is of utmost importance to protect consumer health and maintain customer satisfaction. Quality inspection involves evaluating various attributes such as size, shape, color, texture, and the presence of defects, while safety inspection focuses on identifying contaminants, pesticide residues, and other potential hazards.

In recent years, CV techniques have emerged as powerful tools for quality and safety inspection in the fruits and vegetables industry. CV utilizes digital image processing, pattern recognition, and machine learning algorithms to analyze and interpret visual information. By harnessing computer vision, researchers and industry professionals can automate inspection processes, enhance accuracy, and improve efficiency.

The objective of this review is to provide a comprehensive overview of the application of computer vision techniques for quality and safety inspection of fruits and vegetables. This review aims to highlight the potential benefits and advancements in this field. The review will cover several key topics:

2. RELATED WORK

2.1. Traditional Image Processing Techniques

Several research studies have explored the application of traditional image processing techniques in the assessment of fruit and vegetable quality, as evidenced in previous works (e.g., [4, 5, 6]). These techniques typically involve the extraction of features from images, such as color histograms, texture descriptors, and geometric shapes. For example, Jana et al. [4]. focused on shape-based features for fruit recognition and classification, whereas Chithra and Henila [5]. employed image processing techniques for fruit classification purposes. While these methods provide a straightforward and computationally efficient approach, their efficacy often depends on manually engineered features and may fall short in capturing the intricate variations in the appearance of fruits and vegetables.

In the realm of fruit and vegetable quality assessment, various studies have explored the utilization of traditional image processing methods. For instance, Jana et al. [7]. introduced a new method employing the de novo process to automatically estimate the volume and mass of produce, yielding reliable and efficient results as per the presented data. Another study concentrated on improving fruit quality assessment and defect classification by employing conditional GAN data augmentation techniques, leading to notable advancements in accurately identifying and categorizing defects across a spectrum of fruits and vegetables. However, there exists a significant research gap regarding the adaptability and generalizability of the developed classification model to a diverse array of fruit and vegetable varieties. Further investigations are necessary to ascertain the model's efficacy across different produce types.

In the study conducted by Bird et al. [8], the assessment of fruit quality and defect classification in fruits and vegetables was performed through the implementation of conditional GAN data augmentation techniques. The study presented concrete and precise outcomes within this domain. Their research focused on leveraging conditional GAN data augmentation methods for the evaluation of fruit quality and defect classification, resulting in improved accuracy in identifying defects across diverse fruits and vegetables. Looking ahead, it is crucial for future research initiatives to explore the adaptability of the classification model to various fruit and vegetable types to effectively gauge its generalizability.

Wedha et al. [9]. delved into a thorough examination of the classification system pertaining to fruits and vegetables, showcasing a commitment to understanding and improving this domain. Their study extensively delved into the classification system of fruits and vegetables with an emphasis on enhancing comprehension and refining these systems. To propel progress in this area, forthcoming research should delve into the practical implications of the proposed classification system in real-world agricultural contexts to evaluate its efficacy and relevance.

In their study, Turaev et al. [10]. utilized transfer learning methods to analyze the quality of fruits and vegetables, illustrating how transferring knowledge across various domains can improve evaluation procedures. Their research involved the application of

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transfer learning techniques to assess fruit and vegetable quality, highlighting the advantages of knowledge transfer from diverse domains in enhancing evaluation processes. To advance in this field, forthcoming research should explore the robustness of transfer learning models under varying environmental conditions and across different crop types to ensure their efficacy and adaptability.

In their book "Algorithms in Machine Learning Paradigms," Mandal et al. [11]. evaluated a variety of machine learning algorithms, highlighting their roles in evaluating the quality of fruits and vegetables in agricultural settings. The book provides a comprehensive collection of algorithms leveraging machine learning for quality assessment. Future research directions could involve comparative studies to pinpoint the most effective machine learning algorithms suited to distinct types of fruits and vegetables.

2.2. Comparing Traditional Methods to Computer Vision and Deep Learning Techniques

When comparing traditional manual inspection with computer vision methods in the fruit and vegetable inspection industry, there has been a notable shift towards utilizing computer vision techniques for evaluating ripeness and categorizing agricultural produce. While conventional manual inspection relied heavily on human expertise, it was time-consuming and lacked efficiency. In contrast, computer vision approaches have emerged as a precise and effective solution for this sector.

The innovative fusion of deep learning and computer vision techniques to classify and assess the ripeness of fruits and vegetables provides substantial benefits over manual methods. Through the utilization of automated algorithms, this approach facilitates quicker and more consistent evaluations, thereby minimizing errors and subjective interpretations. Deep learning models efficiently process large datasets, leading to improved accuracy and scalability compared to manual approaches. This advanced computational technique not only enhances classification tasks but also allows for real-time implementation in agricultural settings, enhancing productivity and quality control. Tapia-Mendez et al. proposed a deep learning method for fruit and vegetable classification and ripeness assessment, demonstrating its effectiveness in identifying produce types and ripeness levels accurately and highlighting its potential for automating quality evaluation processes [12].

By leveraging deep learning and artificial intelligence, computer vision systems can automatically and accurately analyze and categorize fruits and vegetables, leading to enhanced production speed and reduced human errors. These methods can harness diverse data like color, texture, and size to ensure precise assessments of ripeness and quality.

Manual inspection, on the other hand, involves subjective and nonstandardized assessments, making it susceptible to human error and inefficiencies. With the technological advancements and the progress of artificial intelligence, the adoption of computer vision techniques for fruit and vegetable inspection is viewed as a sustainable and efficient alternative that boosts the effectiveness of classification and evaluation processes within this critical industry.

In the study by Elhariri and colleagues [13], a random forests-based approach was employed for the classification of crop ripeness stages. Additionally, Bhargava and Bansal [14]. conducted a review focusing on the evaluation of fruits and vegetables quality using computer vision techniques. On the other hand, Jana and Parekh [15]. introduced an intra-class recognition method for fruits using color and texture features along with neural classifiers.

These studies collectively highlight diverse methodologies in the domain of fruit and vegetable analysis. Future research endeavors could potentially amalgamate these approaches to enhance the overall accuracy and efficiency in the classification and assessment of fruits and vegetables.

2.3. Key Quality Attributes and Performance Evaluation

The studies reviewed highlight the ability of CV techniques to evaluate various quality attributes of fruits and vegetables. Common attributes assessed include size, shape, color, surface defects, and ripeness. The performance of these techniques is typically evaluated using metrics like accuracy, precision, recall, and F1-score. While studies report encouraging results, there is still room for improvement in terms of generalizability and robustness to variations in lighting, image quality, and fruit/vegetable varieties.

Key quality attributes play a critical role in the evaluation of fruits and vegetables, impacting their market value, consumer acceptance, and overall utility. Various studies have focused on different aspects of quality assessment using advanced technological approaches. [2]. utilized a computer vision system for quality evaluation in fresh and packaged fruits and vegetables, emphasizing visual appearance as a key attribute. [3]. employed sorting and grading techniques based on computer vision and image processing to assess key attributes related to arecanut quality. Additionally, [4]. work on shape-based recognition and fractal analysis contributed to understanding the intricate details of fruit and vegetable characteristics.

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Performance evaluation in these research endeavors often incorporated algorithms like deep learning, random forests, and support vector machines, underscoring the efficacy of machine learning in assessing quality metrics. Transfer learning, as outlined in recent studies, has demonstrated potential in refining the precision of fruit and vegetable quality appraisal.[10] These varied methodologies collectively enrich our comprehension of critical quality attributes and deliver actionable insights to enhance the overall assessment of fruits and vegetables across diverse applications. Table (1) encapsulates a synopsis of these methodologies for quality criteria.

Table (1): Synopsis of Methodologies for Quality Criteria Evaluation.

Quality Criteria	Techniques Used	Year	Ref.
Visual appearance	Computer vision systems	2020	[2]
Fruit and vegetable classification	Image processing techniques	2018	[3]
Shape recognition	Shape-based analysis	2019	[4]
Ripeness assessment of fruits and vegetables	Transfer learning techniques	2021	[10]

2.3.1. Evaluation of Vegetable and Fruit Quality using Computer Vision

The evaluation of vegetables and fruits quality is crucial in ensuring consumer satisfaction and maintaining product standards. In recent years, CV techniques have emerged as a promising tool for assessing the quality of vegetables and fruits. This paragraph will discuss the research conducted in this field, with a focus on the utilization of CV for quality evaluation.

Bhargava and Bansal conducted a comprehensive review of the use of computer vision in evaluating the quality of fruits and vegetables. They highlighted the potential of computer vision techniques in assessing various quality attributes such as color, shape, size, texture, and defects. The authors discussed the advantages of using CV, including its non-destructive nature, fast processing capabilities, and objective analysis. Examples of images in the preprocessed dataset are displayed in Figure 1 [8]. Healthy lemons are grouped into the healthy class, while moldy, gangrenous, and those with a dark style remaining are grouped to constitute the unhealthy class.

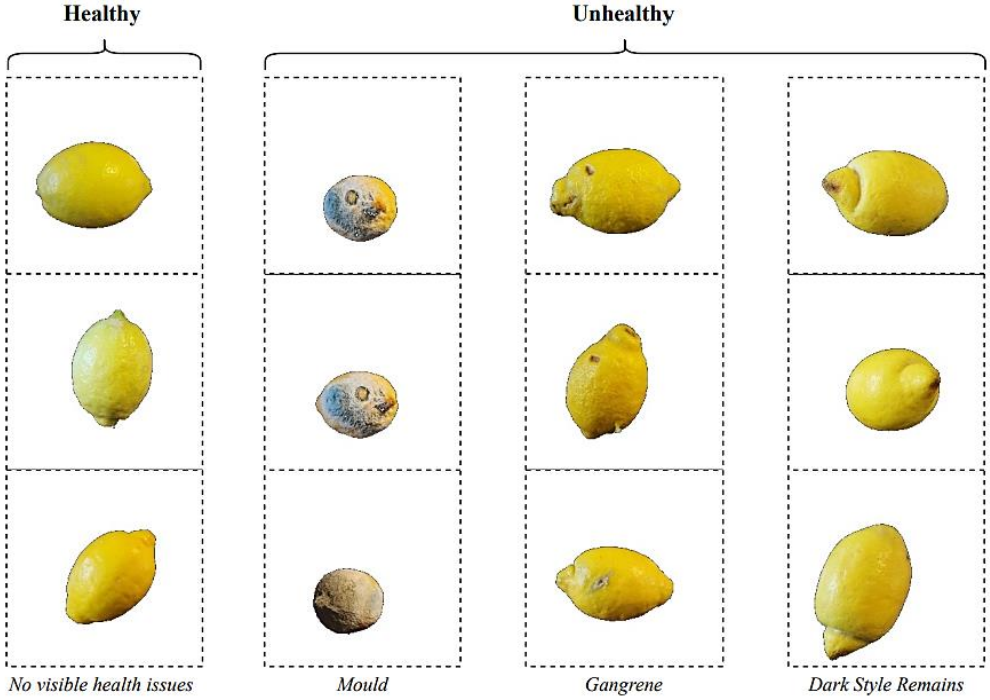

Figure 1: Visualizing healthy and unhealthy lemons within the dataset. Mold, gangrene, and dark spots.

All remaining types are considered unhealthy. The research conducted by these authors demonstrates the potential of computer vision techniques in evaluating the quality of vegetables and fruits. The use of computer vision allows for objective and efficient assessment, enabling producers and retailers to ensure consistent quality standards. Furthermore, the non-destructive nature of CV techniques minimizes product waste and reduces manual labor. Overall, the evaluation of fruit and vegetable quality using CV holds great promise for the industry, leading to improved customer satisfaction and increased efficiency in the supply chain.

2.3.1.1 Methods used in previous studies in the techniques of assessing and classifying the quality of vegetables and fruits:

CV techniques involve extracting meaningful information from digital images or videos. This method is extensively used for tasks like fruit quality evaluation, defect detection, and classification based on visual attributes.

Image processing encompasses operations on images to enhance them for analysis. This includes preprocessing steps like noise reduction, segmentation, feature extraction, and classification using algorithms tailored for image data.

Fractal analysis involves measuring the complexity of shapes in images. It is used for characterizing irregular and complex geometries, such as those found in fruits and vegetables, to aid in their classification based on structural features.

Machine learning algorithms are used for pattern recognition, classification, and prediction tasks based on input data. Techniques like k-Nearest Neighbors (k-NN), Support Vector Machines (SVM), and Deep Learning are commonly employed for fruit and vegetable classification.

Transfer learning involves leveraging pre-trained models on large datasets to improve learning on smaller, specific datasets. This method is beneficial when limited annotated data is available for training new classification models.

Deep learning utilizes neural networks with multiple layers to automatically learn features from data. Convolutional Neural Networks (CNNs) are popular in fruit and vegetable classification tasks due to their ability to extract hierarchical features from images.

2.3.1.2 Data Acquisition

Advancements in computer vision have revolutionized the way we perceive and interact with the world around us. In the agricultural sector, the integration of computer vision techniques holds immense potential for optimizing processes like fruit and vegetable grading and sorting. This section delves into the pivotal role of data acquisition in enabling the successful application of computer vision technologies in this domain.

In the realm of computer vision applications, the acquisition of data is a fundamental aspect that underpins the efficacy of subsequent analysis and decision-making processes. The process of data acquisition typically unfolds through a series of structured steps:

- **Data Collection:** The initial phase of data acquisition involves the systematic gathering of a diverse and representative dataset that correlates with the specific objectives of the computer vision application at hand. This dataset serves as the foundation upon which the algorithms will be trained and validated.

Data can be sourced through various channels and methods, encompassing a spectrum of techniques such as:

- **Raw Data Collection:** This step involves gathering images or videos that will be analyzed, which can be captured from mounted cameras or specialized sensors.
- **Data Labeling:** Images are annotated with labels assigning a category or description to each image for training computer vision models.
- **Data Cleaning:** Data may require cleaning to remove unwanted or corrupted data.
- **Data Splitting:** Data is divided into training, validation, and testing sets to measure the performance of computer vision models.
- **Data Augmentation:** Data augmentation involves applying simple transformations like image rotations or changes in lighting to provide models with more diversity.
- **Selecting Relevant Data:** It is crucial to choose data that effectively represents the problem the computer vision system is trying to solve [7].

These steps are essential in preparing data appropriately for use in computer vision applications. Each step contributes to the quality and effectiveness of the computer vision models developed for various tasks. There are two ways to get data that we can use in CV techniques.

- **Using ready-made datasets**

Utilize online databases like CUI, Roboflow, Kaggle, etc., which offer pre-collected datasets with labeled images for various computer vision tasks such

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as object detection, classification, or segmentation. These datasets are professionally organized, saving time and providing a diverse range of images. However, they may not always align perfectly with specific requirements, so reviewing licensing terms is crucial.

The data preparation process for computer vision involves several key steps to ensure effective model training and accurate real-world execution:

- Normalization Standardize data to have a mean of 0 and a standard deviation of 1.
- Noise Removal Eliminate unwanted noise or artifacts from the data.
- Annotation Annotate data by labeling images with the correct classes or attributes for the model to learn. Annotations can involve:
- Bounding Boxes Drawing boxes around objects in images.
- Segmentation Masks Labeling each pixel with the corresponding object class.
- Key Points Identifying specific points of interest in images.
- Augmentation Increase the training dataset size artificially through transformations to enhance model generalization. Techniques include:
- Rotation: Rotate images by a specified angle.

  Flip mirror images horizontally or vertically.
- Noise Addition Introduce random noise to images.
- Data Splitting Divide the dataset into training, validation, and testing sets. Training data is used for model training, the validation set tunes hyperparameters, and the testing set evaluates model performance on unseen data.

➢ **Setting up your dataset**

This section provides instructions on preparing the data set that researchers prepare, i.e., taking pictures and not ready-made data. Before diving into data analysis, it is important to properly prepare the dataset being captured by the camera. Ensuring that data is well organized and captured under ideal conditions is essential for accurate analysis and model performance. Following these guidelines will help create a solid foundation for your data preparation process. The following points need basic requirements to obtain high-quality images.

Manual data collection is physically taking pictures or videos of objects of interest using cameras or sensors. Here are several points to consider:

- Camera specifications include high resolution (e.g., 4K or higher) for clarity, good low-light performance, fast autofocus, and the ability to manually control settings such as aperture, shutter speed, and ISO. An example of a camera meeting these criteria is some other cameras that meet these specifications include:
- Sony Alpha a7S III: Offers high resolution, good low-light performance, fast autofocus, and manual control over settings.
- Canon EOS R5: Known for high resolution and excellent low-light performance, featuring a fast and accurate autofocus system along with manual control capabilities.
- Nikon Z7 II: Provides high resolution, good low-light performance, fast autofocus, and manual control over settings.
- Hyperspectral Image Data:

Spectral data were obtained through a custom push-broom Hyperspectral Imaging (HSI) system, comprising a monochrome camera, imaging spectrograph, halogen lamps, a computer setup with specific hardware, and a motorized sample table. Acquisition involved a LabVIEW software GUI program and calibration using black-and-white references for relative reflectance determination [3].

2. Lighting Requirements:

- Consistent lighting to reduce shadows and ensure even illumination
- Use of soft boxes or diffusers to create soft, even light - Consider using multiple light sources to eliminate shadows. - Color temperature consistency for accurate color representation.

3. Distance Considerations:

- Maintain a consistent distance between the camera and the subject.
- Use markers or a fixed setup to ensure repeatability - Consider using a tripod for stability and consistency.

4. Shooting Setup:

- A dedicated area with controlled lighting - Backdrop or consistent background - Camera mounted on a tripod - Lighting equipment positioned strategically - Subject placement area clearly marked

5. Additional Considerations:

- Capture images from multiple angles if required - Include various environmental conditions if relevant to your project - Ensure proper focus and exposure for each shot - Consider capturing metadata (e.g., camera settings, time, date) for each image.

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6. Post-Processing:

- Organize and label the images systematically - Perform any necessary cropping, resizing, or color correction - Ensure consistent file formats and naming conventions.

The photo is taken using a smartphone camera without a flashlight to reduce shadows or a digital camera. Pictures of the samples are shown in Figure 3[7].

Figure. 3: Images from the created dataset.

2.4. Utilizing Computer Vision for Enhanced Efficiency in Fruit and Vegetable Sorting:

In the realm of agricultural processing, the utilization of computer vision technologies has emerged as a transformative tool for enhancing efficiency in the sorting of fruits and vegetables. By harnessing the power of machine learning algorithms and advanced image processing techniques, computer vision systems can automate the sorting process with unprecedented accuracy and speed. This innovative approach not only streamlines operations but also minimizes human error, reduces waste, and improves overall productivity in the agricultural sector. In this context, the integration of computer vision holds the promise of revolutionizing traditional sorting methods, paving the way for enhanced quality control and increased efficiency in fruit and vegetable processing industries.

A survey of the research on classifying and grading fruits and vegetables using computer vision techniques [3].

Talk about the significance of automating grading and sorting procedures to increase productivity and efficiency.

Analyzing fruit detection and classification systems based on shape as an illustration of computer vision application [4].

Vegetables and fruits can be sorted and graded using a variety of CV and image processing techniques. To increase efficiency and accuracy, researchers have created a variety of algorithms and techniques to automate the sorting and grading process.

For example, Chithra et al. suggested a fruit classification system based on image processing methods. They distinguished between various fruit varieties using characteristics including color, shape, and texture. The results of the study showed how well computer vision could classify fruits.

presented a method for categorizing vegetables and fruits using fractal analysis. In order to categorize the photos of vegetables and fruits, the researchers examined their fractal dimensions. This technique offered a dependable and effective approach to tell fruits from veggies [5].

In another study, Bird et al. utilized conditional GAN (Generative Adversarial Networks) data augmentation for fruit quality and defect image classification. The researchers used deep learning techniques to enhance the accuracy of fruit quality assessment [8].

These studies highlight the potential of CV and image processing techniques in sorting and grading vegetables and fruits. By automating the classification process, these methods can save time and resources while ensuring accurate sorting and grading results.

3. ADVANTAGES OF COMPUTER VISION

1. Automation CV enables automation in various industries, including agriculture, food production, and quality control. It allows for the development of systems that can perform tasks such as fruit classification, maturity assessment, and quality inspection without human intervention. [23], [24], [25], and [26].

2. Speed and Efficiency CV algorithms can process large amounts of visual data quickly and efficiently. This speed enables real-time or near-real-time analysis and decision-making, leading to improved productivity and operational efficiency [23], [28].

Accuracy and Consistency CV systems can achieve high levels of accuracy and consistency in their classifications and assessments. They are not prone to human errors and biases, resulting in reliable and objective results [23], [26].

Non-Destructive Testing: CV techniques are non-destructive, meaning they can assess the quality, ripeness, or maturity of vegetables and fruits without causing any physical damage. This is particularly important in industries where the produce needs to remain intact for further processing or sale [24].

Scalability: CV systems can be easily scaled up or down to handle different volumes and types of vegetables and fruits. They can adapt to changing production demands and accommodate variations in size, shape, and appearance [23], [25].

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4. DISADVANTAGES OF COMPUTER VISION

1. Complexity and variability vegetables and fruits naturally vary in size, shape, color, and texture, which makes classifying them difficult. Produce that deviates from the usual range or has complex traits may be difficult for CV systems to classify correctly [23, 26, 29].
2. Sensitivity to environmental elements such as reflections, shadows, and illumination can affect computer vision systems. Changes in these variables may have an effect on how reliable and accurate the classification findings are [23, 27].
3. Training Data Requirements: a sizable and varied dataset is frequently needed for training in order to develop accurate computer vision models. Such datasets can require a lot of work and effort to gather and annotate [23, 29].
4. Algorithm Development and Selection: Selecting the best CV algorithm and creating unique solutions applications can be difficult tasks that call for knowledge of machine learning and computer vision methods.
5. Maintenance and System Integration: to guarantee precise and reliable operation, computer vision systems need to undergo routine maintenance, which includes calibration. There may be difficulties integrating these systems into the manufacturing or processing workflows that are currently in place [23].

5. RESULTS

In terms of application, technology, and data, the additional research papers can be summarized as follows:

The study by Mandal et al. covers algorithms in machine learning models, potentially including techniques for categorizing vegetables and fruits. Various machine learning methods and datasets related to fruit and vegetable quality are likely utilized in this research [11].

It was suggested by Tapia Méndez et al. A deep learning-based method to classify and evaluate the ripeness of vegetables and fruits [12]. The research will likely include the use of deep learning models and image data for classification and maturity assessment purposes.

present Elhariri et al. a random forests-based classification technique for crop ripening stages. For classifying ripeness, the research may employ random forest algorithms and visual data [13].

The study by Jana and Parekh focuses on intra-class fruit recognition using neural classifiers and color and texture features. It is expected that color and texture features from fruit photos will be extracted for recognition purposes using neural classifiers [15].

Discussing the key issues and countermeasures of machine vision for vegetable and fruit-picking robots by Xin et al. likely involves exploring the application of machine vision techniques in the context of harvesting produce. The study probably addresses challenges and solutions pertaining to the use of machine vision in automating the picking process for fruits and vegetables [16].

A support vector machine-based technique for classifying the maturity of bell peppers is presented by Elhariri et al. In order to classify ripeness, support vector machine techniques and visual data may be applied in this study [17].

Tao et al. discuss the utilization of text mining as a big data analysis tool in food science and nutrition. Although not directly related to computer vision, this research underscores the use of data analysis techniques in the fields of food science and nutrition.

An Android app for automatically identifying fruits and vegetables using computer vision and machine learning is presented by Appadoo et al. The research probably entails creating an app that identifies fruits and vegetables using machine learning algorithms and computer vision techniques [19].

In their work, Zhou et al. explore the examination of fruit fly regurgitation through the application of deep learning and computer vision techniques. While distinct from fruit and vegetable grading, this research underscores the utilization of computer vision methods in studying biological processes [20]. Gom-os proposes the utilization of colorized depth images for fruit classification. This study likely employs image processing techniques and depth imaging to categorize fruit [21].

Asadi et al. forecast quality characteristics linked to distinct geographic cultivation areas in red-fleshed kiwifruit by combining data from electronic noses and computer vision systems. This study probably integrates information from both electronic nose and computer vision systems to predict quality attributes [22].

Wang et al. introduce a cross-domain fruit classification approach founded on lightweight attention networks and unsupervised domain adaptation. This study probably employs deep learning models and techniques for cross-domain fruit classification [23].

Anjali et al. explore non-destructive methods for determining the maturity index in fruits and vegetables. The study is expected to encompass a range of non-invasive techniques and data pertinent to assessing the maturity of fruits and vegetables [24].

In this study, Elhariri et al. introduced a random forests-based classification method for determining the

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ripeness stages of crops. This research, akin to paper 13, likely involved utilizing image data and applying random forests algorithms for ripeness classification. [26].

These additional research papers cover a wide range of topics related to fruit and vegetable grading, classification, ripeness assessment, and maturity index determination. They utilize various CV techniques, machine learning algorithms, and data types such as image data, depth data, and data fusion from different sensing systems.

The research review by Balderas-Silva et al. provides a comprehensive overview of using computer vision and machine learning for plant disease detection in agricultural monitoring. The authors discuss current methods and highlight the benefits of these techniques for accurate disease identification. However, the review would have been more valuable with specific examples and case studies demonstrating the practical application of these methods in real agricultural settings [27].

The research paper by Ni et al. focuses on monitoring the change process of banana freshness using GoogLeNet, a deep convolutional neural network. The authors propose a method based on image analysis to track the freshness level of bananas. The paper demonstrates the effectiveness of their approach in accurately determining the freshness level. However, it would have been beneficial if the authors had provided more details on the dataset used and the performance metrics of their proposed method. Additionally, exploring the applicability of their approach to other fruits or perishable items would have added further value to the research [28].

Hameed et al.'s comprehensive review discusses various techniques for fruit and vegetable classification. The paper covers a wide range of classification methods, including traditional image processing algorithms and machine learning approaches. The authors highlight the challenges and limitations of existing methods and provide insights into the latest advancements in this field. The review serves as a valuable resource for researchers and practitioners in fruit and vegetable classification. However, it would have been advantageous if the paper had discussed the limitations and potential biases of the selected techniques, as well as suggestions for future research directions [29]. The results summary of computer vision techniques on fruits and vegetables was shown in Table (2).

Table (2): Summary of computer vision techniques on fruits and vegetables.

Ref	Target	data	technology	Accuracy
[11]	classification	1656 images of fruits and vegetable	Naive Bayes	98.33%
[12]	classification and ripeness	32 classes of fruits and vegetable	MobileNet V2	100%
[13]	classification and ripeness	tomato and bell pepper 250 and 175 images	random forests& SVM	-
[15]	recognition of fruits by combining color and texture features	270 fruit images	Neural Network (NN)	-
[17]	Ripeness Classification	bell pepper 175 images	Support Vector Machine	93.89%
[19]	automatically identify fruits and vegetables	1600 images from fruits and vegetables	machine learning classifies	90.6%
[20]	fruit fly detection and tracking	100 video clips 200 images	Yolov5 and Deep Sort	99.8%
[21]	classification	apples and oranges mangoes and bananas	CNN models(AlexNet, GoogleNet, ResNet101, and VGG16)	96%
[22]	classification the quality	kiwifruits	SVM algorithm& SVR	100% 90.17%
[23]	classification	Grape	deep learning-based	95.0% and 93.2%
[26]	classification and ripeness	Tomato 175 images and 55 images	Support Vector Machine (SVM)	92.72%
[28]	classification fruit quality	Banana	transfer learning and established	98.92%
[31]	Evaluated ripeness stages of achacha fruits using spectral data; investigated the impact of fruit surface curvature.	the wavelength range of 400–780 nm for evaluating the ripeness stages of achacha fruits.	Used both classification models (SVM, PLS-DA, ANN, KNN) and regression models (PLSR, SVR) for ripeness stage prediction.	Ranged from 52.25% to 79.75% with the SVM model achieving the highest accuracy at 79.75%.

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Summary of various CV techniques used in vegetable and fruit analysis. These techniques include classification, ripeness detection, and quality assessment. The accuracy of these methods ranges from 90.6% to 100%, depending on the specific algorithm or model used and the target fruit or vegetable. One common approach in these studies is the use of machine learning algorithms such as Naive Bayes, random forests, SVM, and neural networks. These algorithms leverage features extracted from images, such as color, texture, and shape, to classify fruits and vegetables accurately. Transfer learning, where pre-trained models are fine-tuned on specific datasets, is also employed in some studies, demonstrating its effectiveness in achieving high accuracy.

The influence of fruit and vegetable morphology, dimensions, orientations, and positioning on image clarity and classification precision has been a focal point in recent research. Findings from these investigations suggest that the shape of the fruit significantly impacts the precision and quality of image categorization. For example, the spherical nature of fruits like apples, oranges, and tomatoes facilitates clear image capture, thereby enhancing accuracy. In contrast, the curved structure of bananas and the small sizes of olives, dates, and leafy vegetables can pose challenges for achieving clear images, consequently impacting classification accuracy [30].

The review also highlights the use of deep learning models, such as CNNs, in fruit and vegetable analysis. These models have shown promising results in classification tasks, achieving accuracies ranging from 96% to 100%. The use of CNNs allows for the extraction of hierarchical features, enabling more robust and accurate classification.

Additionally, the review discusses the application of CV techniques in detecting fruit fly infestation, which is crucial for ensuring the safety and quality of fruits. The use of object detection models, such as Yolov5, combined with tracking algorithms like Deep Sort, has proven effective in fruit fly detection and tracking, achieving an accuracy of 99.8%.

It's crucial to take into account these CV techniques' limitations, even with the encouraging outcomes. Occlusions, changes in fruit and vegetable look, and lighting conditions are a few examples of factors that can affect how accurate the models are. To overcome these obstacles and create more durable and dependable computer vision systems for fruit and vegetable inspection, more research is required. Notably, many of these constraints are still being addressed by developments in machine learning methods, hardware technologies, and computer vision algorithms. The goal of ongoing research and development is to increase computer vision systems' robustness, accuracy, and usefulness for classification of fruits and vegetables, among other applications.

Research Gaps in Computer Vision for Fruit and Vegetable Quality Assessment While the reviewed studies provide valuable insights into the potential of computer vision (CV) for assessing fruit and vegetable quality, several significant research gaps require attention. Addressing these gaps can lead to the development of more robust, generalizable, and practical CV systems for fruit and vegetable quality assessment, ultimately enhancing efficiency, food safety, and sustainability in the agricultural sector. Below is a summarized table outlining these research gaps:

Table (3): Research Gaps in Computer Vision for Fruit and Vegetable Quality Assessment.

Research Gap	Description
Data Variability	Studies often focus on a limited range of fruits and vegetables, lacking diversity in types, shapes, sizes, and colors. Developing robust models capable of handling a broader variety of produce is essential.
Model Generalizability	Models trained on specific datasets may struggle to generalize to new data, highlighting the need for techniques to prevent overfitting and improve model interpretability.
Integration with Applications	Many studies concentrate on offline analysis, calling for the development of real-time computer vision systems for seamless integration into sorting and grading lines. Considerations such as hardware deployment in agricultural settings and integration with existing infrastructure in packing houses and farms need to be addressed.
Additional Exploration Areas	Further exploration opportunities include combining computer vision with other sensing technologies for a comprehensive quality assessment, developing non-destructive techniques for evaluating internal quality attributes, enhancing defect detection for improved quality control, and establishing standardized protocols and evaluation metrics to facilitate comparison and advancement in computer vision applications within the agricultural sector.

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6. CONCLUSION

In conclusion, the application of CV techniques for the quality and safety inspection of vegetables and fruits holds great potential. Through the evaluation of vegetable and fruit quality, sorting and grading, classification, and volume estimation, CV systems can enhance the efficiency and accuracy of inspection processes in the agricultural industry. The findings from these studies contribute to the development of more efficient and automated systems for ensuring the quality and safety of vegetables and fruits. Finally, the review demonstrates the potential of computer vision technologies in enhancing the quality and safety inspection of vegetables and fruits. These techniques provide accurate and objective assessment, improved efficiency and cost savings. However, more research is needed to address the limitations and challenges associated with these technologies to ensure their widespread practical application in industry.

6.1. Challenges and Future Directions

As the research delves into optimizing quality control through a thorough examination of computer vision methods for assessing vegetables and fruits, several challenges and future directions emerge. The implementation of computer vision techniques for quality assessment in agricultural produce faces hurdles such as scalability, adaptability to diverse produce types, and real-time processing requirements. Additionally, ensuring the robustness and reliability of these systems across varying environmental conditions poses a significant challenge.

Looking ahead, future directions in this field involve enhancing the interpretability of computer vision models, integrating multi-sensor data fusion for improved accuracy, and developing more sophisticated algorithms for anomaly detection and quality prediction. Addressing these challenges and exploring these promising directions will be crucial for advancing the application of computer vision in optimizing quality control processes for vegetables and fruits, ultimately contributing to more efficient and reliable food inspection systems.

7. CONTRIBUTIONS

This paper provides an extensive review of the application of CV techniques for quality and safety inspection of vegetables and fruits. It consolidates the existing literature, emphasizing advancements, challenges, and prospective solutions in this domain. The evaluation encompasses various CV techniques, including image processing, deep learning, and machine learning algorithms assessing their efficacy in detecting defects, classifying produce, and identifying contaminants. Performance analysis delves into the accuracy, speed, and scalability of different CV systems, considering factors like lighting conditions, image acquisition, and feature extraction. Novel approaches and emerging trends in CV for fruit and vegetable inspection are presented, exploring hyperspectral imaging, 3D reconstruction, and multisensor fusion techniques to enhance inspection accuracy and reliability. Challenges in implementing computer vision systems for quality and safety inspection are identified, with discussions on solutions such as data augmentation, transfer learning, and domain adaptation to bolster algorithm robustness. The practical applications of computer vision techniques in the fruit and vegetable industry are underscored, illustrating their role in sorting, grading, and packaging processes to ensure elevated quality and safety standards across the supply chain. Future research directions are outlined, pointing towards the integration of Internet of Things (IoT), robotics, and automation technologies to forge intelligent and efficient inspection systems.

This paragraph can be summarized into points explaining strategies for enhancing agricultural quality assessment using computer vision techniques to address the limitations identified in the reviewed studies in the field of agricultural quality assessment using computer vision and image processing techniques. Several strategies can be considered:

- Enhanced Data Collection: Gather comprehensive datasets reflecting various fruit and vegetable characteristics like shapes, sizes, colors, and defects to enhance model robustness and generalizability.
- Algorithm Optimization: Continuously refine algorithms for improved accuracy and efficiency by adjusting parameters, exploring diverse model architectures, and incorporating advanced machine learning techniques.
- Feature Engineering: Develop new features or enhance existing ones to better represent the unique attributes of different produce types, crucial for enhancing classification accuracy and quality assessment.
- Cross-Validation and Validation Techniques: Implement rigorous cross-validation methods to ensure model reliability and prevent overfitting, with separate test datasets validating model generalizability.
- Integration of Sensor Technologies: Explore integrating additional sensor technologies like hyperspectral imaging to gather more information on produce quality, enhancing classification accuracy through data fusion.

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- Error Analysis and Feedback Loop: Conduct thorough error analysis to pinpoint common misclassifications and model shortcomings, utilizing feedback to iteratively enhance algorithms and tackle specific challenges.
- Interdisciplinary Collaboration: Foster collaboration among agriculture, computer vision, machine learning, and domain-specific experts to leverage diverse perspectives for innovative solutions.
- Real-Time Monitoring and Adaptive Systems: Develop adaptive real-time monitoring systems to adjust to changing environmental conditions and produce quality variations, facilitating continuous learning and performance improvement.

This review has served to highlight the latest developments in CV quality assessment of fruits and vegetables. By understanding current capabilities and limitations, we can pave the way for developing more effective and practical quality control systems. Ultimately, this progress can contribute to the creation of a more sustainable and efficient agricultural sector, ensuring a safe and healthy food supply for future generations and development in the field of agriculture in Libya to increase the economy and maintain food security.

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ABBREVIATIONS AND ACRONYMS

Here are the abbreviations and acronyms used in the provided references:

SVM: Support Vector Machine

CV: Computer Vision

IPA: Information Processing in Agriculture

CNN: Convolutional Neural Network

NN: Neural Network

GAN: Generative Adversarial Networks

PLS-DA: Partial Least Squares Discriminant Analysis

ANN: Artificial Neural Network

KNN: K-Nearest Neighbors

PLSR: Partial Least Squares Regression

SVR: Support Vector Regression

YOLOv5: You Only Look Once version 5

Deep SORT: Deep Simple Online and Realtime Tracking

AlexNet: Alex Krizhevsky Network

GoogleNet: Google Network

ResNet101: Residual Network with 101 Layers

VGG16: Visual Geometry Group 16 Layers

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Implementation of Statistical Control Processes in Benghazi's Food Industry

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ABSTRACT

Quality control is a crucial aspect of any organization aiming to reach a high-quality level by providing products or services that satisfy customer needs. Control charts are among the most effective tools used to detect the occurrence of defects in the manufacturing process so they can be fixed before being delivered to the customers. This paper aims to assess the filling machine's performance in the Al-WAHA factory. In this investigation, a control chart and process capacity were implemented. Comprehensive details on the control chart and process capacity are discussed, along with an overview of the literature on related subjects. 33 samples of 800-gram jars' worth of data were examined. The metrics for performance were computed. Through the control charts S and X, it was found that there were ten out-of-control samples in the mean chart (3, 4, 6, 7, 8, 10, 21, 23, 32, 33) and one observation in the variance chart (30) due to assignable reasons. After excluding the samples that caused the variance in the mean chart, the control charts. Both the S and X charts are within the control limits. Filling process capacity = 0.59, the process is unable to meet the specifications, and about 23.48% of the fillings are above 810 grams and 1.51% are below 790 grams. The CPK value describes the process as decentralized.

KEYWORDS: Quality Control, Statistical Process Control, Food Industry.

1. INTRODUCTION

In the fields of manufacturing, distribution, transportation, finance, health, and public services, control and improvement are among the most crucial business strategies. A company can gain a competitive edge by improving quality and control, which will enable it to satisfy customers and remain competitive [1]. Achieving company business objectives requires maintaining high levels of quality. Company products and services should continue to be characterized by quality, which serves as a competitive advantage. High quality is not merely an extra benefit but rather a fundamental necessity. Quality is not only related to the final products and services provided by the company but also to the way the company's employees perform their work and the work methods aimed at producing the results. or services. Work processes must be efficient and continuously improved. Every employee in all organizational units is responsible for ensuring excellence and continuous improvement in their area of responsibility. Quality control (QC) is the most important requirement for sustainable quality. QC, essential to maintaining quality and updating expectations, can be broadly defined as a system that maintains the desired level of quality through feedback on product/service characteristics of the specified standard [2].

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Statistical process control, or SPC, is a monitoring and control approach that makes use of statistical methods to make sure a process works as efficiently as possible in order to provide a product that complies with specifications. A process that operates consistently and yields the most compliant output with the least amount of waste is referred to as SPC. Design experiments, control charts, and continuous improvement are important SPC techniques [3]. It is possible to identify and correct process variations that could compromise the final product's quality, cutting down on waste and the possibility of customer issues. SPC provides a clear benefit over other quality processes, like inspection, which depend on resources to find and fix issues after they have occurred [4]. This is because SPC places an emphasis on early problem identification and prevention. Process quality encompasses the whole approach that companies use to implement their quality system. The aim of process quality is to ensure that every process is designed with the quality philosophy in mind, which is ensured by putting such measures into place [5]. Walter A. Shewhart introduced control charts, a technically intricate instrument for quality management, to Bell Telephone Laboratories in the 1920s. They distinguish between statistically controlled scenarios (both inside and outside of UCL and LCL) and out-of-control scenarios (beyond UCL or below LCL) by demonstrating how a process develops over time. Control charts are crucial for monitoring processes and identifying the underlying causes of quality issues in order to reduce variability and prevent mistakes [6]. Numerous quality metrics have been suggested to assess

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the performance of processes. In recent years, one of the most well-liked and often applied metrics for evaluating process performance has been process capability indices, or PCIs. A process's ability to produce conforming goods under engineering specification limitations (SLs) is assessed using PCIs [7]. Process capacity, as established by the system of common causes, is the range within which the process's natural variation takes place. People, equipment, processes, materials, and measurements all work together to create products that reliably fulfill design requirements. If the process is in a statistically controlled condition and all exceptional reasons have been ruled out, then the process capacity may be quantified. For production engineers as well as product designers, process competency is crucial. A process capacity study enables one to make quantitative predictions about how well a process will function under particular operating circumstances in order to produce detailed information about the process's performance [8].

In this study, machine changes in jam production were measured using statistical control. Food manufacturing and processing facilities are increasingly utilizing affordable automation technologies in place of more conventional techniques in order to boost production capacity. There might not be many modifications to the automobile because of this engine. In one of the UUM restaurants, the study by Lai Jian Wei et al. looks at statistical control (SPC) as an improvement method. The SPC tool is being used in this study to determine how long students must wait to place food orders at the SME Cafe. The three goals of this study are to ascertain how long students wait for meals, compute the upper and lower control limits, and estimate the processing capacity of Inasis SME Cafe. The total number of students in the student body who have lunch at the SME Cafe, UUM, yields 500 data points for this study. The x and R chart is the data analysis technique employed in this investigation. Results pertaining to the study's declared research goals are given. The outcome of the students' meal wait time at the SMB café is displayed. The period of cooking as determined by the control law design will be displayed in the study's findings [9]. The purpose of this study is to propose a systematic review program by Sarina Abdul Halim et al. to investigate frequent issues that arise from the application of statistical process control (SPC) in the food sector. From four databases, a total of 41 journal papers were carefully chosen and examined. When using SPC in the food business, advantages are the most frequently discussed subjects; incentive, prevention, and key success factors (CSF) are the remaining issues. This evaluation demonstrated the effectiveness of the SPC implementation suggestions for the food business, however, the absence of information and instructions about this implementation has resulted in a decrease in withdrawal. Additionally, a critical evaluation of the current SPC frameworks is provided in this research. In order to systematically manage SPC distribution in the food business, this systematic study indicated that more research is necessary in the SPC distribution sector. One solution to that issue has been suggested: the creation of useful and efficient guidelines to support food manufacturers in using SPC [10]. Control charts and process capacity ratios—two statistical control (SPC) tools—are used in this work by Omar Batina et al. for quality control and improvement. R and Cumulative Sum (CUSUM) control charts are often utilized. The so-called process capacity index (PCI) is the process capacity ratio that is employed. The statistical application Minitab is used to implement these techniques. The effectiveness of gelatin capsules has been examined in this study with regard to the caliber of capsules produced and supplied by various pharmaceutical businesses. The number of faulty capsules was predicted to decrease by 29% as a result of the use of SPC tools in comparison to the previous period of implementation [11]. Madanhire et al. (2016) conducted research on statistical control tools in production systems with the overall objective of modernizing them to increase quality and save costs. This is an effort to rectify the documentation's shortcomings regarding the SPC implementation. SPC has been proven to be highly advantageous to quality procedures like final product inspection because of its emphasis on issue prevention and early identification. It is important to inspect gauges and machinery to ascertain whether they require maintenance or replacement, as malfunctioning equipment is unable to generate high-quality output. It is necessary to write new papers, train managers, and complete activities that will benefit the future. Financial resources should not come before a mechanism for tracking progress and performance results [12]. The following study explains quality control and the role that plays in the food sector, applying statistical control process techniques into practice, determining the reasons behind variance and the origins of subpar performance, and offering various remedies for the existing situation in order to enhance the factory's overall process and evaluate how the process behaves right now. The present study data and results are limited to the EL-WAHA food company. The factory was selected because it's one of the largest factories with thousands of customers every year it has become one of the leading factories in food with different products and production lines; therefore, the process in the factory should be evaluated for suggesting improvements.

2. METHODOLOGY

The jam production process is carried out in the Al-WAHA Factory for Food Industries in different sizes

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250,350 and 800 grams and different fruits such as (strawberries, oranges, and figs) in the Al-WAHA Factory in the Kweifieh Benghazi, Libya, in several steps:

1. How to prepare fruit?
2. Mash the fruit, remove the seeds, and peel it.
3. The fruit pieces turn into juice after the mashing process.
4. The process of heating the juice and combining the sugar and pectin.
5. How to transfer the jam container to the filling machine (12 pistons)?

The SPC chart for problem-solving methodology is the main framework for executing the implementation of SPC tools; thirty-three observations (each consisting of a total of twelve samples measuring weight in grams) at the EL-WAHA factory. The SPC chart consists of the mean chart (upper and lower control level) and the standard deviation chart (upper and lower control level), offering a well-defined and structured approach for implementation. A variety of tools and techniques have been employed in conjunction with the framework, effectively supplementing the work of identifying problem areas in the earlier phases and the proposal of improvement measures in the concluding phases.

3. RESULTS

Before performing any data analysis and performing the control scheme, it must be ensured that the data follows a normal distribution by performing a normality test using the Minitab 17 Statistical Software. After performing the test, notice that the p-value is 0.096, which means that the data follow a normal distribution. Figure 1 presents normal probability plot of jam filling process.

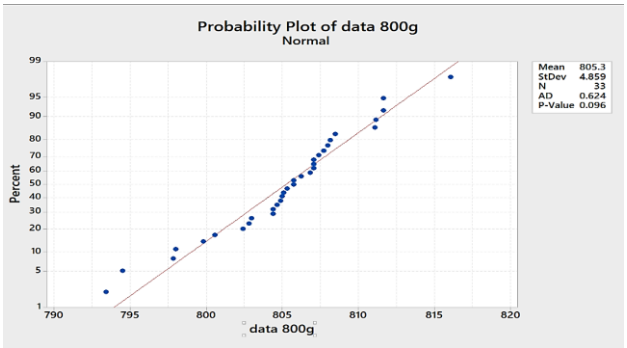

Figure 1. Normal Probability Plot of Jam Filling Process.

3.1 X-chart for Jam Container Weight

This type of control chart is used for characteristics in this study, which are weights that can be measured on a continuous scale. The chart is essential since it helps to monitor the average or mean of the filling process and how it changes over time. It is also used to evaluate whether the filling process is under control or not. Figure 2 shows the X-bar chart for the 33 observations. The control charts show that there are about 10 observations that are out of control (3, 4, 6, 7, 8, 10, 21, 23, 32, 33) due to assignable causes. delete the samples that are out of control and recalculate the S-bar and X-bar control charts.

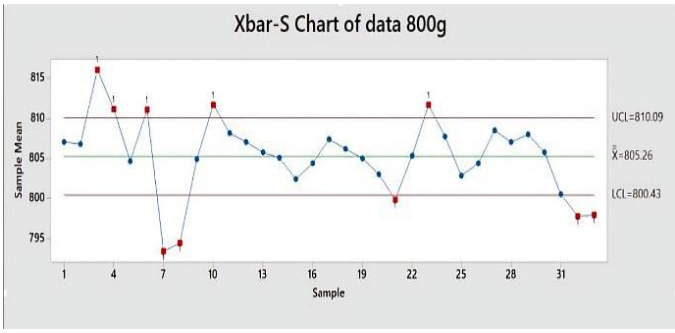

Figure 2. X-bar chart for Jam Filling Process.

The following equations present average or mean of the filling process,

$$CL = \bar{\bar{X}} = \sum_{i=1,k} {}^{\bar{x}}/_{k} \quad (1)$$

$\bar{\bar{X}}$ = 805.26

$$\text{UCL} = \bar{\bar{X}} + A_3 \times \bar{S} \quad (2)$$

UCL=805.26+0.886×5.454=810.092

$$\text{LCL} = \bar{\bar{X}} - A_3 \times \bar{S} \quad (3)$$

LCL = 805.26−0.886×5.454=800.428

Where,

CL is the center line.

$\bar{\bar{X}}$ is the grand mean of all the individual subgroup averages.

$\bar{X}$ is average for each subgroup.

K is the number of subgroups.

UCL is the upper control limit.

LCL is a lower control limit.

A_3 is a coefficient that is determined from tables of statistical constants based on the sample size.

$\bar{S}$ is the standard deviation.

3.2 $\bar{S}$ Chart for Jam Container Weight

The s-chart is used to monitor the variation of the packing process based on samples taken from the factory and Figure 3 shows the S-bar chart that there is a sample outside the control limits.

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The following equations present standards deviation of the filling process,

$$\bar{S} = \frac{\sum_{i=1}^{k} s_i}{k} = 5.454 \quad (4)$$

$$UCL = B_4 \times \bar{S} \quad (5)$$

$$UCL = 1.646 \times 5.454 = 8.980$$

$$LCL = B_3 \times \bar{S} \quad (6)$$

$$LCL = 0.354 \times 5.454 = 1.928$$

where:

$\bar{S}$ is (center line) mean standard deviations of all samples.

S is the standard deviation of the subgroup.

K is the number of subgroups.

UCL, LCL The lower and upper control limits for the s chart.

B_4, B_3 coefficients that are determined from tables of statistical constants based on the sample size.

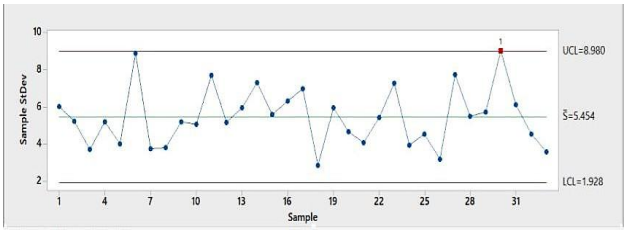

Figure 3. S-bar Chart for Jam Container Weight.

3.3 X-bar Chart for Removed Control Observations

Figure 5.4 shows the X-bar plot after removing the out-of-control sample. This leaves twenty-three observations with twelve samples. On the X-bar chart, there is no indication of a trend, shift, or run observed. Hence, it concludes that the process is under statistical control and operates under the influence of sole causes of variation. That is, the process is stable over time.

$$CL = \bar{\bar{X}} = \sum_{i=1,k} \bar{x}/_k = 18528.33/23 = 805.58 \quad (7)$$

$$UCL = \bar{\bar{X}} + A_3 \times \bar{S} \quad (8)$$

$$UCL = 805.58 + 0.886 \times 5.659 = 810.59$$

$$LCL = \bar{\bar{X}} - A_3 \times \bar{S} \quad (9)$$

$$LCL = 805.58 - 0.886 \times 5.659 = 800.57$$

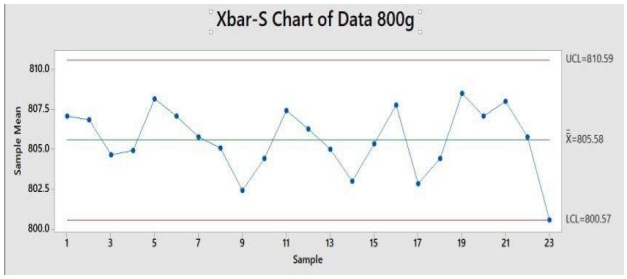

Figure 4. X-Bar Chart for Jam Filling Process.

3.4 $\bar{S}$ Chart for Removed Control Observations

Figure 5.5 shows the standard deviations for each subgroup, as well as, the corresponding centerline and limits. The S chart seems to indicate the variation is in control, as presented in Equation (1.10).

$$\bar{S} = \frac{\sum_{i=1}^{k} s_i}{K} = 5.659 \quad (10)$$

$$UCL = B_4 \times \bar{S} \quad (11)$$

$$UCL = 1.646 \times 5.659 = 9.318$$

$$LCL = B_3 \times \bar{S} \quad (12)$$

$$LCL = 0.354 \times 5.659 = 2.001$$

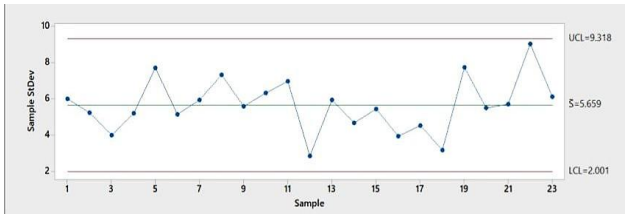

Figure 5. $\bar{S}$ Chart for Jam Container Weight.

3.5 Process Capability

After collecting and analyzing the data using the X-Bar S-chart control, it is now necessary to find out whether the filling process complies with the practical specifications. Therefore, it is necessary to understand the current capability of the system.

$$CP = (USL - LSL) / 6\sigma \quad (13)$$

$$CP = (810 - 790) / 6 * 5.67379 = 0.59$$

$$CPL = (\bar{\bar{X}} - LSL) / 3\sigma \quad (14)$$

$$CPL = (805.26 - 790) / 3 * 5.67379 = 0.8965$$

$$CPU = (USL - \bar{\bar{X}}) / 3\sigma \quad (15)$$

$$CPU = (810 - 805.26) / 3 * 5.67379 = 0.2784$$

$$CPK = \text{Min. of (CPU, CPL)} \quad (16)$$

$$CPK = \text{Min. of } (0.2784, 0.8965) = 0.2784$$

The process is not centralized

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$$\text{CPM} = \frac{cp}{\sqrt{1+(\frac{\bar{\bar{X}}-T}{\sigma})^2}}$$

(17)

$\bar{\bar{X}}$=T=805.26

(18)

$$\text{CPM} = \frac{0.5874}{\sqrt{1+(\frac{805.26-805.26}{5.67379})^2}}=0.5874$$

CP is the process capability index.

USL, LSL The lower and upper specifications limits.

σ is the standard deviation.

$\bar{\bar{X}}$ is mean of the process.

CPL, CPU the lower and upper capability process.

CPK is the process capability index for centering.

CPM is a capability process for the mean target.

CP and CPK are generally referred to as process capability indicators, and they are used to determine the ability of a product to meet specifications.

The current capacity of the filling process is assessed and it can be seen that CP = 0.5874, which indicates that the process is not capable of specification limits. The CPK value describes the process as not centralized. Figure 6 shows the process capacity analysis for the filling process.

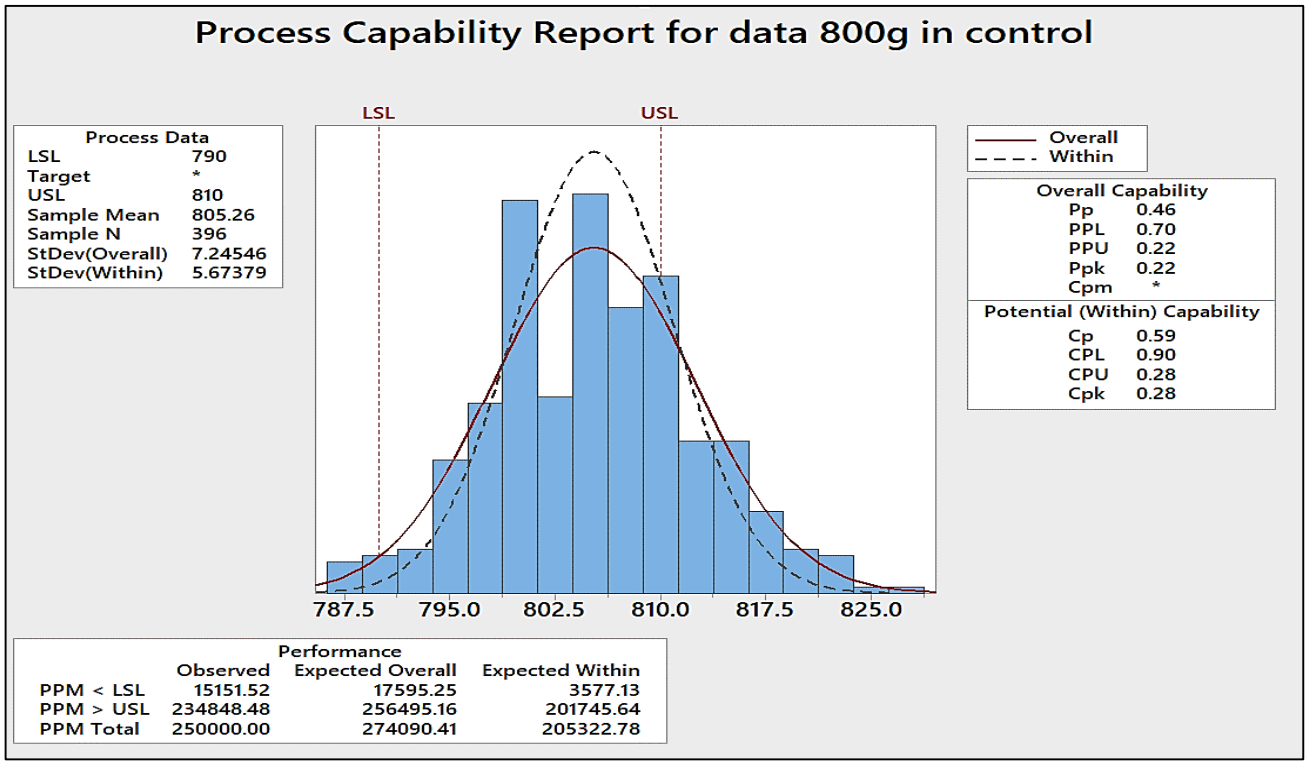

Figure 6. Process Capability Analysis of Filling Process.

To determine the root of the problem a gauge capability analysis should be conducted but due to the limitation of the data difficult to conduct it. The use of gauge capability analysis is to determine if the cause of variation is from operators or machines.

4. CONCLUSION

The objective of this study was to investigate to evaluate the current performance of the jam-filling machine in EL-WAHA. Shewhart control chart methodology was implemented and several recommendations were suggested to improve the efficiency of the production line. Through data collection for 33 random Observations of 800 grams, the calculations relevant to the performance measures, and the analysis of capability methodology, the following conclusions are reached:

Using Shewhart control charts for standard deviation charts indicated the following:

- Initially the process was out of the mean control limits with a mean average of 805.26g.
- Observation numbers 3, 4, 6, 10, and 23 were above the upper limit of 810.9g.
- Observations 7, 8, 21, 32, and 33 outside the lower limit of 800.43g.

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Results from the capability analyses show the following:

- The process wasn't capable of meeting specifications limits that indicate that approximately about 23.48% of the fills are above 810g and 1.51% less than 790g.

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Effect of Polymer Flooding on Oil Recovery Using Reservoir Simulation, Umm-Faroud Field, Sirt Basin, Libya

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ABSTRACT

This work uses Polymer flooding as an Enhanced Oil Recovery (EOR) technique to increase the injected water viscosity to reduce the mobility ratio and improve sweep efficiency. A reservoir model was constructed using the reservoir-simulating method with Computer Modeling Group software (CMGs IMEX) to predict the oil production and water cut from Umm Foroud field, Sirt Basin, Libya. The models are based on data collected from 17 wells from the Umm Foroud field. Off which, five wells were utilized to build the models, while the other 12 wells were used to validate them. Three scenarios were made; the first was used to predict oil recovery with water injection only, with no polymer, the second model to predict oil recovery with polymer flooding of 10% concentration, and the third with polymer flooding of 20% concentration. The viscosity of water increased by two different concentrations of polymers. Results showed that when water viscosity increased, a significant reduction in mobility ratio occurred and hence, the sweep efficiency was improved. Oil production was improved (increased) in the second and third scenarios where the polymer-flooding scenario (10% and 20% polymer solution concentration) was used. However, the water cut was reduced when compared to water injection.

KEYWORDS: EOR, Polymer flooding, CMG software, water injection.

1. INTRODUCTION

In terms of oil recovery, Oil and gas fields can be divided into three distinct phases. Primary, Secondary, and Tertiary /enhanced oil recovery. In the primary stage, oil production from the reservoir occurs because of natural drive mechanisms. When the reservoir pressure is depleted to support the production from the reservoir, secondary oil recovery is applied. For maintaining reservoir pressure, water flooding is used because of its cost-effectiveness and availability of water. Problems such as reservoir heterogeneity, well siting, well spacing, and unfavorable mobility ratio can cause low oil production rates. [1]

Enhanced Oil Recovery (EOR) techniques are expensive and complex; hence, it is recommended to employ EOR only after the primary and secondary oil recovery has been exhausted. In those cases, residual oil cannot be produced because it is uneconomical to extract the remaining oil. [2]

In the tertiary oil recovery stage, about 30-60% of the reservoir's original oil in place can be produced which is good enough compared to primary and secondary recovery stages.[3]

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There are many types of EOR such as chemical flooding, miscible gas flooding, thermal recovery and Microbial EOR [3].

Polymer flooding, alkaline flooding, and surfactant flooding are chemical flooding processes. Surfactants are injected into the reservoir followed by a polymer solution to recover the oil that remains in the reservoir, by reducing the mobility ratio between oil and water, which increases volumetric sweep efficiency. [4]

Surfactants are used to reduce interfacial tension between oil and water. There are many limitations to using chemical flooding such as chemical cost, adsorption and loss of these chemicals in reservoir rock. Chemicals can be injected into injection wells and oil production occurs in other production wells. [4]

The percentage of oil that can be recovered after reservoir depletion is known as the recovery factor. Thus, the oil recovery depends on the recovery factor. The recovery factor magnitude for an oil field depends on geological, physical and economic elements. Around 70% of the reserves remain in the reservoir [5]. Polymer flooding is a very efficient chemical enhanced oil recovery method and has been used since the 1960s. It is widely recognized for its cost-effectiveness and great success in improving oil production. Polymer solutions are used to increase the viscosity of the displacing water which in turn decreases the water/oil mobility ratio, thus oil displacement efficiency is improved [6]. Polymer

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flooding is also used to recover the residual oil effectively from the formation, about 30% of the oil in the reservoir. injection. Polymers are used with water to decrease its mobility by reducing water permeability and increasing its viscosity. [7]

Polymer flooding will not decrease the residual oil saturation, but it is still an efficient way to reach the remaining oil more quickly or/and more economically. [6]

Interfacial tension force between the displacing water phase and the displaced oil phase can be reduced by using surfactants. Wettability altering of the rock surface is also necessary to enhance oil recovery. Polymers are mixed with water and then continuously injected for a period of time. Once 30% of the pore volume has been treated, polymer injection ceases. This decision is usually based on achieving optimal displacement efficiency and reducing the costs associated with continuous polymer usage [7].

Screening criteria for polymer flooding

Salinity and concentration of divalent ions of injected water and reservoir fluids at reservoir temperatures affect the viscosity and stability of polymer solution. The selection of molecular weight is affected by the reservoir permeability range [7]. Table(1) illustrates some of the most important criteria for successful polymer flooding.

Table 1: Screening criteria for polymer flooding [7].

Reservoir temperature (°F)	**<200.**
Crude oil viscosity (cP)	**<200.**
Mobile oil saturation (%PV)	**>10.**
Water-to-oil ratio (WOR)	**<15 preferred**
Average reservoir permeability (mD)	**>20.Lithology Sandstone preferred.**

The reservoir properties of the field, such as mobility ratio, etc. should be discussed in detail before starting any polymer-flooding project.

Mobility ratio

Based on the study of Needham et al.[8], the mobility ratio can be defined as:

$$M= (K_w/\mu_w)/(K_o/\mu_o) \rightarrow M=(K_w \cdot \mu_o) /(K_o \cdot \mu_w)$$

Where: M is mobility ratio, μ_w is water viscosity, μ_o is oil viscosity, K_w is water-

relative permeability, K_o is oil relative permeability.

According to the equation of mobility ratio, displacement is improved when the ratio is equal to or less than one.

The volumetric sweep efficiency is not good for water flooding and the main problem is the fingering effect. However, during polymer flooding, sweep efficiency improves due to decreasing the effect of fingering when it is compared to water flooding as seen in Figure (1). [8]

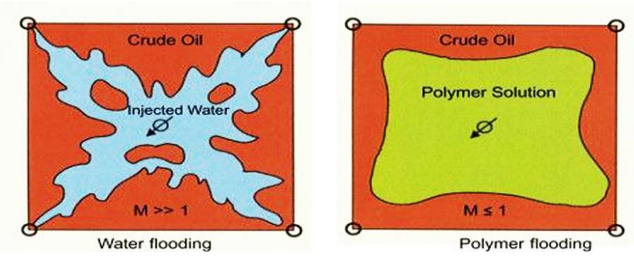

Figure 1: The effect of mobility ratio (The EOR Alliance).

Water Salinity:

According to previous studies, polymer adsorption is directly proportional to water salinity; it is desired to achieve sufficient quantity for adsorption. [9]

Types of polymers

Synthetic and Biopolymers are the two types of polymers that are usually considered in enhanced oil recovery.

Synthetic polymers

PAM (Polyacrylamide): it has a high molecular weight (>1× 106 g/mole). PAM is stable at high temperatures up to 92°C at normal salinity.

Hydrolyzed polyacrylamide is produced by hydrolysis of PAM. HPAM has many advantages. Among these are its cost-effectiveness and its resistance to both bacterial attack and mechanical forces that present during the injection of water. This type can also be used at temperatures up to 99°C. High sensitivity to the water salinity, hardness, and presence of surfactants or other chemicals are considered disadvantages of HPAM [9].

Biopolymers are formed by organisms; and given more hardness causing a good viscosity effect in saline water and a bad viscosity effect in freshwater [9].

Xanthan gum: A polysaccharide polymer produced by different types of bacteria through fermentation of fructose or glucose. This type of polymer is not sensitive to high salinity because it has high molecular weight and rigid chains. In the range of 70°C to 90°C Xanthan gum is considered thermally stable, and highly sensitive to bacterial degradation with low-temperature reservoirs. Furthermore, it may cause plugging. [9]

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In this work PAM (Polyacrylamide), polymer flooding recovery method was used to regulate the mobility ratio of the injected fluid for better volumetric sweep efficiency.

2. METHODS

Reservoir simulation is a powerful and inexpensive tool, which can predict what is going on in the reservoir and the amount of production from substitute operations.

The simulator used in this paper is the IMEX black oil simulator in the Computer Model Group (CMG), which includes many options such as polymer flooding and dual porosity.

"CMG offers a reservoir engineering tool CMOST which can make history matching, sensitivity analysis and optimization of reservoir models" [10].

Figure 2: CMG software [10].

The main steps for model construction are as following:

1. Input reservoir data in CMG software,
2. Model building,
3. Estimate the best recovery factor using polymer flooding,
4. Model Verification
5. and Result dissection.

2.1 Case Study

"Umm-Faroud is a Libyan oil field located in Sirte Basin as shown in Figure (3) it was discovered by drilling well A- 1 in 1962.

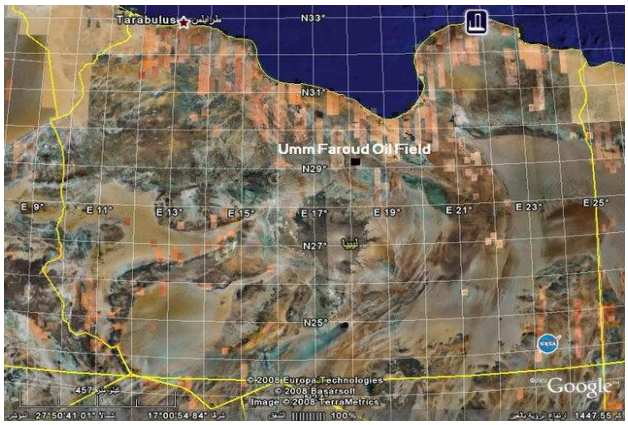

Figure 3: Umm-Faroud Oil Field Location.

17 wells have been drilled in the field until December 1995, (eight oil producers, six water injectors and 3 water sources). Three production formations, namely Bucharma "B1", "B2" and Dahra "B", successively at sub-sea depths of 1850 ft, 1900 ft and 2200 ft. Oil production was from Dahra "B" formation from six oil production wells (A01, A04, A06, A07, A10 and A14) at the rate of 6000 BOPD, reached 14,000 BOPD in early 1966 then declined rapidly due to a drop in reservoir pressure and increasing water cut. According to laboratory data, the field is an under-saturated oil reservoir; the bottom aquifer does not provide adequate pressure support to the reservoir due to formation tightness. The main production mechanism is rock and fluid expansion [11].

2.2 Model Description

The model was built using CMG simulator, based on the data collected from the Umm-Faroud field, such as thickness, petrophysical parameters (porosity and permeability), PVT properties, permeability saturation data, capillary pressure saturation data, initial pressure and saturation, well locations, and aquifer model design data. In addition, some experimental report's data such as relative permeability, bubble point pressure and saturations.

Input Data for CMG Software:

Three-dimensional model with five wells field units 35X35X8 Cartesian grid with 9800 grid cells.

The input data are shown in Table (2)

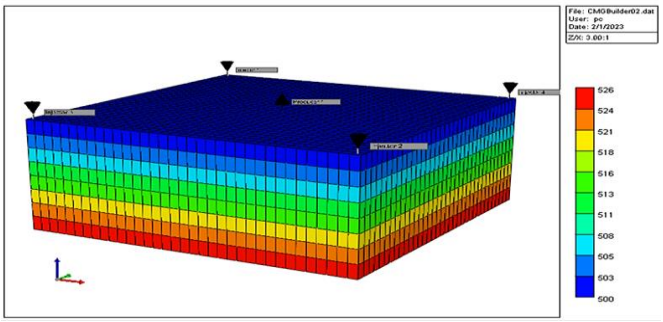

Figure 4: Reservoir grids form CMG software.

Table 2: Reservoir Data for the Model

Property	Value
Original Reservoir Pressure	1003 psi
Datum Depth	2210 ft ss
Saturation Pressure	253 psi
Oil Gravity	47 API@60 F
Reservoir Temperature	136 F
Viscosity Of Crude @ $P_{sat.}$	0.68 CP
Viscosity Of Gas @ $P_{sat.}$	0.0103 cp
Viscosity Of Crude @ $P_{initial}$	0.72cp
Viscosity Of Gas @ $P_{sat.}$	0.0135 cp
Hydrogen Sulfide	Positive
FVF Water @ 1000 p sia.	1.016
Water Viscosity	0.48 cp
Formation Water Salinity	57,000 ppm

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Table 3: Represented data in CMG software.

Property	Value
Grid dimension	35*35*8
Water density	62.4 lb./cuft
Gas density	17.3 lb./CF
Water compressibility	3.3*10-6 psi -1
Rock compressibility	5*10-6 psi -1
Water formation volume factor	1
Water viscosity	0.48. cp
Separation condition (flash temperature and pressure)	60F 14.7 psi
Reservoir oil saturation pressure	253psi
Initial water saturation	0.44
Average porosity	19%
Average permeability	55md
Initial oil saturation	0.56
Reservoir rock type	Lime stone
Wellbore radius	0.25 ft.

2.3 Reservoir Fluid Properties

This section deals with fluids filling the reservoir rocks. Oil, gas and formation water properties are covered under pressure- volume -temperature section PVT, the black oil model is the most common where the oil properties, such as formation volume factor Bo, solution gas oil ratio R_s and oil viscosity.

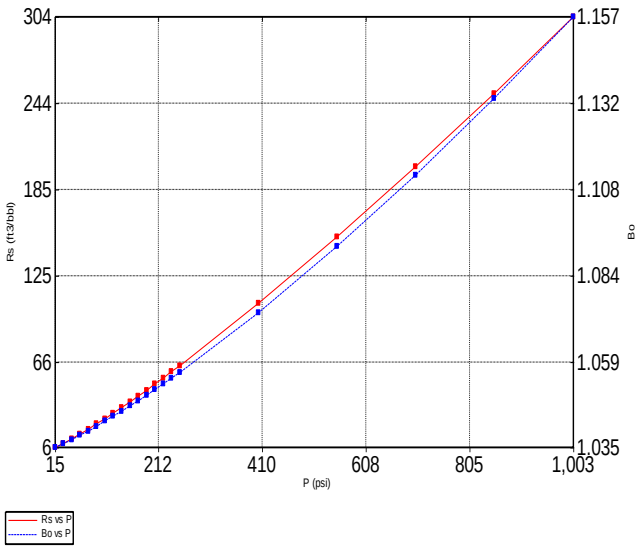

Figure 5: Bo and Rs with pressure.

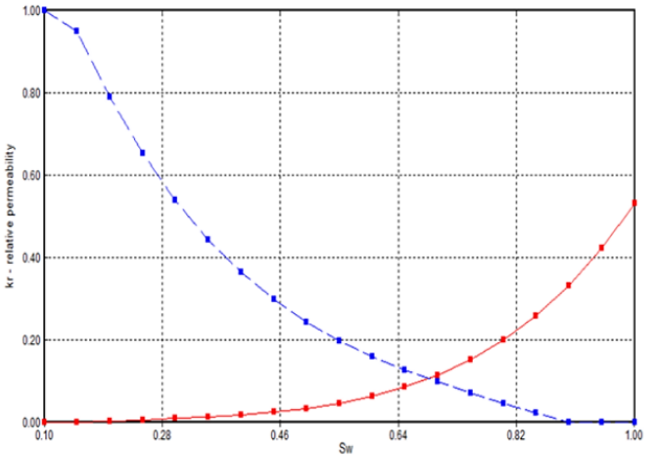

Figure 6: Relative permeability curves.

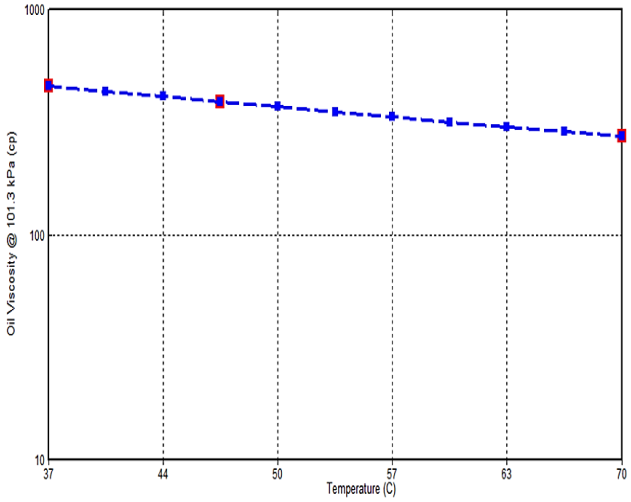

Figure 7: Oil viscosity with temperature curve.

2.4 Sensitivity Analysis:

The sensitivity analysis was run using different parameters to predict the best scenario of economic water injection and polymer flooding to achieve the highest oil recovery factor.

2.5 Well Specifications:

In this part, the constrain of the wells can be controlled and apply the design character of the water injection, Bottom hole pressure, and Surface water rate. The production period remained constant for all the scenarios for almost 5 years (2003-2008).

3. RESULTS AND DISCUSSION

In the first case, water injection was supposed without using a polymer solution. The result shows a reduction in the oil rate and an increase in water cut, the main reason is the difference in viscosity of injected water and remaining oil and its effect on mobility ratio.

There was an improvement in the oil rate and a reduction in water production after using 10% of the polymer solution (second scenario) with the injected water.

The third scenario, (with 20% of polymer) shows a higher oil rate and the recovery factor reaches 7.8%.

When 20% of the polymer solution was used there was a slight improvement in the oil production rate because of the low viscosity of the oil.

It is recommended to use a polymer flooding process to increase sweep efficiency in the water injection method and achieve high recovery factor in oil reservoirs.

3.1 Case (1) water injection without polymer.

In this scenario, water injection without using polymer was supposed; Figure (8) illustrates the oil production rate. Water cut was high as seen in Figure (9) Figure (10) illustrates the cumulative oil production for water injection without polymer.

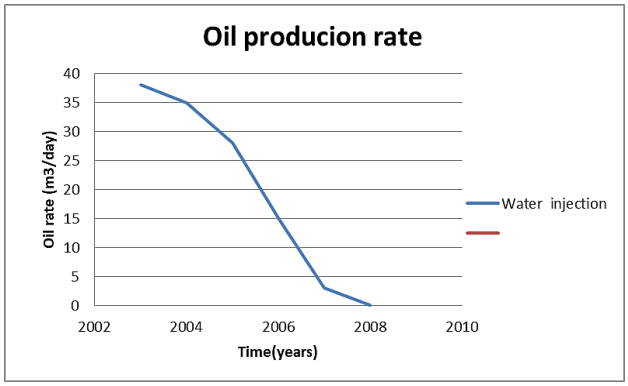

Figure 8: oil rate curve for case (1).

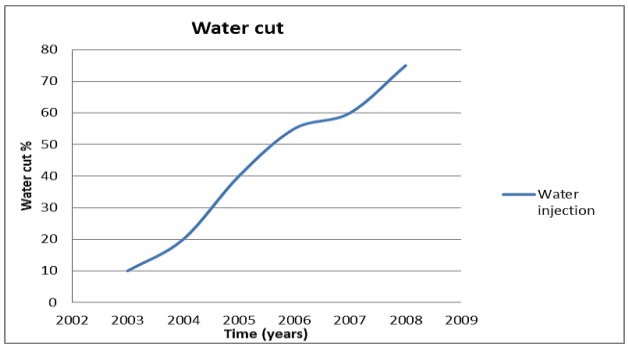

Figure 9: water cut curve for case (1).

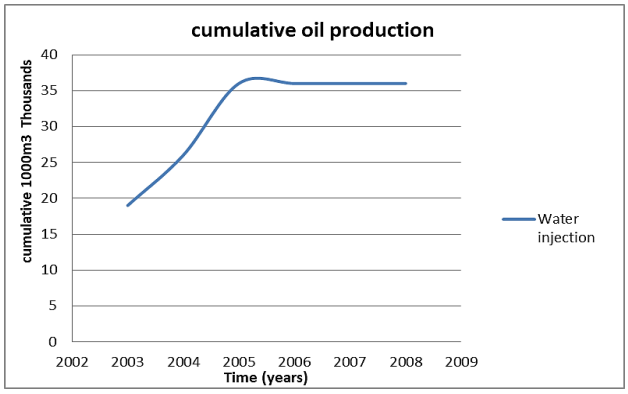

Figure 10: cumulative oil curve for case (1).

3.2 Case (2)

In this case, water injection was supposed with 10% of polymer concentration in Injection wells.

Figure (11) illustrates the oil rate. It indicates that there is an improvement in the oil rate after using 10% polymer concentration, and a reduction in water cut as

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seen in Figure (12). Figure (13) illustrates the cumulative oil production for polymer flooding with 10% concentration.

When compared to the first case, the improvement is clear, as shown in Figure (14) and Figure (15).

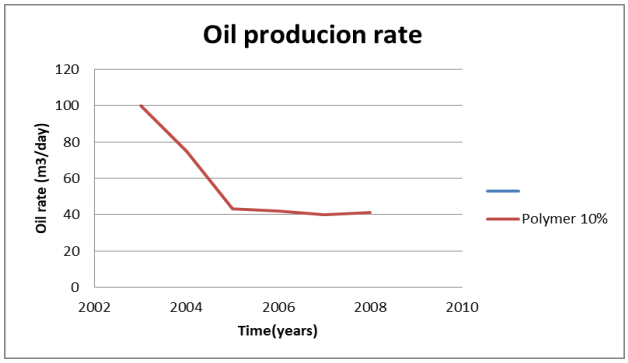

Figure 11: Oil rate curve for case (2), (with 10% of polymer).

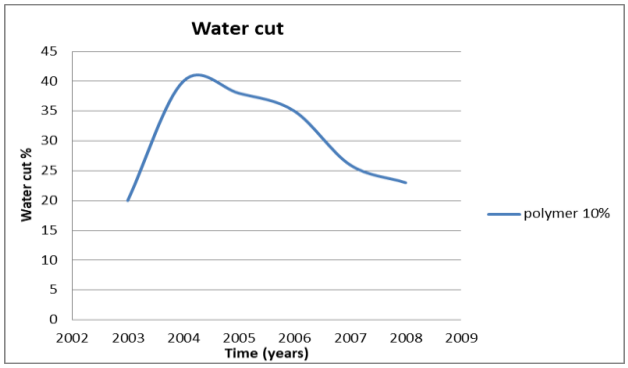

Figure 12: Water cut curve case (2), (with 10% of polymer).

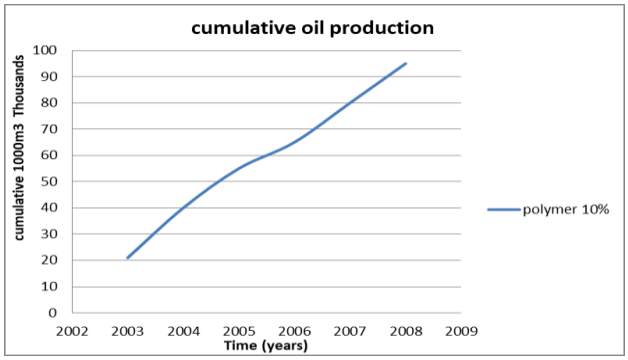

Figure 13: Cumulative Oil rate curve for case (2).

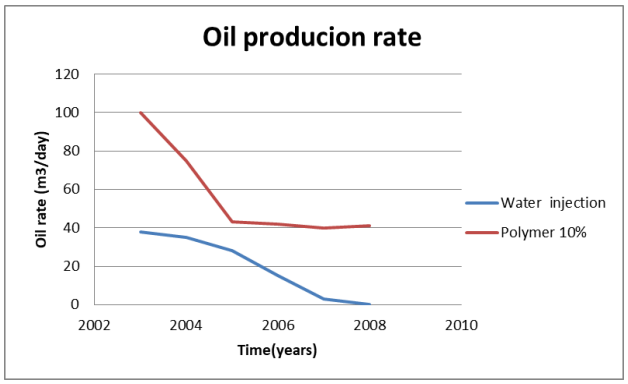

Figure 14: Oil rate curve for case (1) and (2).

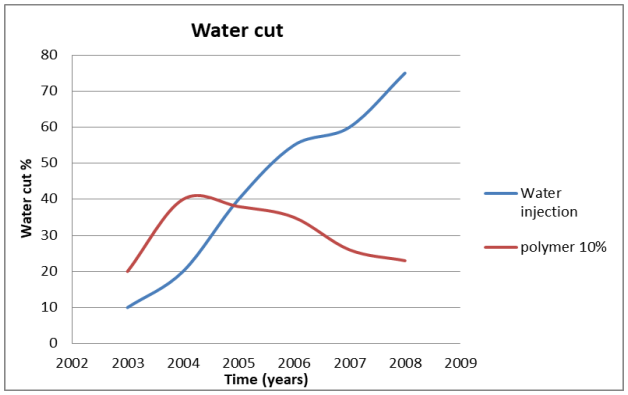

Figure 15: water cut curve case (1) and case (2).

Case (3)

In this case, 20% polymer concentration was supposed instead of 10% concentration.

Figure (16) illustrates the oil rate; there is more improvement in the oil rate after using 20% of polymer concentration, also water cut was slightly reduced, and the cumulative oil was increased as shown in Figure (17) and Figure (18) respectively.

Figure (19) illustrates the difference in oil rate between the second case and third case.

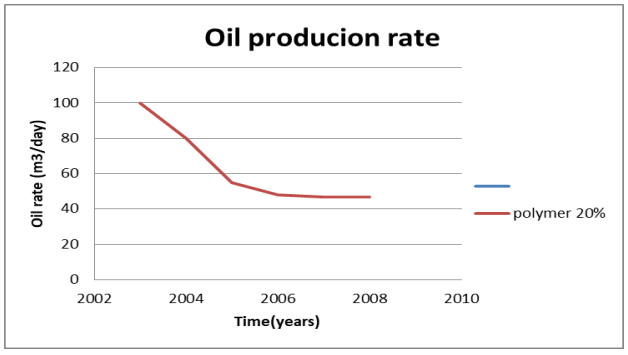

Figure 16: oil rate curve for case (3), with 20% of polymer.

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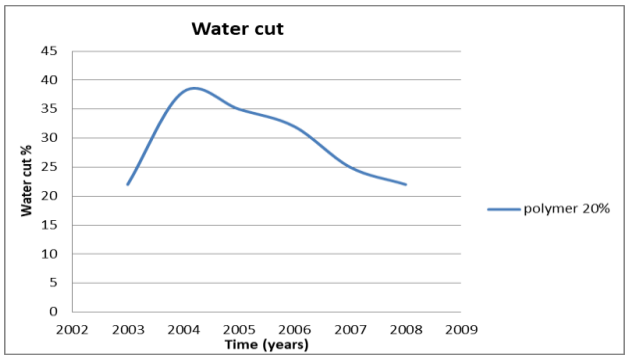

Figure 17: Water cut curve from case (3), with 20% of polymer.

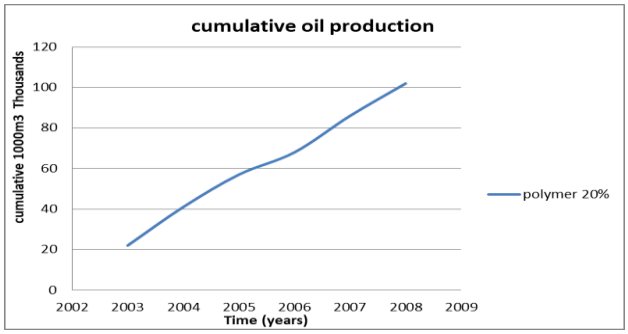

Figure 18: Cumulative Oil curve for case (3).

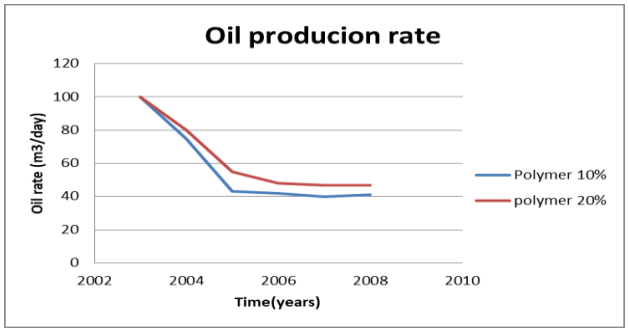

Figure 19: Oil rate curve for case (2) and case (3), from CMG software.

COMPARESION of RESULTS

After comparing the first scenario with the second and third scenarios, polymer with 20% concentration shows a better oil rate than using 10% of polymer concentration. However, no significant decrease in water cut as shown in Figure (20) and Figure (21).

In addition, the cumulative oil production was increased when the polymer was used (in 10% and 20% concentration) with increasing displacement efficiency and sweep efficiency, as seen in Figure (22)

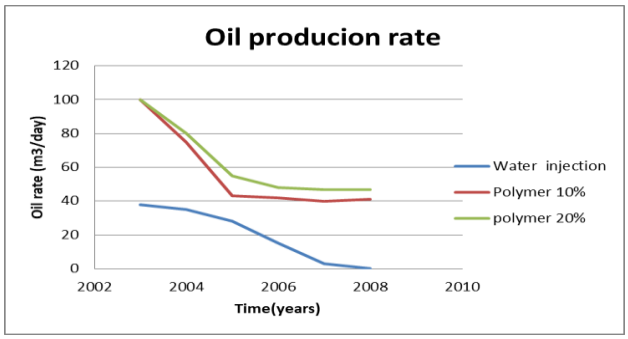

Figure 20: Oil rate curves for all cases.

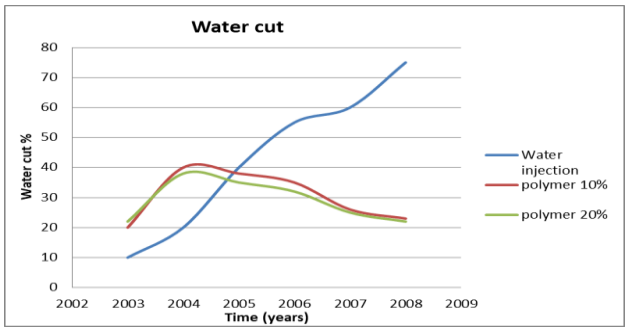

Figure 21: Water cut curves for all cases.

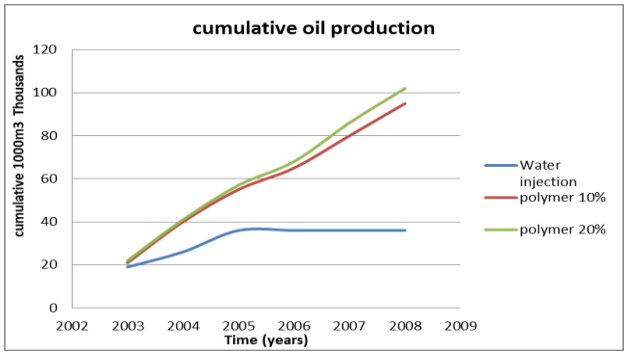

Figure 22: cumulative oil curves for all cases.

4. CONCLUSION

- This study has shown how polymer flooding is effective in oil recovery compared with water flooding.
- In the first scenario, where water injection without polymer was used in the injection wells. the liquid rate was low and there was no stability in the oil rate, gas oil ratio, and water cut was also high at the end of the water injection technique.
- In the second and third scenarios, polymer with 20% concentration shows a better oil rate than using 10% of polymer concentration. Good sweep efficiency can be achieved with a regular pattern with an optimal polymer concentration.

- There is many software available in companies and petroleum fields for use in sensitivity analysis techniques and drawing the required graphs such as OFM, Pipe Sim. and CMG. However, the most suitable software to be used for sensitivity analysis optimization is, (CMG) computer modeling group because it is very easy to use and highly useful reservoir simulation software.

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Surgeons Opinions on Management of Normal Appendix during Laparoscopy for Right Iliac Fossa Pain

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ABSTRACT

Right iliac fossa (RIF) pain is a common presentation in surgical emergencies, often leading to the diagnosis of acute appendicitis. However, the management of a normal appendix encountered during laparoscopic exploration for RIF pain remains debated among surgeons, with implications for patient outcomes and healthcare resources. This study aimed to assess the opinions of surgeons regarding the management of a normal appendix during laparoscopic surgery for RIF pain of uncertain etiology. A cross-sectional survey was conducted among 150 surgeons in Benghazi, yielding a 65.33% response rate. The survey collected demographic data, management opinions, and factors influencing decision-making regarding the removal of a normal appendix during laparoscopic procedures. The results showed that of the 98 respondents, approximately 80% reported that they routinely remove a normal appendix during laparoscopic surgery, primarily to prevent future appendicitis and avoid patient confusion. While most surgeons explained the risks and benefits of this decision to their patients, opinions varied on whether the decision should be made collaboratively. Notably, only 2% reported complications related to the removal of a normal appendix. The findings indicate a significant lack of consensus among surgeons concerning the management of a normal appendix during laparoscopic procedures. While many opt for routine removal, a substantial minority advocate for a more selective approach. The variability in practices highlights the need for clear, evidence-based guidelines to standardize care and optimize patient outcomes. This study underscores the heterogeneity in the management of normal appendices during laparoscopic exploration for RIF pain. Further research is necessary to develop definitive recommendations that can guide surgeons in clinical practice.

KEYWORDS: Right Iliac Fossa Pain, Acute Appendicitis, Laparoscopic, Appendectomy, Normal Appendix.

1. INTRODUCTION

One of the most common presentations seen in surgical emergency departments is right iliac fossa (RIF) pain [1], which can arise from a variety of pathological causes originating in the gastrointestinal, urological, vascular, and gynecological systems. Among these, acute appendicitis is widely recognized as one of the most prevalent causes of acute abdominal pain requiring urgent surgical intervention.[2] The challenge in diagnosing acute appendicitis lies in the broad range of potential pathologies that can manifest with similar symptoms, as well as the variable nature of clinical presentations.

Surgeons often rely on a combination of patient history, physical examination findings, laboratory tests, especially inflammatory markers like white blood counts, ESR and C-reactive protein, and diagnostic imaging, including ultrasound scans and computerized tomography scans, to establish the diagnosis [3]. However, the similarities between appendicitis and other conditions can make it difficult to reach a definitive conclusion, especially in cases where the clinical picture is unclear.

The importance of timely appendectomy is well-established, as delayed treatment is associated with an increased risk of complications such as perforation and abscess formation [4]. Consequently, many surgeons have a low threshold for operating on patients presenting with RIF pain, even when the diagnosis of appendicitis is uncertain [5]. The advent of laparoscopic surgery has significantly impacted the diagnostic and management approaches for patients with RIF pain [3].

Unlike open appendectomy, where the surgeon is typically committed to removing the appendix once it is visualized, laparoscopic exploration may reveal a macroscopically normal appendix [6]. This scenario introduces a dilemma for the surgeon, as the management of a normal appendix during laparoscopy for RIF pain remains a subject of ongoing debate.

Some surgeons advocate for the routine removal of the appendix in such cases, citing the potential for microscopic pathology or future development of appendicitis [6]. Others, however, believe that the appendix should be left in situ, as unnecessary appendectomy may expose patients to additional surgical risks without clear benefit [6].

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This lack of consensus among surgeons regarding the management of a normal appendix during laparoscopy for RIF pain has important clinical implications, as it can affect patient outcomes and healthcare resource utilization. Understanding the opinions and decision-making processes of surgeons in this context can help guide clinical practice and inform future research in this area. This study highlights a lack of consensus among surgeons regarding the management of a normal appendix during laparoscopy for right iliac fossa pain.

2. METHODOLOGY

A cross-sectional survey study assessing the views of 150 surgeons in Benghazi via means of an online survey.

The survey collects the following information:

- Demographic and practice characteristics of the participants (e.g., years of experience, practice setting, annual volume of appendectomies).
- Opinions on the management of a normal appendix encountered during laparoscopy for RIF pain, including factors influencing the decision-making process.
- Factors that would influence the decision to remove or leave in situ a normal appendix, such as patient age, history of prior abdominal surgery, and presence of other intraoperative findings.
- Perceived risks and benefits associated with the different management strategies for a normal appendix.
- Preferred approach to obtaining informed consent from the patient regarding the management of a normal appendix.

Ethical Considerations:

The study protocol was reviewed and approved by the research ethical committee at the Libyan International Medical University with certificate reference number: MDC-2023-00105.

3. RESULTS

The study attained a response rate of 65.33%, with 98 participants responding out of the total sample size of 150.

All 98 participants answered all the questions in the questionnaire.

The majority of the surgeons (around 80%) reported that they do remove the normal appendix during laparoscopy for right iliac fossa pain of uncertain origin. The most common reasons cited were to prevent future appendicitis, address possible inflammation of the appendix mucosa, and avoid future confusion for the patient about having an appendix. Only 2.6% attributed their decision to remove the appendix to the presence of chronic inflammation (see Fig. 1).

Most surgeons (around 80%) reported that they sometimes or always explain the risks and benefits of removing a normal appendix to their patients before the surgery.

Only 2 surgeons reported complications from removing a normal appendix during this type of surgery (injury to adjacent bowel and collection).

The participants' responses to the question regarding whether removing a normal appendix during this type of surgery typically resolves the patient's right iliac fossa pain were as follows: 46% responded 'usually,' 14.3% said 'not usually,' while 36% indicated that it depends on the specific case.

40.8% of surgeons believe that the appendix should be removed in such cases, while 26.5% think it should not be removed. Meanwhile, 32.7% believe that the decision to remove the appendix in these cases should be made on a case-by-case basis.

There was no clear consensus on whether the decision to remove a normal appendix should be made by the patient, the surgeon, or collaboratively. Responses were split between these options.

Most surgeons (around 57%) said they would recommend removing a normal appendix during laparoscopy for right iliac fossa pain of uncertain origin, with some caveating this depending on the individual case (26.5).

Only 2 surgeons were aware of specific guidelines on this topic, such as from SAGES (Society of American Gastrointestinal and Endoscopic Surgeons).

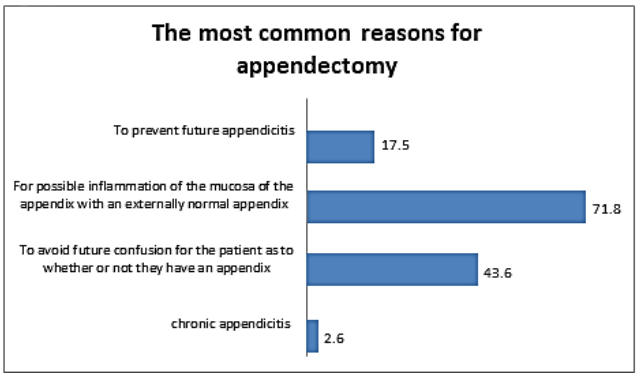

Figure 1. The responses for the most common reasons for appendectomy.

4. DISCUSSION

This survey provides insights into the diverse practices and perspectives of surgeons regarding the management of a normal appendix during laparoscopic exploration for right iliac fossa pain of uncertain etiology. The majority of respondents reported that they do routinely remove the appendix in such cases, citing reasons such as preventing future appendicitis, addressing potential microscopic inflammation, and avoiding future confusion for the patient.

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However, a sizable minority indicated that they take a more selective approach, removing the normal appendix only in certain circumstances.

The lack of consensus among the surveyed surgeons reflects the ongoing debate and uncertainty in the literature regarding the optimal management of the normal appendix in this clinical scenario. While some studies have suggested that prophylactic appendectomy can improve outcomes by addressing subclinical pathology [7, 8], other research has found that this practice does not reliably resolve symptoms and may expose patients to unnecessary surgical risks [9, 10].

The management of a normal appendix encountered during laparoscopy for right iliac fossa pain remains a point of contention in the literature. The primary argument for removing a visually normal appendix is the concern that endoluminal appendicitis, reported in 11–58% of seemingly normal appendices, may be missed intraoperatively [8, 11, 12].

This could lead to the need for a subsequent appendectomy. However, some argue that endoluminal appendicitis, confined to the mucosa, may not progress to suppurative appendicitis and does not necessarily cause localized pain [11].

Conversely, several studies have suggested that leaving a normal appendix in place is safe. One prospective study of 109 diagnostic laparoscopies found that only 1 out of 9 readmitted patients required an appendectomy when the appendix was left in place [13].

Another 10-year follow-up study of 63 patients randomized to appendectomy or diagnostic laparoscopy alone reported no subsequent development of appendicitis in the latter group [14].

Nonetheless, some data indicates increased complications from removing a normal appendix [8, 9].

Additionally, patient perceptions may play a role, as one study found that 61% of 176 patients who underwent laparoscopy for right iliac fossa pain were mistaken about whether their appendix had been removed [15].

This has led some to argue that removing the appendix regardless of appearance adds little morbidity [16].

However, the optimal management strategy remains unclear given the mixed evidence.

A key challenge appears to be the difficulty in accurately distinguishing a truly "normal" appendix pre-operatively, as macroscopic appearance may not always correlate with microscopic pathology. Additionally, predicting which patients are most likely to benefit from prophylactic appendectomy remains an area of uncertainty.

Interestingly, the survey responses indicate that the decision-making process is also variable, with some surgeons favoring a collaborative approach with the patient, while others feel the decision is best made by the surgeon alone. This highlights the importance of effective surgeon-patient communication and shared decision-making in this context.

The lack of clear, evidence-based guidelines on this topic was also noted by several respondents. The development of such guidelines, potentially drawing on expert consensus and incorporating patient preferences, could help standardize and improve the quality of care for patients presenting with right iliac fossa pain of unclear etiology.

5. CONCLUSION

In conclusion, this survey reveals significant heterogeneity in the management of the normal appendix during laparoscopic exploration for right iliac fossa pain.

Further research is warranted to establish more definitive, evidence-based recommendations to guide surgeons and optimize outcomes for this patient population.

It is also essential to encourage surgeons to engage in continuous medical education, urge them to stay updated with the latest research and scientific recommendations, and provide these resources to them.

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The Effect of Iron Deficiency Anemia on HbA1C among Non-Diabetic Adults in Benghazi, Libya

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ABSTRACT

Iron Deficiency Anemia (IDA) is the most common hematological disorder that has an impact on various physiological processes in the body. This research aims to investigate the relation between IDA and HbA1c levels, a marker of long-term glycemic control. Data from 100 patients with IDA and 100 as a control group were collected from the First Medical Tech Laboratory in Benghazi, Libya, and analyzed using SPSS version 21. The distribution of age and sex among the groups was described using frequency and summary statistics. The statistical analysis showed that the data follows a normal distribution. However, it was not homogenous. Consequently, the non-parametric Mann-Whitney U test was employed. The results indicated no statistically significant correlation between IDA and HbA1c levels ($p = 0.08$), suggesting that IDA may not have a significant impact on long-term glycemic control. These findings contribute to the existing body of literature on the relationship between IDA and HbA1c levels, and many researchers suggest the fact that IDA increases HbA1c levels; others align with our results by showing no correlation; some even suggest that IDA decreases HBA1c levels. These conflicting results highlight the need for further research to shed light on the underlying mechanisms involved.

KEYWORDS: Anemia, Diabetes, Iron Deficiency Anemia, Libya, Benghazi, Young Adults, Hba1c, Hemoglobin.

1. INTRODUCTION

Anemia is a serious problem in developing countries, particularly among nutritionally compromised individuals. It impairs growth and increases the risk of mortality and morbidity [(1)]. One of the most prevalent causes of anemia is iron deficiency. Blood loss from gastrointestinal bleeding and blood loss during menstruation are the two primary causes of iron deficiency anemia [(2)].

IDA has a major negative influence on living quality and work abilities and may result in recurrent hospitalization, delayed discharge, and higher healthcare expenses [(3)]. Iron deficiency anemia affects 4-5 billion people worldwide, according to the World Health Organization. The primary component of hemoglobin, which distributes oxygen throughout the body, is iron. It contributes to the general function of cells by supporting the enzymatic system, brain development, and oxygen usage.

IDA symptoms include shortness of breath, dizziness, fatigue, recurrent infections, and poor appetite. They might be produced by hemolysis or a higher demand for iron [(4)]. Iron deficiency accounts for around 50% of all cases of anemia. Worldwide, iron deficiency is responsible for 35,057,000 DALYs lost and 841,000 deaths. The diagnosis of IDA is typically established by assessing iron levels, with values below 10 mmol/L, and ferritin levels, with values below 10 mg/L, indicating iron deficiency [(5)].

HbAlc, a glycated hemoglobin, is formed by the glycosylation of hemoglobin. HbA1c is formed by the binding of glucose to the N-terminal valine of both B-chains of the hemoglobin molecule. The result indicates a person's glycemic status over the past 2-3 months. This test is used to determine glycemic status in diabetics and people who have impaired glucose tolerance. The American Diabetes Association (ADA) suggests maintaining HbAlc levels below 7% for all diabetics (2007 guidelines) [(6)]. HbA1c levels can be impacted by several factors, including blood glucose, hemolytic anemias, hemoglobinopathies, acute and chronic blood loss, pregnancy, IDA, and uremia.

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A variety of theories have been brought out to explain why the presence of IDA causes an increase in HbA1c levels. One theory suggests that changes to hemoglobin's quaternary structure cause the globin chain to glycate more quickly [7]. Secondly, the lower hemoglobin levels associated with IDA, coupled with a constant glucose concentration, may lead to a higher proportion of glycated hemoglobin. As HbA1c is measured as a percentage of total hemoglobin, this relative increase in the glycated fraction could contribute to elevated HbA1c levels [8].

Moreover, the reduced generation of red blood cells in IDA patients increases the average age of circulating erythrocytes. This causes each red blood cell to be exposed to glucose for a longer time, perhaps contributing to greater HbA1c levels [9]. Previous research findings on the link between IDA and HbA1c levels were conflicting, requiring more investigation. Specifically, there is a need to investigate the effect of IDA on HbA1c levels in non-diabetic persons in Benghazi. Several studies examined the relationship between iron deficiency anemia (IDA) and glycated hemoglobin (HbA1c) levels.

Some research supports the hypothesis that IDA raises HbA1c levels, and the severity of iron deficiency anemia exacerbates this effect [10]. However, an investigation carried out at Cukurova University found that IDA decreases HbA1c levels [9]. Another study found that whereas IDA initially reduced HbA1c levels, HbA1c levels recovered to normal during a two-month iron supplementation period, indicating a strong correlation between IDA and HbA1c [11].

Moreover, while moderate forms of IDA may not significantly impact HbA1c levels, severe forms of IDA have been associated with increased HbA1c levels. The specific mechanism through which IDA influences HbA1c remains unclear. Given the divergent findings in the literature, further investigation is warranted to determine the relationship between IDA and HbA1c levels. The purpose of this study is to close this knowledge gap and offer valuable insights into the relationship between IDA and HbA1c levels in this particular cohort. The results have the potential to improve diabetes diagnostic accuracy, especially for this particular group in the Benghazi area.

2. METHODS AND MATERIALS

2.1. Study design and population

A case-control study with 200 subjects targeted for inclusion in the study.

2.2. Inclusion criteria:

Adults with iron deficiency anemia who are non-diabetic. The diagnosis of IDA is typically established by assessing iron levels, with values below 10 mmol/L and ferritin levels, with values below 10 mg/L indicating iron deficiency.

2.3. The exclusion criteria for this research:

- Patients who are diagnosed with diabetes or who have glucose intolerance.
- Patients who have abnormalities in their hemoglobin structure, liver problems, alcohol ingestion, renal impairment, or rheumatic diseases.

To determine the sample size, we used the Cochran formula. Since there is no specific data available on the number of adults with IDA in Benghazi, the population size was estimated at 54,000. This estimation is based on the total number of adults in Libya (400,000) and the fact that Benghazi accounts for approximately 14% of the Libyan population. Considering that around 25% of adults worldwide are diagnosed with anemia and approximately half of these cases are IDA, the estimated prevalence of IDA in the population was 12.5%.

3. DATA COLLECTION

Data on non-diabetic people newly diagnosed with IDA was requested from the First Medical Tech Laboratory in the Benghazi area. One hundred people in all will be selected to fulfill the study's inclusion requirements. Furthermore, a control group consisting of one hundred individuals who are neither anemic nor diabetic was chosen. Gender will not be taken into account when choosing participants. The collected data will include the participant's past medical history, complete blood count, ferritin level, random blood glucose, and glycated hemoglobin (HbA1c). The level of HbA1c considered to be raised will be defined as 5.7%, following the guidelines of the American Diabetes Association (ADA). All collected data was analyzed and statistically interpreted using statistical software, such as SPSS version 21 (Statistical Package for the Social Sciences). Appropriate statistical tests, such as t-tests or Mann-Whitney tests, were used to assess the relationship between iron deficiency anemia and HbA1c in non-diabetic individuals.

4. RESULTS

The sample size used was 200 samples from otherwise healthy adult non-pregnant females; 100 had IDA, while the other 100 had normal HB levels of about 12 g/dL. The age distribution ranges from 16 to 51, with an average age of 29 and a standard deviation (SD) of 8. The normal group had an age average of 29 with an SD of 9, while the IDA group had an average age of 30 and an SD of 6.

4.1. Age distribution:

The figure below shows the age distribution of the samples, clarifying the normal group and the IDA group.

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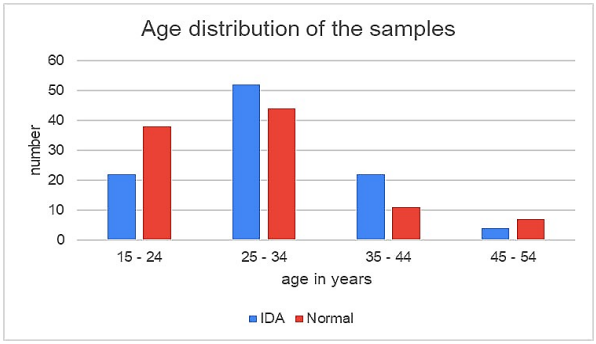

Fig. 1. Distribution of age of the IDA and normal groups.

4.2. Blood Parameters of Normal and IDA Groups

When the normal population results were compared to the IDA results of the obtained data, a statistically significant difference was found using a t-test with a two-tailed distribution and two samples with equal variance. All results for HB, HCT, RBC number, and serum ferritin had a P value < 0.05. These results revealed that data was collected accurately and that the statistical procedure was precise. Data shown in Table 1 is explained in Figure 2. (A, B, C, and D) stand for HB, HCT, RBC count, and serum ferritin, respectively.

Table 1: Blood Parameters of Normal and IDA Groups

Groups	HB (g/dl)	HCT (%)	RBC (no.)	S. Ferritin (ng/mL)	
IDA group	Average	7.6	21	3.5	19.4
	SD	0.98	2.16	0.48	6.16
Normal group	Average	12	32.3	3.9	39.6
	SD	1.23	3.11	0.57	9.97

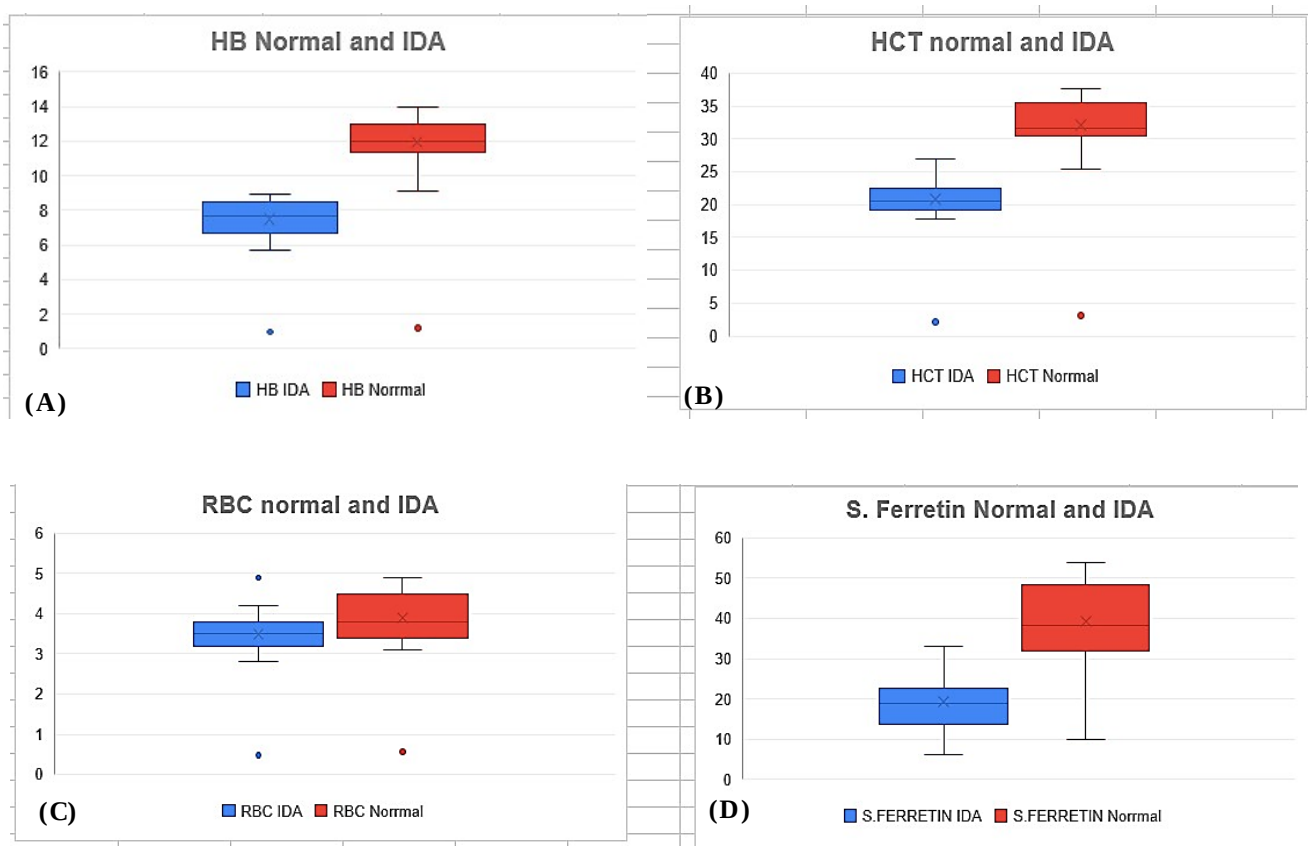

Fig. 2. shows the blood analysis of the normal and IDA groups for (A) HB, (B) HCT, (C) RBC numbers, and (D) serum ferritin.

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4.3. Blood sugar parameters of normal and IDA groups:

When comparing the HBA1C data of the normal population and the IDA group statistically, the p-value was more than 0.05, indicating that there was no significant difference between the two groups. However, Figure 3 and Table 2 showed that the IDA group had considerably higher fasting blood sugar levels than the normal group.

Table 2. Blood sugar parameters of normal and IDA groups.

Groups		FBS (mg/dL)	HbA1C (%)
IDA group	**Average**	90.5	4.96
	SD	11.4	0.96
Normal group	**Average**	81.7	4.86
	SD	10.1	0.52

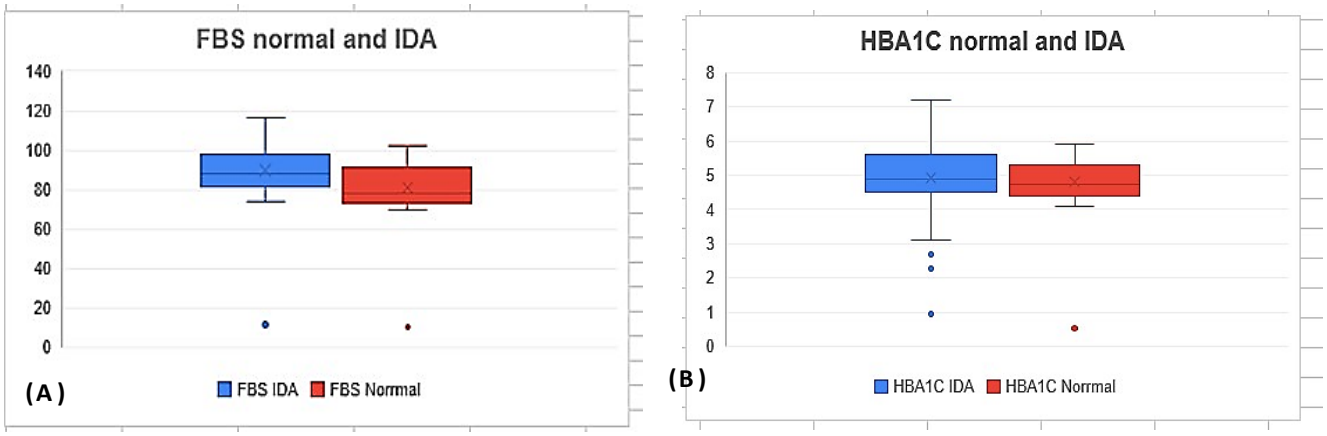

Fig. 3. Shows the blood analysis of the FBS (A) and the HBA1C (B).

5. DISCUSSION

IDA is the most prevalent cause of anemia and the most common nutritional deficiencies worldwide. The characteristic of IDA is a decrease in serum ferritin, which shows a depletion in the body's iron reserves. IDA also exhibits a decrease in hemoglobin and blood indicators such as MCV and MCH. A common method for evaluating glycemic control in diabetics during the last three months is glycated hemoglobin, or HbA1c. In addition to blood sugar levels, HbA1c can be influenced by illnesses such as uremia, hemoglobinopathies, acute and chronic blood loss, pregnancy, and hemolytic anemias [12]. This study aimed to evaluate the relationship between iron deficiency anemia (IDA) and HbA1c levels because there have been contradictory findings from previous studies on the relationship between IDA and HbA1c.

It has been shown that patients with IDA had considerably lower glycated hemoglobin levels than the healthy control group. Iron supplementation resulted in a subsequent elevation in HbA1c n two months after treatment started [12]. In contrast, it has documented higher levels of HbA1c in non-diabetic patients with IDA, which fell to near-normal levels following iron supplementation [13]. Our study used a two-independent sample t-test to examine the association between IDA and HbA1c levels. The normality assumption was met. However, the homogeneity of variance was not so; a non-parametric Mann-Whitney U test was employed, which resulted in a p-value of 0.08, indicating no statistical significance in the correlation between IDA and HbA1c levels.

Another study conducted by van Heyningen and Dalton R.G. found no difference in HbA1c levels between nondiabetic individuals with IDA before and after treatment with iron and healthy controls [14]. Further analysis revealed that women with severe anemia had considerably lower HbA1c levels than those with mild anemia. Low serum ferritin, Hb, MCV, MCH, and MCHC levels are indicators of IDA. Based on these data, we propose that HbA1c decreases with the severity of IDA. There is insufficient data on the link between HbA1c and anemia severity in non-diabetic patients [15].

Furthermore, the investigation was conducted on non-diabetic women with and without IDA. The IDA group of 21 women was then separated into two groups based on

the severity of anemia: mild (n = 9) and moderate-severe (n = 12). The HbA1c readings were not different between the two severity groups. However, the absolute HbA1c concentrations showed a significant difference in mean values between the two groups [15].

Currently, the specific processes involved are not well understood. The IDA likely influences HbA1c levels through its effect on erythrocyte lifespan, changes in glucose metabolism, or other undiscovered mechanisms. Additional study is needed to validate these pathways and have a better understanding of the link between IDA and HbA1c levels [16]. In contrast to our work, the degree of anemia determines how IDA impacts HbA1c levels. When the total variability of the HbA1c test is taken into account, these increases may not be clinically important while being statistically significant [17]. Furthermore, in the non-diabetic population, IDA has been found to positively correlate with increased HbA1C levels [18]. It has been shown that there is a favorable relationship between hemoglobin, ferritin, and HbA1c [19]. The study emphasizes that individuals with IDA had lower HbA1c levels, which may rise if IDA is corrected [20].

6. CONCLUSION

Although the results of this study did not show a statistically significant association between IDA and HbA1c levels, the inconsistent findings in the literature and the limitations of our investigation suggest the need for more research. Future research should look at the severity of anemia and iron deficiency, as well as the underlying causes. More understanding of the link between IDA and HbA1c levels can help clinicians monitor and treat IDA as well as glycemic control.

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Evaluation of Practice and Awareness of the Safety Profile of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) among Dental Practitioners: A Cross-Sectional Study

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ABSTRACT

Non-steroidal anti-inflammatory drugs (NSAIDs) are the common medications used by dental practitioners to relieve dental pain and control post-operative signs of inflammation. NSAIDs, irrespective of their benefits, have a lot of hazards because of misuse and faulty prescriptions by dentists. The aim of this study is to evaluate the current use of NSAIDs during dental practice and to evaluate the association of the level of education and years of experience of dental practitioners with the awareness of the safety profile of NSAIDs. This observational cross-sectional study was conducted in Benghazi city between August and October 2024. The sample size is composed of 341 dentists. Participants were selected randomly from approximately every dental clinic in Benghazi. The questionnaire is composed of sections including assessment of drug use and drug-precautionary awareness. It is structured with checklist answers and was formulated in English. It is filled by the dentists during a visit to their dental clinics on the basis of an interview. The Statistics Package for Social Science Version 21 (SPSS) software was used for transferring and analysis of data. The results showed that the females accounted for the majority (60.7%). General practitioners represented 67.7% of the participants. About 61.0% of the dentists had clinical experience of less than 10 years. Ibuprofen and Ketoprofen were the most prescribed NSAIDs, 67.2% and 51.6, respectively. More than fifty percent (55.4%) of the participants used to prescribe NSAIDs for less than three days. Postoperative pain and dental pain were the most common clinical indications that NSAIDs were prescribed, 71.3% and 59.5%, respectively. Pregnancy was the most cited to be contraindicated (58.9%). Awareness of avoiding NSAIDs in the case of peptic ulcer patient was associated with years of experience of the dentists (P=0.030). Participants agreed that nausea was the most side effects (45.2%). Awareness of the interaction between NSAIDs and warfarin was associated with the level of education (P=0.006). The outcomes of the study have revealed less comprehension regarding scientific background knowledge of NSAIDs. There was little effect of level of education and years of experience on the awareness of the safety profile of NSAIDs during dental practice. Therefore, a lot of efforts should be focused on improving the knowledge for making proper therapeutic decisions and minimizing the risk of serious adverse effects on the patients who attend dental clinics.

KEYWORDS: Benghazi; Dentists; Clinical experience; Level of education; NSAIDs; Safety profile.

1. INTRODUCTION

Anti-inflammatory drugs, analgesics, antimicrobials, and antipyretics are often prescribed by dental practitioners in many fields of dentistry. Analgesics and anti-inflammatory drugs are widely used over-the-counter (OTC) [(1)]. Non-steroidal anti-inflammatory drugs (NSAIDs) are the most commonly used by dental practitioners to relieve dental pain and control post-operative signs of inflammation such as in endodontic treatment and extraction of teeth. Additionally, patients have used to take NSAIDs as self-medications to relieve pain related to a toothache [(1)].

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Vane and Piper first explained the mechanism of non-steroidal anti-inflammatory drugs (NSAIDs) for inhibiting cyclooxygenase (COX) enzymes which are responsible for prostaglandins (PGs), prostacyclin (PGI_2), and thromboxane (TxA2) biosynthesis from arachidonic acid (derived from cell membrane phospholipid) [(2)]. Prostaglandins have an essential role in providing protective and regulatory physiological functions in human body systems. For instance, PGE2 leads to a decrease in gastric acid secretion, while PGE2 and PGI2 increase the production of mucus, PGE2 and PGI2 maintain renal blood flow, and bronchial smooth muscles are relaxed by PGE2 and PGI2α. Moreover, contraction of the uterus is facilitated by PGE2 which progresses to labor [(3)]. Two cyclooxygenase (COX) enzymes are involved in prostaglandins biosynthesis; COX-

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I has protective functions such as gastric protection, maintaining of renal blood flow, and regulation of vascularity, and COX-2 is involved in normal renal function and vascular prostacyclin synthesis [3]. COX-1 is present in most cells, while COX-2 is induced in inflammatory cells but not at sites of GIT and platelets. COX-2 will be produced in the site of damaged dental pulp tissue and periodontitis which induces prostaglandin synthesis that leads to the activation of a pain mechanism and inflammatory manifestations [4].

Thus, inhibiting prostaglandins may give rise to serious adverse effects that were reported in many studies, especially in long-term use [5]. NSAIDs should be avoided in pregnancy due to their potential adverse effects [5, 6]. NSAIDs have a harmful role in the deterioration of renal function and increase the risk of peptic ulceration. Moreover, asthmatic and cardiovascular patients have limitations regarding the use of NSAIDs [7]. A lot of side effects such as nausea, abdominal pain, and heartburn during intake of NSAIDs were reported in many studies [5, 8, 9]. NSAIDs were also reported to potentiate some drug interactions with other medications [10-12].

NSAIDs can be identified according to the type of cyclooxygenase (COX) enzymes that were inhibited. Acetylsalicylic acid (Aspirin) is a non-selective COX inhibitor, but has more potential to be a selective COX-1 inhibitor. Piroxicam, Indomethacin, Ketoprofen, Diclofenac, Naproxen, and Ibuprofen are non-selective COX inhibitors. Meloxicam is selective COX-2 inhibitors, noting that Celecoxib is a highly selective COX-2 inhibitor [13-15]. Naproxen also has low selectivity to inhibit COX-2 [16]. Differently, NSAIDs can be identified clinically based on the duration of action; short-acting with rapid onset, such as Ketoprofen, Ibuprofen, Diclofenac Na and Aspirin (half-life is less than 6 hours), and long-acting NSAIDs such as Naproxen, Meloxicam, and Celecoxib (half-life is more than 10 hours). In acute pain, short-acting NSAIDs are more suitable. Conversely, for chronic conditions, long-acting is preferred [17].

Misuse and prescription of NSAIDs in the wrong way with a lack of thorough knowledge regarding their maximum daily dose, indications, contraindications, drug interactions, and side effects will lead to serious sequelae [18]. Therefore, our guide to using NSAIDs properly without any complications is based on the recorded medical history of the patient as well as on the experience and scientific background of health professionals.

To date, no studies have been found in the literature in regard to the knowledge of the proper use of NSAIDs in the city of Benghazi among dentists. Therefore, the current study was designed to evaluate the current awareness regarding the use of NSAIDs during dental practice and to evaluate the association of the level of education and years of experience of dental practitioners with the awareness of the safety profile of NSAIDs.

2. MATERIAL AND METHODS

2.1. Study design

This observational cross-sectional study was conducted in Benghazi city between August and October 2024. Informed consent was taken from all participants for agreement to fill out the questionnaire. The questionnaire was formulated in English and was filled by the dentists in approximately 2 minutes during a visit to their dental clinic on the basis of an interview. Participants were selected randomly from approximately every dental clinic in Benghazi. The questionnaire was filled with check-list answers and composed of three sections, including personal information, manner of practicing NSAIDs, and knowledge of the safety profile regarding NSAIDs.

2.2. Sample size calculation

The sample size was composed of 341 participants representing dentists working in dental clinics in Benghazi and was calculated according to Krejcie and Morgan Table (19). The sample size was affirmed by using the Raosoft online calculator (www.Raosoft.com) (20), assuming that approximately 3000 dentists work in the dental clinics. The confidence level of 95% with a 5 % marginal error was taken into consideration to achieve the value of the sample size.

2.3. Statistical Analysis

The statistics package for Social Science version 21 (SPSS) software was used for transferring and analyzing data. Results of the study were presented in descriptive analysis as frequencies (n) and percentages (%). Analysis of qualitative data was done using the Chi-squared test. A two-tailed P value of less than 0.05 was considered a significant association.

3. RESULTS

A total of 341 questionnaires were collected over two months. Females accounted for the majority (60.7%). General practitioners represented 67.0% of the participants. About 61.0% of the dentists had clinical experience of less than 10 years. The age group of (31-40) was the predominant (48.1%), (Table 1).

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Table 1. Demographic and professional data of dentists in Benghazi (n = 341)

Variable	Frequency (%)
Gender	
Male	134 (39.3 %)
Female	207 (60.7 %)
Age	
25-30	112 (32.8 %)
31-40	164 (48.1 %)
41-50	45 (13.2 %)
51-60	11 (3.2 %)
>60	9 (2.6 %)
Nationality	
Libyan	331 (97.1 %)
Non-Libyan	10 (2.9 %)
Education	
Bachelor degree	231 (67.0 %)
Master degree	93 (27.3 %)
PhD	14 (4.1 %)
Diploma	3 (0.9 %)
Clinical Rank	
General Practitioner	231 (67.7 %)
Specialist	110 (32.3 %)
Years of experience	
<10 years	208 (61.0 %)
10-20 years	97 (28.4 %)
> 20 years	36 (10.6 %)

3.1. The clinical practice of NSAIDS

Ibuprofen and Ketoprofen were the most prescribed NSAIDs by participants, 67.2% and 51.6, respectively, followed by Naproxin, Diclofenac K, and Diclofenac Na (36.1%, 26.1%, and 19.6%), respectively, (Table 2).

More than fifty percent (55.4%) of them have been prescribed NSAIDs for less than three days (short period) and 44.0% have been prescribed NSAIDs up to seven days.

Postoperative pain, dental pain, and odontogenic infections were the most common clinical situations in which NSAIDs were prescribed (71.3%, 59.5%, and 49.6%), respectively. NSAIDs were used in the treatment of temporomandibular joint pain by approximately twenty percent (20.8%) of dentists. Participants who have been prescribed NSAIDs with antibiotics sometimes account for 51.3%. Over sixty (63.6%) of the participants had prescribed proton pump inhibitors as needed with NSAIDs (Table 2).

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Table 2. Clinical practice of dentists in Benghazi (n = 341)

Clinical Practice	Frequency (%)
In your current practice, how many times do you prescribe NSAIDs?	
Always	24 (7.0 %)
Frequently	80 (23.5 %)
Sometimes	202 (59.2 %)
Rarely	32 (9.4 %)
Never	3 (0.9 %)
Which types do you prescribe during dental practice (Yes)?	
Ketoprofen	176 (51.6 %)
Ibuprofen	229 (67.2 %)
Naproxen	123 (36.1 %)
Diclofenac Na	67 (19.6 %)
Diclofenac K	89 (26.1 %)
Aspirin	11 (3.2 %)
Piroxicam	3 (0.9 %)
Meloxicam	1 (0.3 %)
In which situations do you use NSAIDs (Yes)?	
TMJ pain	71 (20.8 %)
Infections	169 (49.6 %)
Post-operative	243 (71.3 %)
Dental pain	203 (59.5 %)
What period do you often prescribe?	
Short [less than 3 days]	189 (55.4 %)
Intermediate [between 3 and 7 days]	150 (44.0 %)
Long [more than 7 days]	0 (0.0 %)
Never	2 (0.6 %)
In your current practice, how often do you prescribe NSAIDs with Antibiotics (Yes)?	
Always	26 (7.6 %)
Frequently	74 (21.7 %)
Sometimes	175 (51.3 %)
Rarely	58 (17.0 %)
Never	8 (2.3 %)
Do you prescribe Omeprazole (proton pump inhibitor) with NSAIDs (Yes)?	
Always	10 (2.9 %)
Sometimes	217 (63.6 %)
Never	114 (33.4 %)

Ibuprofen was preferred to be used more by dentists with 10 to 20 years of clinical experience as well as those with less than 10 years (70% and 69.2%, respectively, *P* value = 0.026). Participants with more than 20 years of experience and a higher academic degree preferred to use Diclofenac Na. Years of experience and level of education of the dentists were highly significantly associated with the prescribing of Diclofenac Na (*P* value = 0.000 and 0.004, respectively) (Table 3).

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Table 3. Association between types of NSAIDs used by dentists in Benghazi with years of experience and level of education (n = 341)

Type of NSAIDs (yes)	<10 years (%)	10-20 years (%)	>20 years (%)	*P* value
Ketoprofen	108 (51.9)	50 (51.5)	18 (50.0)	0.977
Ibuprofen	144 (69.2)	68 (70.1)	17 (47.2)	0.026*
Naproxen	75 (36.1)	35 (36.1)	13 (36.1)	1.000
Diclofenac Na	31 (14.9)	19 (19.6)	17 (47.2)	0.000*
Diclofenac K	59 (28.4)	22 (22.7)	8 (22.2)	0.491
Aspirin	9 (4.3)	1 (1.0)	1 (2.8)	0.284
Piroxicam	0 (0.0)	2 (2.1)	1 (2.8)	0.079
Meloxicam	0 (0.0)	1 (1.0)	0 (0.0)	0.390

Type of NSAIDs (yes)	Diploma (%)	BDS (%)	MSc (%)	PhD (%)	*P* value
Ketoprofen	0 (0.0)	125 (54.1)	44 (47.3)	7 (50.0)	0.233
Ibuprofen	2 (66.7)	155 (67.1)	64 (68.8)	8 (57.1)	0.853
Naproxen	2 (66.7)	92 (39.8)	26 (28.0)	3 (21.4)	0.071
Diclofenac Na	0 (0.0)	34 (14.7)	28 (18.3)	5 (35.7)	0.004*
Diclofenac K	1 (33.3)	60 (26.0)	24 (25.8)	4 (28.6)	0.978
Aspirin	0 (0.0)	8 (3.5)	8 (3.2)	0 (0.0)	1.000
Piroxicam	0 (0.0)	2 (0.9)	1 (1.1)	0 (0.0)	1.000
Meloxicam	0 (0.0)	0 (0.0)	1 (1.1)	0 (0.0)	0.323

*** <0.05 is a statistically significant association.**

3.2. Awareness of the safety profile of NSAIDS

Pregnancy was the most cited to be contraindicated (58.9%) followed by renal diseases, allergy to other medications, peptic ulcer, liver disease, and asthmatic patients (49.3%, 41.6%, 39.0%, 37.8%, and 35.5%), respectively. Dentists' qualifications and years of experience were associated with the avoidance of giving NSAIDs to peptic ulcer patients (*P* value = 0.022 and 0.030), respectively. Additionally, dentists who have been practicing dentistry for more than 20 years emphasized NSAIDs cannot be used for patients with ulcerative colitis, breast-feeding and celiac disease (38.9%, 36.1%, and 19.4%) with *P* value (0.032, 0.040, and 0.012), respectively, (Tables 4 and 5).

Participants agreed that nausea was the most common side effect (45.2%), followed by abdominal pain, allergic reaction to NSAIDs, heartburn, and vomiting (39.3%, 36.7%, 29.0%, and 22.3%), respectively. Awareness of heartburn as a side effect that may be caused by using NSAIDs was highly significantly associated with the level of education and years of experience (*P* value = 0.000 and 0.001), respectively. Furthermore, level of education was significantly associated with awareness of abdominal pain as one of the frequent side effects (*P* value = 0.004), especially in those with a degree of PhD and Diploma (64.3% and 100%), respectively, (Tables 4 and 5).

Warfarin was reported by 27.6% of the dentists to have interaction with NSAIDs, followed by oral contraceptives and beta blockers (14.1% and 13.8%), respectively. Dentists with an MSc degree have a significant awareness regarding interactions of warfarin with NSAIDs (40.9%, *P* value = 0.006). Years of experience were associated with the awareness of Ranitidine interaction (*P* value = 0.032), (Tables 4 and 5).

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Table 4: Association of awareness of safety profile of NSAIDs with years of experience regarding dentists in Benghazi (n = 341)

Awareness	Total no	<10 years (%)	10-20 years (%)	>20 years (%)	*P* value
Awareness of side effects of NSAIDs (Yes)					
Abdominal pain	134 (39.3)	73 (35.1)	48 (49.5)	13 (36.1)	0.052
Nausea	154 (45.2)	91 (43.8)	44 (45.4)	19 (52.8)	0.603
Heartburn	99 (29.0)	46 (22.1)	36 (37.1)	17 (47.2)	0.001*
Diarrhea	47 (13.8)	26 (12.5)	15 (15.5)	6 (16.7)	0.680
Dyspnea	21 (6.2)	12 (5.8)	4 (4.1)	5 (13.9)	0.107
Vomiting	76 (22.3)	47 (22.6)	21 (21.6)	8 (22.2)	0.983
Rise in blood pressure	3 (0.9)	2 (1.0)	0 (0.0)	1 (2.8)	0.308
Allergy to NSAIDs	125 (36.7)	73 (35.1)	38 (39.2)	14 (38.9)	0.756
Awareness of contraindications for using NSAIDs (Yes)					
Pregnancy	201 (58.9)	116 (55.8)	59 (60.8)	26 (72.2)	0.163
Angina	31 (9.1)	12 (5.8)	12 (12.4)	7 (19.4)	0.013*
Myocardial Infarction	47 (13.8)	30 (14.4)	11 (11.3)	6 (16.7)	0.667
Stroke	38 (11.1)	21 (10.1)	11 (11.3)	6 (16.7)	0.511
Peptic ulcer	133 (39.0)	70 (33.7)	44 (45.4)	19 (52.8)	0.030*
Asthma	121 (35.5)	67 (32.2)	39 (40.2)	15 (41.7)	0.284
Renal insufficiency	168 (49.3)	104 (50.0)	42 (43.3)	22 (61.1)	0.178
Liver diseases	129 (37.8)	74 (35.6)	38 (39.2)	17 (47.2)	0.392
Allergy to other medications	142 (41.6)	78 (37.5)	45 (46.4)	19 (52.8)	0.122
Heart failure	55 (16.1)	34 (16.3)	11 (11.3)	10 (27.8)	0.072
Hypertension	91 (26.7)	57 (27.4)	26 (26.8)	8 (22.2)	0.810
Crohn's disease	40 (11.7)	24 (11.5)	9 (9.3)	7 (19.4)	0.267
Ulcerative colitis	76 (22.3)	40 (19.2)	22 (22.7)	14 (38.9)	0.032*
Celiac disease	26 (7.6)	11 (5.3)	8 (8.2)	7 (19.4)	0.012*
Breast feeding	92 (27.0)	46 (22.1)	33 (34.0)	13 (36.1)	0.040*
Awareness of drug-interaction of NSAIDs with other medications (Yes)					
Warfarin	94 (27.6)	51 (24.5)	32 (33.0)	11 (30.6)	0.278
Oral hypoglycemic	21 (6.2)	13 (6.3)	5 (5.2)	3 (8.3)	0.792
Beta blockers	47 (13.8)	29 (13.9)	12 (12.4)	6 (16.7)	0.811
ACEIs	21 (6.2)	11 (5.3)	8 (8.2)	2 (5.6)	0.598
Oral contraceptives	48 (14.1)	22 (10.6)	19 (19.6)	7 (19.4)	0.067
Prednisolone	16 (4.7)	7 (3.4)	5 (5.2)	4 (11.1)	0.129
Ranitidine	12 (3.5)	7 (3.4)	1 (1.0)	4 (11.1)	0.032*
Diuretics	20 (5.9)	13 (6.3)	3 (3.1)	4 (11.1)	0.202

*** <0.05 is a statistically significant association.**

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Table 5: Association of Awareness of safety profile of NSAIDs with level of education regarding dentists in Benghazi (*n* =341)

Awareness	Total no	Diploma (%)	BDS (%)	MSc (%)	PhD (%)	*P* value
Awareness of side effects of NSAIDs (Yes)						
Abdominal pain	134 (39.3)	3 (100.0)	79 (34.2)	43 (46.2)	9 (64.3)	0.004*
Nausea	154 (45.2)	2 (66.7)	100 (43.3)	44 (47.3)	8 (57.1)	0.611
Heartburn	99 (29.0)	0 (0.0)	52 (22.5)	42 (45.2)	5 (35.7)	0.000*
Diarrhea	47 (13.8)	0 (0.0)	32 (13.9)	13 (14.0)	2 (14.3)	1.000
Dyspnea	21 (6.2)	0 (0.0)	11 (4.8)	9 (9.7)	1 (7.1)	0.319
Vomiting	76 (22.3)	0 (0.0)	52 (22.5)	21 (22.6)	3 (21.4)	1.000
Rise in blood pressure	3 (0.9)	0 (0.0)	2 (0.9)	1 (1.1)	0 (0.0)	1.000
Allergy to NSAIDs	125 (36.7)	1 (33.3)	79 (34.2)	40 (43.0)	5 (35.7)	0.502
Awareness of contraindications for using NSAIDs (Yes)						
Pregnancy	201 (58.9)	2 (66.7)	142 (61.5)	50 (53.8)	7 (50.0)	0.515
Angina	31 (9.1)	1 (33.3)	17 (7.4)	12 (12.9)	1 (7.1)	0.145
Myocardial infarction	47 (13.8)	0 (0.0)	34 (14.7)	12 (12.9)	1 (7.1)	0.874
Stroke	38 (11.1)	1 (33.3)	24 (10.4)	10 (10.8)	3 (21.4)	0.225
Peptic ulcer	133 (39.0)	2 (66.7)	78 (33.8)	46 (49.5)	7 (50.0)	0.022*
Asthma	121 (35.5)	2 (66.7)	75 (32.5)	38 (40.9)	6 (42.9)	0.263
Renal insufficiency	168 (49.3)	3 (100.0)	113 (48.9)	44 (47.3)	8 (57.1)	0.378
Liver diseases	129 (37.8)	2 (66.7)	87 (37.7)	33 (35.5)	7 (50.0)	0.509
Allergy to other medications	142 (41.6)	1 (33.3)	89 (38.5)	44 (47.3)	8 (57.1)	0.287
Heart failure	55 (16.1)	1 (33.3)	38 (16.5)	11 (11.8)	5 (35.7)	0.084
Hypertension	91 (26.7)	1 (33.3)	65 (28.1)	23 (24.7)	2 (14.3)	0.632
Crohn's disease	40 (11.7)	2 (66.7)	26 (11.3)	11 (11.8)	1 (7.1)	0.090
Ulcerative colitis	76 (22.3)	2 (66.7)	46 (19.9)	25 (26.9)	3 (21.4)	0.146
Celiac disease	26 (7.6)	1 (33.3)	15 (6.5)	10 (10.8)	0 (0.0)	0.120
Breast feeding	92 (27.0)	1 (33.3)	59 (25.5)	28 (30.1)	4 (28.6)	0.783
Awareness of drug-interaction of NSAIDs with other medications (Yes)						
Warfarin	94 (27.6)	0 (0.0)	52 (22.5)	38 (40.9)	4 (28.6)	0.006*
Oral hypoglycemic	21 (6.2)	0 (0.0)	10 (4.3)	10 (10.8)	1 (7.1)	0.151
Beta blockers	47 (13.8)	0 (0.0)	33 (14.3)	13 (14.0)	1 (7.1)	0.947
ACEIs	21 (6.2)	0 (0.0)	10 (4.3)	10 (10.8)	1 (7.1)	0.151
Oral contraceptives	48 (14.1)	0 (0.0)	33 (14.3)	14 (15.1)	1 (7.1)	0.900
Prednisolone	16 (4.7)	1 (33.3)	8 (3.5)	6 (6.5)	1 (7.1)	0.083
Ranitidine	12 (3.5)	0 (0.0)	9 (3.9)	3 (3.2)	0 (0.0)	1.000
Diuretics	20 (5.9)	0 (0.0)	11 (4.8)	8 (8.6)	1 (7.1)	0.410

*** <0.05 is a statistically significant association.**

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4. DISCUSSION

Dentists have used to prescribe different types of NSAIDs regularly in dental practice to manage pain and inflammation as reported in our study. This should be based on well-scientific knowledge gained from their academic learning and clinical experience in the field. Our suspected results of the study are to find more awareness of accurate clinical manipulation of NSAIDS during clinical practice, especially among recently graduated practitioners, as a reflection of close contact with academic-based knowledge as well as among dental practitioners with more clinical years of experience in the dental field.

Ibuprofen was the first line of NSAIDs used among our participants. This was in line with many studies; a multicenter, observational cohort study by Bradbury who stated that Ibuprofen and Diclofenac adhered to prescribing physicians' acceptance for managing pain in Ireland [21]. A survey conducted in Tunisia, the capital, in 2021, cited that 82% of dentists were prescribing Ibuprofen during dental practice [22]. In addition to the study by Halling et al., in Germany, that demonstrated a significant increase in prescriptions among dentists (80.1%, $P < 0.05$) [23]. Our survey revealed that more than half of recent graduate participants with years of experience of less than 10 years cited that Ibuprofen was the most used NSAIDs in dental practice, as well as those with 10-20 years of experience who have reported similar results (P=0.026), which was also described similarly in a recent study in Yemen that reported 66.6% of dentists have an experience of less than 5 years and 80.5% of dentists involved in this study were prescribing Ibuprofen for dental pain [24].

On the other hand, preferring to use Diclofenac Na was highly significantly associated with participants with more than 20 years of experience and those with a higher academic degree (P=0.000 and P=0.004), respectively. Yu's study, in 2020, was in agreement with our outcomes as it reported that Diclofenac was the most frequently prescribed analgesic along with Acetaminophen in many dental conditions and proper prescription was significantly associated with more experienced and post-graduated dentists (P value 0.004) [25]. Like other NSAIDs, the risk of adverse effects was reported to be increased when Diclofenac Na was used to relieve pain and reduce inflammation. It is a non-selective COX inhibitor, leading to inhibition of the protective function of lining mucosa of the stomach, increasing the risk of heart attack and stroke, reduction of kidney function, and association with liver toxicity [26, 27]. This may explain why dentists with less clinical experience and those with low qualifications included in our study avoid manipulating clinically with Diclofenac.

The aforementioned complications of Diclofenac Na were related to dose quantity, duration, and presence of risky patients. These adverse effects can be minimized by shortening the duration with the minimum effective dose, and may use appropriate gastro-protective agents when necessary. Alternative therapeutic options may be used when a potential risk overweighs its benefit, in addition to health care professional consultation [26].

Diclofenac potassium (K) was used by more than twenty-five percent of dentists involved in our study rather than Diclofenac Na. Diclofenac K is another type of Diclofenac that was formulated to overcome the resistance of absorption of sodium-salt preparation of Diclofenac in the acidic medium of the stomach. Diclofenac Na reaches a peak in approximately 2 hours [28]. In contrast, Diclofenac K powder sachet has an affinity for dissolving in acidic media that facilitates rapid absorption and reaching a peak within 8 minutes; in addition, Diclofenac potassium sachet can be taken safely with food [28]. These may give more preference to prescribing Diclofenac (K) than Diclofenac (Na) by the dentists in our study. Nonetheless, 75 mg intramuscular (IM) Diclofenac Na has been reported to have a significant effect in relieving acute pain after 30 minutes, in comparison with 75 mg Diclofenac K tablet [29].

In the present study, it is striking that Ketoprofen has been demonstrated by participants as the second most used NSAIDs during dental practice, despite the absence of a significant effect of years of experience and educational level on prescribing of Ketoprofen. A meta-analysis study by Sarzi-Puttini et al. showed ketoprofen was more effective over diclofenac and ibuprofen in controlling pain [30]. Additionally, pain was reported to be significantly lowered by using Ketoprofen in comparison with diclofenac after 6 hours post-surgery [31]. Studies by Sarzi-Puttini et al. also reported that Ketoprofen was reported as well-tolerated in the elderly, and was considered as a safe, rapid, and more effective NSAIDs [30, 32]. The trend of our participants to use Ketoprofen most frequently may be related to their experience of its favorable characteristics in clinical practice that was mentioned in the previous studies.

A lot of general practitioners have preferred to prescribe Naproxen in our study, more than thirty-five percent. Naproxen was reported by 78% of dentists in a study by Teoh et al. in Australia as an appropriate choice in the treatment of dental pain due to its accepted safety profile [33]. A similar trend was expressed by Şermet et al. in Istanbul, Turkey [34], which gave support to the high frequency of our results. Cooper et al. cited that in post-operative dental surgery, a single dose of Naproxen was significantly higher than Ibuprofen in relieving the pain [35]. In addition to the reported studies that demonstrated its safety for cardiovascular risk [16, 36], Naproxen was approved by the Food and Drug Administration (FDA) as the safest non-aspirin NSAIDs, due to its low selectivity for COX-2 [37]. Remarkably, cardiovascular risk was highly significantly associated with selective COX-2 inhibitors such as Celecoxib with approval by FDA [16, 32, 36, 38].

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One participant used to prescribe Meloxicam frequently. Noticeably, this participant has a degree of master's (M.Sc.) and has clinical experience of 10 to 20 years, which may reflect the understanding of using this medication. Meloxicam was reported to be more tolerated regarding the gastrointestinal system when compared with other NSAIDs [39]. Many studies reported its efficiency in relieving post-operative pain. A double-blind randomized parallel-group clinical trial study reported that a single dose of Meloxicam 15 mg had more analgesic and anti-trismus effects than using Diclofenac after extraction of a difficult tooth in the lower jaw 'third molar' [40]**.** Another recent study in 2020, revealed that administration of 15 mg meloxicam before 60 minutes of surgical removal of the mandibular third molar had a significant reduction in post-operative pain and edema (*P* value = 0.000) [41].

Piroxicam is another NSAID which is related to Meloxicam (Oxicam group). In our study, 2 participants were used to prescribe it. Piroxicam has a maximum daily dose of 20 mg, and should be prescribed for young people who have no comorbidity with other diseases and should be avoided in the elderly [42]. Nevertheless, other studies have cited that Meloxicam was more effective in pain relief and with substantial duration of action than Piroxicam and Diclofenac [39, 42].

Interestingly, our study has shown that fewer participants have used Aspirin to relieve dental pain (3.2%). As reported, chronic use of high doses leads to an increased risk of gastric ulceration and renal dysfunction [4]. In general, aspirin should be avoided in children less than 16 years of age, as it may develop Reye's syndrome [43]. Ibuprofen of 400 mg was reported to be favorable and more effective in relieving dental pain with markedly longer action than 650 mg of Aspirin [44].

More than half of our participants were prescribed NSAIDs for less than 3 days in order to reduce discomfort related to their side effects. Nausea, abdominal pain, allergy to NSAIDs, heartburn, vomiting, and diarrhea were reported by our participants as the most common side effects, respectively. The outcomes of our study were in agreement with a study by Muthanna that reported more than half (53.9%) were aware of most gastrointestinal side effects of NSAIDs [24]. Awareness of heartburn and abdominal pain were the lonely significantly associated with the degree of academic qualification (*P* value = 0.000 and 0.004), respectively. Otherwise, there was no effect of levels of education among dentists on the awareness of the side effects of NSAIDs.

In this context, vomiting, rashes, gastric pain, blurred vision, and dizziness have been reported less frequently with the use of Ibuprofen, and high doses of Ibuprofen may cause seizures, dyspnea and an increase in blood pressure [9]. For patients with hypersensitivity to Aspirin (aspirin-induced asthma), NSAIDs should be avoided, especially Ibuprofen [8]. Aside from Aspirin, all NSAIDs, when taken at normal therapeutic doses, could raise blood pressure (BP) in hypertensive patients as well as normal individuals [45, 46].

As expected, in the present study, pregnancy was the most cited to be avoided with NSAIDs (58.9%), followed by renal diseases, allergy to other medications, peptic ulcer, liver disease, and asthmatic patients, respectively. In the study of Monisha, participants avoided the use of NSAIDs during pregnancy and renal insufficiency (88% and 80%, respectively) [47]. Regarding pregnancy, The Food and Drug Administration (FDA) included most NSAIDs in category (B) during the first three months of pregnancy and as category (D) during the last three months [5], and FDA recommended avoiding the use of NSAIDs after week 20 of pregnancy [48, 49].Our participants with higher qualifications affirmed to avoid giving NSAIDs to peptic ulcer patients (P value = 0.022). Additionally, a dentist who has been practicing dentistry for more than 20 years emphasized NSAIDs cannot be used for patients with peptic ulcers (P value = 0.030). Awareness of some gastrointestinal diseases such as ulcerative colitis and celiac was associated with years of clinical experience by dentists (P value = 0.032 and 0.012), respectively.

Adverse effects were reported in many studies; long-term use of NSAIDs may cause kidney and gastrointestinal complications and many medically compromised patients may deteriorate with NSAIDs comorbidity [50, 51]. The risk of myocardial infarction as well as renal and hepatic dysfunction was elevated with chronic high doses of Ibuprofen. Ibuprofen has been reported to cause gastrointestinal bleeding, consequently potentiating the risk of gastric ulcers. In addition, renal damage, heart failure, hyperkalemia, and bronchospasm were related to high doses of Ibuprofen use [9]. A lot of studies have reported that Aspirin and NSAIDs such as Ibuprofen could have induced an attack in children and adult patients with asthma (a non-allergic mechanism) [52-54].

In the case of breastfeeding, about twenty-five percent of participants preferred not to give NSAIDs to avoid harmfulness to the infant and was significantly associated with more clinically experienced dentists (*P* = 0.040). However, no clear explanations were clarified by the participants regarding avoidance of prescription, but Donaldson and Goodchild' study revealed and explained that Aspirin with a dose of more than 100 mg was reported to develop Reye syndrome and platelet dysfunction and, in contrast, other than Selective COX-2 inhibitors, Ibuprofen, and other NSAIDs can be used for mother-feeding patients [55]. Additionally, Rigourd et al. in other studies also supported the safety of Ibuprofen and Ketoprofen for mother-feeding patients as the relative infant dose (RID) was significantly lower than 1% in both [56, 57].

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In our survey, a lack of knowledge and awareness were markedly observed regarding drug-interactions with NSAIDs irrespective of Warfarin. Warfarin was expressed in our survey as the most avoided drug with NSAIDs. Similar findings described by Sharma et al. (79%) [12]. The study of Battistella et al. also confirmed the hazard of co-prescription of NSAIDs with warfarin that agreed with the avoidance reported in our study [10]. There was only a significant association between the awareness of hazards of co-administration of NSAIDs with Warfarin and the educational degrees of the dentists ($P = 0.006$).

There was controversy in some outcomes of previous studies regarding Warfarin; Battistella et al. reported that the risk of bleeding in upper GI in those taking warfarin concomitantly with non-selective and selective COX-2 inhibitors was in similar increase compared with control patients not treated with NSAIDs [10]. On the contrary, Sarzi-Puttini et al. have reported no interaction between Ketoprofen and warfarin was observed [32].

Avoidance of prescribing NSAIDs with oral contraceptive medications was the second most reported drug-interaction by our participants. The risk of venous thromboembolism in women on oral contraceptive medication was reported by Meaidi et al. to be significantly associated with concurrent use of NSAIDs [58].

Other medication-interactions with NSAIDs were cited in many studies. Angiotensin converting enzyme inhibitors (ACEIs), Calcium-channel blockers, Beta-blockers, and Diuretics have been found to have low significant interaction with NSAIDs in elderly hypertensive patients [11, 59-61]. Other studies revealed that a statistically significant increase in BP was reported when NSAIDs (other than Naproxen and Aspirin) were co-administered with Beta-blockers, angiotensin receptor blockers (ARBs) and ACEIs; NSAIDs attenuated their action while having found low effect on BP with diuretics and calcium channel blockers [54, 62].

Concurrent use of NSAIDs even in a short-term with glucocorticoids will result in an increased risk of gastrointestinal bleeding [12, 63] that was demonstrated in our study by fewer participants. Similarly, interaction with oral hypoglycemics was also reported by fewer participants as NSAIDs were reported to increase their half-life [12].

About fifty percent of our participants reported concurrent use of antibiotics with NSAIDs in some particular situations. Antibiotics could be prescribed concurrently with NSAIDs, and no evidence of the presence of adverse effects was reported [64]. Effects of NSAIDs were cited to be reduced when used with Antacids [59] which was notified and significantly associated with high years of experience in our survey ($P = 0.032$).

It is worthwhile highlighting some critical points regarding a prophylactic dose of Aspirin 75-100 mg that is commonly used by dental patients. Co-administration of NSAIDs (other than Diclofenac) with Aspirin may potentiate clot formation due to its competitive access to the site of platelet-expressed COX-1 [8]. Potential interaction with Aspirin could be reduced if Ibuprofen is taken more than 30 minutes after a prophylactic dose of Aspirin, according to FDA [54, 65].

More than sixty percent of dentists in our survey have reported that Omeprazole, a gastro-protective agent, was used with NSAIDs in some instances as needed. A Study by Bakhriansyah et al. demonstrated that non-selective COX inhibitors and selective COX-2 used with PPIs were significantly associated with a decrease in the risk of gastro-intestinal perforation, ulceration, and bleeding in comparison with non-selective COX inhibitors that used alone ($P < 0.05$) [66]. Another study revealed that ketoprofen 200 mg when administrated with omeprazole 20 mg once daily had significantly more comfortable postoperative pain [67]. Accordingly, for some systemic diseases that require long-term use of NSAIDS such as osteoarthritis, PPI is preferred to be used [63]. In contrast, short-term use of NSAIDs was more practiced in dentistry and that may not necessitate the use of PPI, unless in the case of accompanying discomfort and for those with high risk.

Finally, this survey highlighted the utilization and clinical manipulation of NSAIDs during dental practice and the work has attempted to put the level of education and period of clinical experience in focus despite the lack of sources of data in the literature concerning this issue.

5. CONCLUSION

To conclude, the study results have revealed less comprehension regarding scientific background knowledge of NSAIDs. There was little effect on the level of education and years of experience with awareness of using NSAIDs during dental practice. The safety profile of NSAIDs should be kept in consideration by physicians to reach the proper therapeutic decision. In addition, many parameters including the age and weight of the patient, medical history, intensity of pain, and understanding of pharmacokinetics and pharmacodynamics of NSAIDs will guide physicians in making the decision.

6. RECOMMENDATIONS

According to the outcomes of the study, further workshops and events are needed to close the gap and should be continued to improve the level of knowledge and practice regarding the use of NSAIDs, and to minimize the risk of a lot of serious adverse effects on the patients who attend dental clinics.

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