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Evaluation of the phytochemicals and antimicrobial properties of *Tetrapleura Tetraptera* and *Piper Nigrum*

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ABSTRACT

The search for new substances with antibacterial activities has become an urgent necessity due to the resistance of many bacteria of medical importance to antibiotics. In an attempt to seek out new antibacterial agents from plants, *E. coli*, *S. aureus*, and *Salmonella spp* susceptibility to the seed extracts of *Tetrapleura tetraptera and Piper nigrum* were assessed. A Qualitative phytochemical screening was also done to establish the various phytochemicals found in the plants. To achieve these findings, the dried seeds of *Tetrapleura tetraptera and Piper nigrum* were collected in the Bamenda food market and ground. Further, the powder obtained was subjected to aqueous and alcoholic extractions separately in which the alcoholic and aqueous extracts of *Tetrapleura teraptera and Piper nigrum* seeds were evaluated for their antibacterial potential against *E. coli, S. aureus,* and *Salmonella spp* using agar diffusion. The obtained results indicated that *S. aureus and E. coli* were susceptible to the alcoholic and aqueous extract of *Tetrapleura tetraptera* (with a MIC of 50mg/ml; 100mg/ml), respectively, for *S.aureus* and (25mg/ml; 50mg/ml) for *E.coli.* For *S. aureus,* susceptibility to aqueous extract of *Piper nigrum* shows sensitivity (with MIC of 100mg/ml). Complete resistance was registered with the alcoholic extracts of *Piper nigrum*. Furthermore, the phytochemical screening results indicated the presence of resins, alkaloids, glycosides, tannins, flavonoids (present in all powder), and saponins (absent only in *Piper nigrum).* In conclusion, the alcoholic and aqueous extract of *Tetrapleura tetraptera* seeds has antibacterial activity against *S. aureus* and *E. coli*. It was proposed that further studies should be carried out on the susceptibility of *Tetrapleura tetraptera* to other bacteria.

Keywords : *Tetrapleura tetraptera, Piper nigrum*, Antimicrobial properties, *E. coli*.

1. Introduction

For centuries, people have recognized the health benefits of plants. This has become even more relevant today as the effectiveness of antibiotics declines in the face of increasingly resistant pathogens (Abdallah, 2017). Spices packed with bioactive compounds have a long history of use across cultures for various purposes beyond just flavoring food (Gupta et al., 2014; Jessica Elizabeth et al., 2017). They act as natural preservatives, extending shelf life and preventing food spoilage and foodborne illness (Liu et al., 2017). Additionally, some spices have applications in both food production and traditional medicine, where they can inhibit infections and eliminate harmful pathogens. The antibacterial efficacy of some spices and seasonings have been proved scientifically, such as black seed (*Nigella sativa*) (Abdallah & Koko, 2017), garlic bulb (*Allium sativum*) (Shafiur Rahman et al., 2006), onion (*Allium cepa*) (Kim, 1997), thyme (*Thymus vulgaris*) and clove (*Syzygium aromaticum*) (Nzeako et al., 2006), cinnamon bark (*Cinnamomum verum*) (Julianti et al., 2017), oregano (*Origanum vulgare*) (Saeed & Tariq, 2009), cumin (*Cuminum cyminum*) (Allahabri et al ., 2010) and many more. In light of the current worldwide focus on natural products, medicinal plants, and traditional medicine, it is necessary to reinvigorate research on spices to develop novel natural pharmaceuticals. It is worth noting that a significant percentage, up to 80%, of the global population continues to depend on medicinal plants and natural products as their primary source of healthcare (Beyene et al., 2016). This study highlights the medicinal and nutritional importance of black pepper (*Piper nigrum*) and *Tetrapleura tetraptera* fruits and their efficacy as antibacterial agents.



Figure 1. *Piper nigrium* seed and powder.



Figure 2. *Tetrapleura tetraptera* seed and powder.

2. Experimental part

2. 1. Materials

A good quantity of dry spices of *Tetrapleura tetraptera* and *Piper nigrum* were obtained from the Bamenda food market from randomly selected plants in February 2021. These spices were brought to the laboratory and passed in an incubator for 24 hours to dry. The surface of the working table was then disinfected with a 1:10 dilution of hypochlorite for 15 minutes. The spices were well ground on the grinding stone to obtain powder. The powder was then accurately weighed out using a balance, divided into three portions, and kept in two separate air-tight Containers for later use.

2. 2. Geographical distribution, medicinal importance, and classification of plants.

2. 2. 1. *Tetrapleura tetraptera*

- **Geographical distribution and medical importance**

Tetrapleura tetraptera is native to tropical Africa with a distribution range extending from Mauritania to Tanzania (Anyamele et al., 2023), commonly known as the “Aidan tree” in Nigeria, "Kikangabalimu" in Uganda, "Prekese" in Ghana, and “four cona” in Bamenda, Cameroon. The tree prefers humid and tropical climates, thriving in rainforests and regions with rich, well-drained soils. *Tetrapleura tetraptera* has significant medicinal value, particularly in traditional African medicine. Some of its key medical benefits include antimicrobial properties, Antioxidant Properties, Anti-inflammatory and Analgesic Effects**.** Its medicinal benefits are attributed to bioactive compounds such as alkaloids, flavonoids, saponins, tannins, phenols, and glycosides, which are essential for health (Adesina et al., 2016; Ekwenye & Okorie, 2010).

- **Botanical classification**

Kingdom: Plantae
Order: Fabales
Family: Fabaceae
Genes: Tetrapleura
Species: *Tetrapleura tetrapterae*

2. 2. 2. *Piper nigrum*

- **Geographical distribution and medical importance**

Black pepper (*Piper nigrum*) is one of the most widely used spices in the world spices and is considered “ The King of spices’’ among various spices (Damanhouri & Ahmad, 2014), which has a significant geographical distribution such as India, Indonesia, Malaysia, and Brazil (Ahmad et al., 2012). The peppercorns of *Piper nigrum*, along with their active constituents, are commonly utilized in a variety of culinary dishes. Additionally, various parts of *Piper nigrum*, including its secondary metabolites, serve multiple purposes in medicine, as preservatives, and as natural control agents. Biologically, *Piper nigrum* holds significant value. Research has demonstrated that both peppercorns and the secondary metabolites of *Piper nigrum* exhibit a range of biological activities, including anti-apoptotic, antibacterial, anti-colon toxin, antidepressant, antifungal, anti-diarrheal, anti-inflammatory, anti-mutagenic, anti-metastatic, and antioxidative effects (Ashokkumar et al., 2021; Zou et al., 2024).

- **Botanical classification**

  Kingdom: Plantae

  Order: Piperrales

  Family: Piperaceae

  Genus: Piper

  Species: *Piper nigrum*

2. 3. Aqueous extraction

In the first portion, 25 g of the powdered spices were placed in a clean and sterile 200 ml sterile container, and the appropriate amount of distilled water was added. The container was well mixed by shaking intermittently. After 48 hours, the content was filtered using Whatman No1 filter paper into another clean sterile container. This container and its contents were then evaporated to dryness in an incubator at 500 degrees Celsius.

2. 4. Alcoholic extraction

For the second portion, 25 g of the powdered spices were placed in a clean and sterile 200 ml container and the same\ appropriate amount of methanol was added. The container was shaken intermittently for 48 hours, after which its contents were filtered using Whatman No1 filter paper into another clean, sterile container. This container and its contents were then evaporated to dryness in an incubator at 60 degrees Celsius.

2. 5. Fractionation of the extract

1g of each extract was dissolved in two pre-sterilized vial bottles containing 5 ml of distilled water. This gives a concentration of 100 mg/ml.



Figure 3. Alcoholic and aqueous extraction of *Piper nigrium.*



Figure 4. Alcoholic and aqueous extraction of *Tetraplera tetraptera*

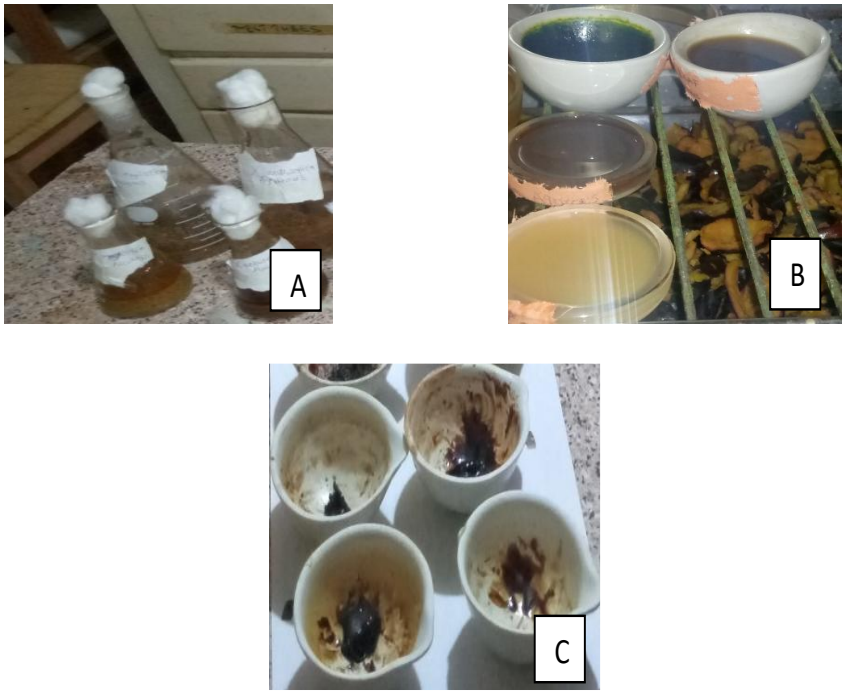

Figure 5. (A) Alcoholic and aqueous extraction, **(B)** removal process of solvent, and **(C)** Extract.

2. 6. Phytochemical screening

The methanolic and aqueous extraction of these spices (*Piper nigrum* and *Tetrapleura tetraptera*) were used as the samples for qualitative phytochemical screening of resins, saponins, flavonoids, alkaloids, and glycosides following the standard procedures described by (Evans, 1997).

- **Detection of resins**

0,5 g of the powdered spices were added to 5 ml of boiling ethanol. It was then filtered through Whatman No1 filter paper and the filtrate was diluted with 4 ml of 1% aqueous HCl. The formation of a heavy resinous precipitation indicated the presence of resins (Evans, 1997).

- **Detection of saponins**

0,5 g of each sample powder spice was stirred with 10 ml of distilled water in a test tube. The test tube and its contents were then placed in a water bath to heat up to boiling point. Frothing which persists in warming was taken as preliminary evidence for the presence of saponins.

- **Detection of flavonoids**

0,5 g of each sample of the powder spices was dissolved in 2 ml dilute NaOH solution. A few drops of concentrated H_2SO_4 were then added. The presence of flavonoids was indicated by the disappearance of color (Evans, 1997).

- **Detection of alkaloids**

0,5 g of each sample of the powder spices was stirred with 5 ml of 2 N HCl in a water bath. The content of the test tube was then filtered using Whatman No1 filter paper and 1ml of the filtrate was tested with a few drops of Dragendorff's reagent and a second 1ml portion treated similarly with Wagner Wagner's reagent.

- **Detection of glycosides**

0,5 g of each sample of the powdered spices was stirred with 10 ml of boiling distilled water. This was filtered and 2 ml of the filtrate was hydrolyzed with a few drops of concentrated HCl and the solution was rendered alkaline with a few drops of ammonia solution. 5 drops of this solution were added to 2 ml of Benedict's qualitative reagents and boiled. The appearance of a reddish-brown precipitate showed the presence of glycoside.

- **Detection of tannins**

0,5 g of each sample of the powdered spices was stirred with 10 ml of boiling distilled water. This was filtered, and a few drops of 6% ferric chloride were added to the filtrate. The second portion of the filtrate was treated with a few drops of iodine solution. The appearance of a faint bluish coloration confirms the presence of tannins.

2. 7. Identification of the test organisms

A pure culture of *Staphylococcus aureus*, *E. coli,* and *Salmonella* was obtained from the Bamenda Regional Hospital, they were all identified based on microscopical staining reactions and biochemical tests.

2. 7. 1. Identification of *S. aureus* on biochemical test

- **Catalase test**: This test was used to identify both gram-negative bacilli and gram-positive cocci isolated from MacConkey and blood agar.
- **Coagulase test**: this test was used to differentiate pathogenic *S. aureus* from nonpathogenic *Staphylococcus*. A drop of plasma was placed on a glass slide, using a wire loop, and a well-isolated colony was taken from the culture plate and emulsified with the drop of plasma. Agglutination was observed indicating *S. aureus* on motile bacteria.

2. 7. 2. Identification of *E. coli*

- **Indole test**: this test was carried out for all gram-negative bacilli isolated from MacConkey agar to differentiate indole-producing from non-indole-producing bacteria.
- **Motility test**: this test was done to differentiate motile from non-motile bacteria. A drop of the sub-cultured colony from peptone water using a pasture pipette was placed on a slide, covered with a cover slide, and observed under objective 10 after 2 minutes *E. coli* was also positive for catalase.

2. 7. 3. Identification of *Salmonella*

- *Salmonella* is the only test organism that was positive for catalase.

2. 8. Preparation of required media

3.8 g of the Muller Hinton agar powder was dissolved in 100 ml of distilled water and the solution was sterilized by autoclaving at 121 ℃ for 15 minutes and then waited to cool to 45 ℃. It was then poured into 5 sterile Petri dishes, where it cooled and solidified under sterile conditions. These petri dishes were dried and incubated for 24 hours to validate contamination by any microbe.

2. 9. Susceptibility testing

- **Preparation of isolate**

Susceptibility testing was done using the agar well diffusion technique.

- **Inoculum standardization**

A small piece of *staphylococcus aureus* pure culture was picked up from the plate with the aid of a sterile inoculating loop, diluted into 10 ml of pre-prepared alkaline peptone water in a test tube, and incubated for 24 hours. A small piece of *E. coli* and *Salmonella* pure culture was also picked up from the plate and diluted into 1 ml of sterile distilled water in a clean test tube. The test organisms were then adjusted to a turbidity of 0.5 McFarland by adding the pure culture progressively in 10 ml and 1 ml sterile distilled water respectively until it matched with the 0.5 McFarland standard.

- **Susceptibility testing against *staphylococcus aureus***

A plate of Muller Hinton agar was used and the standard inoculum of *Staphylococcus aureus* was poured on the plate. The excess inoculum was removed aseptically and the surface of the plate was allowed to dry. Three wells were dug on each section of the plate using a sterile radio antenna of about 4 mm; one well was filled with the aqueous extract, the second with the ethanol extract, the third with a solution of 1 mg/ml of chloramphenicol (positive control) and the fourth well was left empty (negative control).

- **Susceptibility testing against *E. coli.***

A plate of Muller Hinton agar was used, and the appropriate amount of inoculum of *E. coli* was poured on the plate. Excess inoculum was removed from the surface of the plate and allowed to dry. Three were dug with the help of a sterile radio antenna of about 4 mm. The plate was incubated at 37^0 C for 24 hours after which the antimicrobial sensitivity was evaluated.

- **Susceptibility testing against *Salmonella***

Not much work was done for *Salmonella* testing because the bacteria strain was resistant to all the extracts.

3. Results

3. 1. Phytochemical screening results

Table 1. Types of compounds identified in the phytochemical screening of *Tetrapleura tetraptera* and *Piper nigrum.*

Seed powder	Phytochemicals					
	Saponins	**Resins**	**Alkaloides**	**Tannins**	**Glycosides**	**Flavonoids**
Piper nigrum	-	++++	++	+	+	+
T. tetraptera	+	+++	+	+	+	++

(-): absent; (+): present, (++++) highly present

3. 2. Antimicrobial susceptibility results

Table 2. Evaluation of MIC (mg/ml) and antimicrobial susceptibility testing of *Tetrapleura tetraptera* and *Piper nigrum* on *S. aureus, E. coli,* and *Salmonella*.

Extract	*S. aureus*	*E. coli*	*Salmonella*
Alcoholic extract of *P nigrum*	100.00	100.00	00.00
Aqueous extract of *P nigrum*	100.00	100.00	00.00
Alcoholic extract of *T tetraptera*	50.00	25.00	00.00
Aqueous extract of *T tetraptera*	100.00	50.00	00.00

4. Discussion

Results of the phytochemical screening components (Saponin, resins, alkaloids, tannins, glycosides, flavonoids) of spices during this study indicated that *Tetrapleura tetraptera* contains all the six secondary metabolites studied, antibacterial susceptibility testing on *Staphylococcus aureus* and *E. coli* was sensitive to the aqueous, and alcoholic extract of *Tetrapleura tetraptera* at an MIC of 100 mg/ml for *S. aureus* and 50mg/ml for *E. coli* respectively at incubation temperature of 24 hours. On the other hand, the phytochemical screening of *Piper nigrum* revealed that the spice is highly rich in resins, alkaloids, flavonoids, glycosides, and tannins. The susceptibility testing on *Staphylococcus aureus* with the aqueous extract revealed it to be sensitive with an MIC of 100 mg/ml.

5. Conclusion

To conclude, the antibacterial susceptibility testing using an aqueous extract of *Tetrapleura tetraptera* and *Piper nigrum* on *Staphylococcus aureus* and *E. coli* revealed sensitivity, while the alcoholic extract of *Tetrapleura tetraptera* and *Piper nigru*m was also sensitive on *Staphylococcus aureus* and *E. coli*. On the other hand, the aqueous extract of *Piper nigrum* was sensitive only to Staphylococcus. Both the alcoholic and aqueous extracts of *Tetrapleura tetraptera* and *Piper nigrum* were resistant to *Staph* and *E. coli*. All these spices have phytochemical properties except for saponin which is absent in *Piper nigrum*. To the medical laboratory students; these plant extracts should be used to **Conflict of Interest**

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Data Availability

No data was used for the research described in the article.

test for the susceptibility of other groups of bacteria.

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Knowledge, attitude, and practices towards diabetes and diabetic retinopathy among diabetic patients at Medical Palestinian Complex, Ramallah

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ABSTRACT

Diabetes Mellitus (DM) is a worldwide growing burden. Diabetes and its complications constitute a major morbidity burden among the Palestinian population**.** The main aim of this study was to document the knowledge, attitude, and practices (KAP) of diabetic patients towards diabetes and diabetic retinopathy. This cross-sectional study was conducted over two months at a Medical Palestinian Complex (PMC) outpatient clinic in Ramallah. Fifty diabetic patients were included in the study, and the KAP of patients was assessed using a verbally administered questionnaire. Patients were placed in different categories, such as "good/poor" knowledge, "positive/negative" attitude, and "good/poor" practice. The study involved 50 participants, primarily male, with an average age of 54 years. Overall, knowledge and attitude scores regarding diabetes and diabetic retinopathy were found to be poor, while practice scores were suboptimal for diabetes and poor for diabetic retinopathy. The main barrier to regular follow-up was inadequate knowledge about the importance of eye check-ups. While there was no significant difference in knowledge or attitude towards diabetes and diabetic retinopathy, participants with higher education levels and income demonstrated better practice scores. Additionally, a positive attitude towards diabetes and diabetic retinopathy was associated with better diabetes practice. KAP regarding DM and DR were generally poor among the patients. So, there is an urgent need to improve education and awareness of DM and DR among diabetics, as it is a powerful tool for controlling the disease and its complications by improving patient compliance with treatment and follow-up.

Keywords: Knowledge, Attitude, Practice, Diabetes Miletus, Diabetic retinopathy.

1. Introduction

Diabetes Mellitus (DM) is one of the most common chronic illnesses. The World Health Organization estimates that 8.5% of the population worldwide have diabetes mellitus, a rate that has grown since 1980. Moreover, an estimated number of 422 million adults over 18 years have DM (*Palestine (West Bank) STEPS Survey 2010- 2011 Fact Sheet.*, 2012; *World Health Organization Annual Report* 2016). Currently, there are more than 30 million Americans who have been diagnosed with diabetes, and by 2034, it is predicted there will be 44.1 million Americans with diabetes overall due to rising obesity rates, longer life expectancies, and other causes (*Estimates of Diabetes and Its Burden in the United States.*, 2014). Further, 422 million people worldwide suffered from diabetes mellitus in 2015; among them, 1.6 million died per year. Also, half a million Lebanese are estimated to have DM if the incidence of 11% holds in 2020 (Atlas, 2015; *Diabetes*, 2020).

Diabetic retinopathy is a common diabetic condition that affects people between the ages of 25 and 74 and can result in blindness in Americans who are working age. Retinopathy affects 28.5% of diabetic individuals in the United States who are 40 years of age or older; worldwide, the prevalence is 34.6%. Estimates indicate that as diabetes becomes more common, the 14 million Americans who already have diabetic retinopathy could double by 2050, primarily as a result of the swelling Hispanic American population (*Preferred Practice Pattern Guidelines Diabetic Retinopathy*, 2020). Early screening, correct diagnosis, and routine follow-up and treatment are approaches to reduce the new incidence of diabetic retinopathy and vision loss (Tan & Wong, 2023). One eye-related consequence of diabetes is called diabetic retinopathy, which is damage to the blood vessels in the retina. The likelihood of developing this eye problem increases with the time you have diabetes and the degree of blood sugar management (Farooq & Bapar, 2021). Diabetes mellitus (DM) and its consequences are a major source of morbidity among Saudi nationals. It is imperative to raise awareness of this prevalent disorder to enhance early detection and effective response (Al-Yahya et al., 2020).

In the Gaza Strip and the West Bank, respectively, 12.3% and 15.1% of the serviced refugee population aged 40 and over were diagnosed with diabetes mellitus in 2015 (Abu-Rmeileh et al., 2012). These rates were three times higher than those in the West and the highest among the other MoH-served regions and according to current projections, this percentage will increase to 20.8% by 2020 and 23.4% by 2030 (Mikki et al., 2017). Based on information provided by the chief of the non-communicable illnesses department, UNRWA served about 42,000 patients with diabetes in the Gaza Strip in 2016. And, eighty percent of Gaza's population is made up of Palestinian refugees, in which UNRWA clinics provide free medical care to them. In the West Bank's general population in 2008, diabetic retinopathy accounted for the second-highest percentage of instances of severe visual impairment (14% of cases) and the third-highest percentage of blindness (8% of all cases). In Ramallah clinics, 376 patients with type 2 diabetes had a 33% prevalence of Dr in 2012 (Mikki et al., 2017). Thirty percent of people with diabetes had never had an eye examination (Mikki et al., 2017).

In the US, professional foundations, associations, and Institutes of eye care have recommended the annual eye screening exam for the diabetic population, despite these instructions and recommendations, not all diabetic patients are doing the recommended retinal exam (Abu-Rmeileh et al., 2012). According to studies, the development of diabetic retinopathy is largely predisposed to high blood pressure, long-term diabetes mellitus, and high blood sugar. Diabetic retinopathy can be effectively delayed in its beginning and prevented from progressing with strict blood sugar control. In the early stages of DR, almost all patients are asymptomatic. Research suggests that early diagnosis and intervention could help patients with DR avoid losing their vision. As a result, early identification and intervention are critical to avoiding blindness as a major side effect of the illness (Mikki et al., 2017).

This study has the potential to improve patient outcomes and diabetes care in Ramallah by assessing the knowledge, attitudes, and practices of diabetic patients regarding their condition and diabetic retinopathy. The gathered information will be used to improve targeted educational activities and public health campaigns, enabling healthcare providers to tailor treatments that address specific gaps and promote proactive self-care. Because it is crucial to determine the knowledge, attitudes, and

practices of diabetics in developing countries, this study set out to evaluate and record the knowledge, attitudes, and practices (KAP) of diabetics on their condition and diabetic retinopathy.

2. Methodology

2. 1. Study design, settings, and population

A cross-sectional study was conducted from the first of October 2022 to the end of December, 2022 alongside our main research. The two-month investigation was carried out at the Ramallah outpatient clinic of the Palestinian Medical Complex (PMC). The study included adult patients with diabetes who were at least 18 years old and had type 1 or type 2 diabetes. Further, we disseminated a questionnaire via the PMC outpatient clinic in Ramallah, using a single person in charge. This two-month cross-sectional investigation was carried out at (PMC).

2. 2. Sampling technique and Sampling size

The study's subjects were selected randomly from the patient population with diabetes at the Medical Palestinian Complex in Ramallah. This strategy increases the sample's representativeness by ensuring that each member of the population has an equal probability of being included in the research. To calculate the sample size, a method that accounts for a 95% confidence level and a predefined anticipated correlation coefficient of 0.5 was employed. This algorithm is required for correlation analysis to offer statistical power and reliability. The study's requirements finally led to the selection of a minimum sample size of 50 participants, taking into account practical restrictions, resource availability, and the need for adequate statistical power.

2. 3. Inclusion criteria

Adults (18 years of age or older) who met the following criteria were eligible to participate in the study: they had to be regular patients at the Medical Palestinian Complex (PMC) outpatient clinics, have a documented diagnosis of diabetes mellitus (Type 1 or Type 2), and have had this condition for at least a year. These restrictions guaranteed a targeted sample for the study of attitudes, behaviors, and knowledge related to diabetes and diabetic retinopathy.

2. 4. Exclusion criteria

Those who had only recently been diagnosed with diabetes (less than a year ago), pregnant women (due to concerns about gestational diabetes), and patients with severe concomitant diseases that could restrict their participation (such as terminal illness or severe cognitive impairment) were among the exclusion criteria. These criteria allowed the study to focus on diabetic patients who would be good candidates for a detailed investigation of attitudes, practices, and knowledge regarding diabetes and diabetic retinopathy.

The first stage in working together to create the questionnaire was a thorough examination of the language. The knowledge and practice parts were created to minimize the impact of "leading questions," hence most of the questions were meant to be open-ended. Meanwhile, the questions in the attitude section were worded with a language that invited participants to agree, disagree, or remain undecided. Each member of our team gave the questionnaire to each patient orally. The demographical variables of this study were age, gender, marital status, level of education, and monthly income. Based on research by Srinivasan et *al.* (Srinivasan et al., 2017), the KAP-45, an instrument used to assess knowledge, attitude, and practice, was changed. There were eight attitude questions (four for each condition), thirteen knowledge questions (five about diabetes and eight about diabetic retinopathy), and twenty-four practice questions (six about diabetes and eight about diabetic retinopathy). An interesting observation was that several questions in the knowledge and practice sections were open-ended, yet the questions in the attitude section were given as assertions. If a participant successfully answered five of the nine "must-know" questions about diabetic

retinopathy and nine questions about diabetes, they were deemed to have "sufficient knowledge". Similarly, individuals who met the criteria for four or more "must-do" items were seen to be exhibiting "good practice" in both situations. In terms of attitudes, respondents who expressed a good opinion of diabetes and diabetic retinopathy and received three or more points for their comments were classified as having a "positive attitude." The face validity approach was used to assess the KAP-45 questionnaire's Arabic translation. Two Arabic and English bilingual speakers initially translated the English version into Arabic. A team of experts then reviewed the questionnaire and made cultural modifications. Lastly, feedback from the pilot study helped to refine the KAP-45 questionnaire's Arabic version.

2. 5. A pilot study

A pilot study was conducted to assess the questionnaire's suitability and identify any practical issues with its use. The design and readability of the instruments used to collect data were carefully scrutinized during this pilot experiment. As a result, six patients, or 10% of the total sample, took part in this preliminary investigation. The pilot study was conducted at Palestine Complex Hospital (PMC). To make the instrument better, changes were made in response to the results of the pilot study.

2. 6. Statistical analysis

SPSS version 25 was used for the analysis to determine the demographics and questionnaire responses. Frequencies and percentages were used to express categorical data. As shown, means and standard deviation (SD) were used to express continuous data. To look into the correlations between the variables, one-way ANOVA and the independent sample t-test were employed. For every analysis, a P-value of less than 0.05 was deemed statistically significant. Finally, to ascertain whether patient knowledge, attitudes, and practices about diabetes and diabetic retinopathy were associated in any way, the Pearson Correlation Coefficient was employed.

2. 7. Ethical considerations

Patients were told of the study's goal before its execution. The patient had the freedom to leave the study at any moment, and it wouldn't impact their access to medical care. They were also informed that they could choose not to participate in the study and that it would still be respected if they did not. On September 25, 2022, the Modern University Ethics Committee (Ref: muc002\2022) approved this study. Before their involvement in the trial, the patients gave their informed consent. There was assurance of anonymity, confidentiality, beneficence, and non-maleficence. The MOH gave its approval before the study got underway.

3. Results

3. 1. Demographic data of the patients

Table 1 distributes the demographic data of the patients in the study sample and shows that more than one-third of them (34%) are between 50 and 59 years old, with another 26% who are between 60 and 69 years old. Also, most of the patients (60%) are males and are mostly married (66%). Moreover, around one-third of the patients have a primary school level of education, and the highest percentage (38%) have a monthly income of less than 2000 NIS, with 20% for each with an income of 2000 to less than 3000 NIS and 3000 to less than 4000 NIS. One participant's demographic data is missing from our dataset. The absence of this data point compromises the general integrity of our conclusions about [particular elements evaluated], but it does not influence the completeness of our demographic study. Whenever possible, we have taken into consideration this missing data in our statistical analyses to ensure the validity of our findings.

Table 1. Distribution of patients' demographic data (n=50)

Variable	Values	N	%
Patient's age	18 – 30 years old	1	2.0%
	31 – 39 years old	6	12.0%
	40 – 49 years old	8	16.0%
	50 – 59 years old	17	34.0%
	60 – 69 years old	13	26.0%
	70 years and older	5	10.0%
Gender	Male	30	60.0%
	Female	19	38.0%
	Missing	1	2.0%
Marital status	Married	33	66.0%
	Divorced	4	8.0%
	Widowed	7	14.0%
	Single	5	10.0%
	Missing	1	2.0%
Educational level	Illiterate	8	16.0%
	Primary school	17	34.0%
	Secondary school	11	22.0%
	Bachelor's degree	13	26.0%
	Post-graduate	0	0.0%
	Missing	1	2.0%
Monthly income	Less than 2000 NIS	19	38.0%
	2000 - < 3000 NIS	10	20.0%
	3000 - < 4000 NIS	10	20.0%
	4000 - < 5000 NIS	5	10.0%
	5000 - < 6000 NIS	3	6.0%
	6000 - < 7000 NIS	2	4.0%
	7000 NIS and more	0	0.0%
	Missing	1	2.0%
Data were based on frequencies (N) and percentages (%)			

3. 2. Patients' level of knowledge about diabetes mellitus and diabetic retinopathy

The distribution of patients' satisfaction with the knowledge of diabetic retinopathy (DMR) and diabetes mellitus (DM) is shown in **Table 2**. Seven patients (14.0%) had a score of nine or above, indicating an excellent degree of knowledge. Forty-three patients (86.0%) had a score of less than nine, indicating a low level of knowledge. Thirty patients (60.0%) received a score of five or above, indicating an excellent level of knowledge. Twenty patients (40.0%) had a score of less than five, indicating a low degree of knowledge. It was clear from these statistics that a greater percentage of patients had inadequate knowledge of both DMR and DM than did those who had adequate knowledge. In particular, DM (14.0%) had a lower percentage of patients with

a good degree of knowledge than DMR (60.0%). This suggested that there could be differences in the patient's knowledge of the two variables.

Table 2. Distribution of patients' level of knowledge of DM and DMR (n=50)

	Value	N	%
Level of knowledge of DM	Good level of knowledge (9 or above)	7	14.0%
	Poor level of knowledge (below 9)	43	86.0%
Level of knowledge of DMR	Good level of knowledge (5 or above)	30	60.0%
	Poor level of knowledge (below 5)	20	40.0%

3. 3. Attitude of patients toward diabetes mellitus and diabetic retinopathy

The distribution of patient attitudes about diabetic retinopathy (DMR) and diabetes mellitus (DM) is shown in **Table 3**. Positive attitude was categorized in 22 patients (44.0%) (Scoring 3 and above). A negative attitude was categorized in 28 patients (56.0%) (Score below 3). A positive attitude was categorized in 23 patients (46.0%) (Scoring 3 and above). A negative attitude was categorized in 27 patients (54.0%) (Score below 3). According to the statistics, a greater percentage of patients had a negative attitude about DMR and DM than did those who had a favorable perspective. Compared to DM (44.0%), the percentage of patients with positive attitudes was somewhat greater for DMR (46.0%). Nonetheless, in both cases, the gap between positive and negative opinions was very similar.

Table 3. Distribution of patients' attitudes towards DM and DMR

	Value	N	%
Level of attitude of DM	Positive attitude (3 and above)	22	44.0%
	Negative attitude (below 3)	28	56.0%
Level of attitude of DMR	Positive attitude (3 and above)	23	46.0%
	Negative attitude (below 3)	27	54.0%

3. 4. Patients' practice regarding diabetes mellitus and diabetic retinopathy

The distribution of patient practices about diabetes mellitus (DM) and diabetic retinopathy (DMR) is shown in **Table 4**. Thirty patients (60.0%) who had a score of 4 or above were classified as having good practice. Twenty patients (40.0%) had a score of less than four, indicating inadequate practice. Twenty patients (40.0%) received a score of four or above, indicating good practice. Thirty patients (60.0%) had a score of less than four, indicating inadequate practice.

This data suggested that there were differences in the patient practice level distribution between DM and DMR. In particular, a higher percentage of patients (60.0%) than DM (40.0%) showed inadequate practice toward DMR. In contrast, a larger proportion of patients (60.0%) demonstrated good practice for DM in contrast to DMR (40.0%). This implies that patients' practice levels for the two diseases differ from one another.

Table 4. Distribution of patients' practice towards DM and DMR (n=50)

	Value	N	%
Level of the practice of DM	Good practice (4 and above)	30	60.0%
	Poor practice (below 4)	20	40.0%
Level of practice of DMR	Good practice (4 and above)	20	40.0%
	Poor practice (below 4)	30	60.0%

3. 5. Analytical results

This part investigates the relationship between patients' demographic data (as independent variables) and their level of knowledge, attitude, and practice toward diabetes and retinopathy (as dependent variables). As the variables of demographic data are categorical and all of the dependent variables are at scale type, an independent sample t-test was conducted to investigate the relationship according to dichotomous (2-option) demographic data (gender), while a one-way ANOVA was used to investigate the relationship according to the rest of the demographic data (as non-dichotomous variables), taking into consideration that the number of values for the following demographic factor has been diminished for a more reliable analytical test. There was no significant difference in the level of knowledge about diabetes mellitus and retinopathy among patients according to all of the demographic factors. None of the demographic factors are related to any significant differences in mean attitude level between the patients. Regarding patients' demographic factors and their level of practice towards DM and DR, results revealed that patients with bachelor's degrees in education had significantly the highest practice scores (mean = 86.15) compared to others like illiterate people (mean = 65, p-value = 0.032), as well as the patients with an income level of 4000 to less than 6000 NIS, having the highest practice scores (mean = 85) compared to others like who have less than 2000 NIS of income (mean = 63.16, p-value = 0.034).

Table 5. level of knowledge, attitude, and practices based on demographic characteristics (n=50)

Factor	Value	Knowledge		Attitude		Practice	
		DM Mean	DR Mean	DM Mean	DR Mean	DM Mean	DR Mean
Age	< 50 years old	35.29	36.36	45.00	55.00	78.67	58.67
	50 – 59 years old	37.72	43.85	61.76	61.76	75.29	54.12
	60 years and older	36.93	38.27	54.17	51.39	63.33	48.89
	p-value	0.906	0.730	0.315	0.580	0.088	0.675
Gender	Male	36.7	40.68	55.30	52.50	76.00	53.33
	Female	38.39	40.19	54.55	61.84	65.26	55.78
	p-value	0.612	0.951	0.595	0.286	0.090	0.791
Marital status	Married	37.25	41.87	55.00	57.58	75.15	56.97
	Divorced/widowed	36.90	42.79	55.30	59.09	67.27	45.45
	Single	35.29	22.73	54.55	50.00	68.00	56.00
	p-value	0.966	0.394	0.997	0.835	0.501	0.573
	Illiterate	28.68	30.68	50.00	53.12	65.00	37.50
	Primary school	42.21	43.20	57.35	54.41	64.71	54.12

Education	Secondary school	33.16	39.67	52.27	63.63	72.73	50.91
	Bachelor's degree	38.01	40.56	55.76	55.76	86.15	63.08
	p-value	0.170	0.773	0.946	0.845	0.032	0.343
Monthly income	< 2000 NIS	36.53	36.36	55.26	59.21	63.16	53.68
	2000 - < 4000 NIS	37.35	48.08	48.75	55.00	77.00	53.00
	4000 - < 6000 NIS	36.03	30.68	68.75	53.13	85.00	60.00
	6000 NIS and more	41.18	40.91	50.00	37.50	80.00	50.00
	p-value	0.978	0.391	0.479	0.786	0.034	0.954

Table 6 shows the correlations between all subscales and shows that a more positive attitude towards DM is significantly associated with better practice toward DM (Pearson = 0.420, p-value = 0.002) and that a more positive attitude towards DM is significantly associated with a more positive attitude towards DR (Pearson = 0.524, p-value < 0.001), with a significant increase practice towards DM with more positive attitude towards DR (Pearson = 0.274, p-value = 0.046), and a significant increase in patients' practice towards DR correlated with more positive attitude towards DR (Pearson = 0.300, p-value = 0.034), while no other subscales are significantly correlated.

Table 6. The correlations between all subscales (n=50)

Factor	**Diabetes mellitus (DM)**						**Diabetic retinopathy (DR)**					
	Knowledge		**Attitude**		**Practice**		**Knowledge**		**Attitude**		**Practice**	
	(r)	**P**	**(r)**	**P**	**(r)**	**P**	**(r)**	**P**	**(r)**	**P**	**(r)**	**P**
DM know			- 0.06	0.66	-0.19	0.18	0.23	0.11	- 0.11	0.46	0.11	0.47
DM attitude	- 0.06	0.66			0.42	0.002	- 0.06	0.69	0.53	<0.001	0.23	0.11
DM practice	- 0.19	0.18	0.420	0.002			0.14	0.36	0.274	0.046	0.22	0.13
DR know	0.23	0.11	- 0.06	0.69	0.14	0.36			0.15	0.32	0.19	0.19
DR attitude	- 0.11	0.46	0.52	<0.001	0.27	0.046	0.16	0.32			0.30	0.03
DR practice	0.11	0.47	0.23	0.11	0.22	0.13	0.19	0.19	0.3	0.03		

Generally, results showed that patients had a poor level of knowledge of DM and DR, as well as a negative attitude towards DM and DR, with poor practice towards DM and DR. Also, only higher levels of education and income were associated with improved practice towards DM. In contrast, no other significant difference in DM knowledge and attitude or DR knowledge, attitude, and practice was found according to patients' demographic factors. Also, a more positive attitude towards DM was significantly associated with better DM practice and a more positive DR attitude, with a more positive DR attitude and better DM practice.

4. Discussion

The KAP patterns of diabetic patients concerning diabetes and diabetic retinopathy were recorded in this cross-sectional investigation. Fifty patients who visited the PMC outpatient clinic were included in the study. The study's average knowledge score for DM was low, which is in line with a different study by John et al. that was carried out in India and found that 58% of the sample had little knowledge (Srinivasan et al., 2017). Furthermore, our participants' expertise in DR is lacking. Even though 62% of participants said that patients should undergo yearly eye exams, just 42% said that checkups should be done frequently.

This outcome is in line with another Turkish study by Cetin E et *al*., which discovered that just 41.9% of participants thought yearly eye exams were essential (Çetin et al., 2013). Just 20.7% of Jordanians said that yearly eye exams should be performed (Alali et al., 2022). However, the majority of respondents (78.0%) were aware that diabetes might impact various eye structures, which was in line with findings from two prior Saudi Arabian studies. The first study found that 82.6 percent of respondents were aware that diabetes can affect the eye (Mikki et al., 2017). The second survey, conducted by Al Zarea B in the Al Jawf region of Saudi Arabia, found that 75.6% of respondents were aware of ocular issues (Al Zarea, 2016).

Additional research from Jordan and Oman showed that 88.2% and 72%, respectively, were aware that DR is a complication of DM (Bakkar et al., 2017; Khandekar et al., 2010). Comparable studies carried out in India showed that just 27% and 17.01% of the patients knew that diabetic retinopathy (DR) was an eye consequence of the disease (Hussain et al., 2016; Stratton et al., 2001). Thus, to inform newly diagnosed DM patients about potential visual problems and the value of routine ocular screening and follow-up, we recommend that they be sent to a diabetes educator.

Glycemic management affects the prevalence of diabetic renal disease (Pescosolido et al., 2014), as well as blood pressure control (Stratton et al., 2001). However, according to 70.0% of our participants, inadequate glycemic management is a significant risk that exacerbates diabetic kidney disease. Another significant component linked to DM is hypertension. Studies have indicated that strict blood pressure management in people with diabetes and hypertension can postpone the onset of diabetic retinopathy (DR). High blood pressure raises the risk of both the development and progression of DR (Hussain et al., 2016).

There was a bad attitude regarding DM and DR. Regardless of their blood sugar level, the majority of our participants (82.0%) concurred that it is crucial to follow up with an ophthalmologist. Furthermore, the majority of them (74.0%) think that when their vision is good, it's not necessary to follow up. Conversely, a study conducted in Saudi Arabia by Abdulrahman Al Yehya et al. found that 62.9% of the participants did not think it was necessary to follow up when their vision was good. Consequently, the patient should be informed that diabetic patients with DR have a silent blinding condition and that "good vision" is not a reliable measure of retinal health. It is the responsibility of ophthalmologists to provide these fundamental facts to their diabetic patients in their clinics (Zimmer-Galler et al., 2015).

Additionally, our study's subjects displayed inadequate DM and DR practices. This makes sense given our sample's poor knowledge and attitude levels. Over two-thirds (78.0%) of the sample follow up regularly for a funduscopic screening exam (Raza et al., 2019). A similar result revealed that 73% of his sample underwent routine funduscopic screening exams. Twenty-two percent of our participants don't follow up. A similar conclusion has been made by (Pescosolido et al., 2014). It revealed that although 82.6% of his group knew they had DM problems in their eyes, only 65% of them underwent frequent eye exams. Several factors, besides ignorance, could be to blame for this, like insufficient funds, insufficient time, insufficient family support, and challenges with transportation. According to our survey, 31.3% of respondents indicated they couldn't afford it or weren't aware that it was necessary. A potential obstacle to adherence to routine follow-up is lack of time, which comes in second at 12.5% with 18.8%. Accordingly, we recommend that diabetes patients have the funduscopic screening examination performed at the same time and location as their routine follow-up in addition to patient education.

The similarities and differences between this research and others can be attributed to differences in healthcare systems, cultures, and geographic areas. These factors have an impact on how patients perceive and manage diabetes and diabetic retinopathy (DR), which in turn affects patient awareness levels and adherence to medical recommendations. Healthcare policy and economic conditions have an impact on patient behaviors and outcomes over time, and methodological choices and sample characteristics can have an impact on study results. Effective therapies should consider these various qualities to enhance diabetes care and patient outcomes in a range of settings.

5. Limitations

Restricting the sample size so that it is not representative of the entire population. Other treatment centers were not included in the study, and the study was limited to one medical center (PMC) clinic. It was restricted to a questionnaire and omitted information on the severity of diabetic retinopathy or the glycemic control level.

6. Conclusion

This study does not represent the entire Palestinian community or residents of Ramallah City, but it provides an overview of the awareness, attitudes, and practices of diabetics concerning diabetes mellitus (DM) and diabetic retinopathy (DR). The results indicated that patients had poor knowledge and negative attitudes towards both DM and DR, with poor practices regarding DM but good practices towards DR. Higher education and income levels were linked to better DM practices. A positive attitude towards DM was associated with better DM and DR practices. Lack of knowledge was a major barrier to regular DR screening. The findings highlight the importance of diabetic education to improve patient knowledge, control diabetes, and reduce complications, particularly through regular ocular screening for DR.

7. Recommendations

A diabetes educator should be consulted by patients who have just been diagnosed with diabetes mellitus (DM) to discuss possible ocular problems and the significance of routine eye exams and follow-ups. Our results highlight the importance of diabetic education; patients who are aware of diabetes mellitus (DM) and its consequences are more equipped to adopt healthy behaviors, which helps them better manage their condition. All stages of care—primary, secondary, and tertiary—should incorporate health education. Making use of the media, leaflets, and posters, and planning diabetic retinopathy screening camps on events like World Diabetes Day can greatly increase awareness, especially among those with less education and financial resources.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Author Contributions

All authors participated in the drafting, revising, and critical review of the article; they agreed on the journal to which the work will be submitted; they reviewed and agreed on all versions of the article before submission, during revision, the final version accepted for publication, and any significant changes introduced at the proofing stage; and they all made a significant contribution to the work reported, whether that be in the conception, study design, execution, acquisition of data, analysis, and interpretation, or all these areas.

Disclosure

The authors report no conflicts of interest for this work.

List of Abbreviations

WHO	World Health Organization
CDC	Center for Disease Control
PMC	Palestinian Medical Complex
DM	Diabetes Mellitus
DR	Diabetic Retinopathy
KAP	Knowledge, Attitude, Practice
F	Frequency
%	Percentage
NIS	New Israeli Shekel

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Quality evaluation and determination of heavy metals (Fe, Zn, and Pb) in Libyan sidr honey by Atomic Absorption Spectroscopy

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ABSTRACT

This work aimed to evaluate four samples of honey collected from the area extending from the city of Misrata in the east to the city of Tripoli in the west and up to the city of Bani Walid in the south of Libya. Various tests (pH estimation, moisture content estimation, ash content, and electrical conductivity) were applied to confirm the quality of honey samples**.** The pH values were 4.4 to 5.8, the moisture content was 12% to 17%, while the ash content was 0.10% to 0.2%, and the electrical conductivity was 0.32 to 0.50 mS/cm. However, there is a variation in the results obtained due to differences in regions. By comparing the obtained results with international standards, all honey samples were found to be acceptable and lower than the maximum level of FAO limits. The concentration of zinc was less than the maximum level of 20 (µg/g) in the Bani Walid and Zliten samples (12.8 and 18.6 µg/g, respectively), while Misrata and Tripoli samples were higher than the WHO limit, with 21.7 for the former and 29.58 for the latter. However, the lead content was slightly higher than the WHO limit of 2 (µg/g) in the Zliten sample with 2.1 (µg/g), while the other three samples were within acceptable limits with 1.15 µg/g for the Bani-Waleed sample, 1.35 µg/g for the Tripoli sample, and 1.49 µg/g for the Misurata sample. Nevertheless, the Misurata sample had the highest iron level with 50 µg/g among the four samples. It was found to be higher than the WHO limit (40 µg/g), while the other three samples were lower than the maximum level with 37 µg/g, 35 and 40 µg/g for Bani-Waleed, Tripoli, and Zliten samples, respectively. Honey can be used as a biosensor of environmental pollution with heavy metals.

Keywords: Honey, biosensor, heavy metals, atomic absorption.

1. Introduction

Libya has a special geographic location and a large space of 1.6 million Km^2, which provides various ecosystems (El-Hajaji, 2017). The eastern and middle parts of the country have the most plant cover, such as Wadi alkuf and Wadi majer. Different kinds of flowers can be found there, which are considered the main food for honeybees (Al-Traboulsi & Alaib, 2021; Requier et al., 2015). Honeybees feed on nectars of vegetation or plants and produce honey by collecting, transforming, and combining the plant extract with specific substances stored in honeycombs (Rikohe, 2023; Singh, 2022). Honey has various properties (nutritional and medicinal) because of its special chemical composition, which contains carbohydrates, proteins, vitamins, and minerals (Khan et al., 2014; Tafere, 2021). Heavy metals might pollute honey and cause serious health issues for humans (Islam et al., 2014). The journey of searching for food for honeybees makes the latter cover a circle of 5 km^2, and contact with various surfaces during this journey might be considered a biosensor of pollution (Danner, 2017; Porrini et al., 2002). Heavy metal content in Libyan Sidr honey has not been investigated until now in the central district of Libya, which encourages this work to be done. Analyzing honey can indicate the contamination of heavy metals, which reflects environmental pollution (Lazor et al., 2012). Iron and zinc are essential elements that the human body needs for normal health and growth due to the roles of iron and zinc in the immune system (Silva et al., 2019). Iron deficiency leads to anemia and degeneration of the nervous system (Ponka, 2004). Zinc can help the skin against ultraviolet radiation and decrease cancer risks (Rostan et al., 2002). Human activities increase the level of heavy metals circulating in the environment (Mishra et al., 2019). The concentration of heavy metals at the biosphere level is increasing rapidly due to industrial activities, which causes environmental problems (Masindi & Muedi, 2018). Nevertheless, the accumulation of metals in the human body might cause severe damage with longer consumption of honey (Solayman et al., 2016). Lead is another metal that might be found in honey, and even its low content is considered a serious threat because of its toxicity (Islam et al., 2014). This search aimed to evaluate the quality and select heavy metal content in Libyan honey.

2. Materials and methods

Five natural liquid honey samples (50 g) were collected from different Libyan cities (Bani-Waleed, Zliten, Misurata, and Tripoli) in June 2023. The selected location of the study (10, 11, and 14) in Libya can be seen in **Figure 1**.

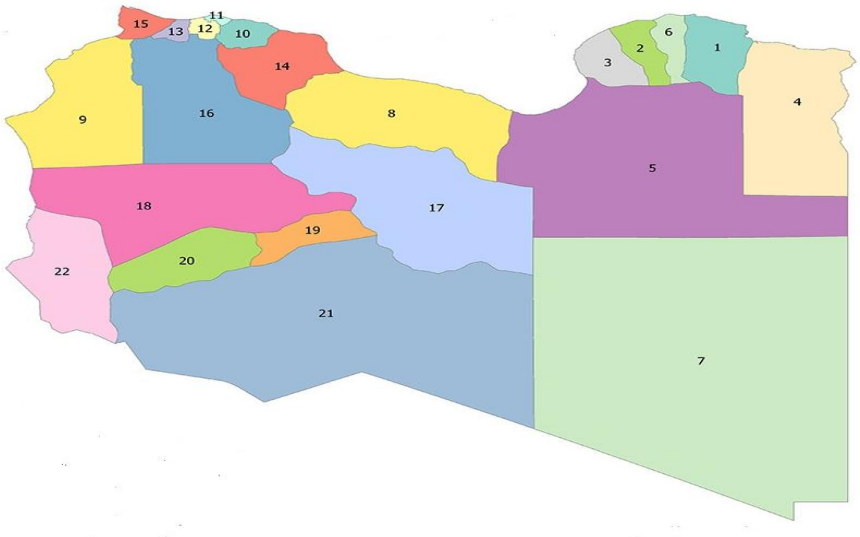

Figure 1. Demonstrates the districts of Libya

2. 1. Samples preparation for AAS measurements

2 g of each honey sample were weighed and placed in a dry oven at 105 °C for 24 h then cooled down. After that, 1 g of each sample was taken into a 100 ml flask and 20 ml of an acidic mixture of 1:1 (HNO_3 and $HCLO_4$) was added to the flask and heated at 70 °C for 2 h and cooled down. 5 ml of concentrated HCl was added and the volume continued to 50 ml with distilled water (Ploegaerts et al., 2023).

2. 2. Physiochemical properties of honey samples

pH, moisture, ash content, and electrical conductivity were measured to estimate the quality of the honey.

2. 3. Determination of (Fe, Zn, and Pb) by AAS

Atomic absorption spectroscopy model varian spectra 220Z at Delta Scientific Laboratory was used to determine the heavy metal content in honey samples.

3. Results and discussion

3. 1. pH measurements

2g of each honey sample was dissolved in 10 ml of hot distilled water, and a pH400 portable pH meter was used.

Table 1. Shows the pH values for the honey samples and FAO standard.

Honey samples	pH values
Bani Waleed	4.4
Misurata	5
Zliten	4.8
Tripoli	5.8
FAO	5

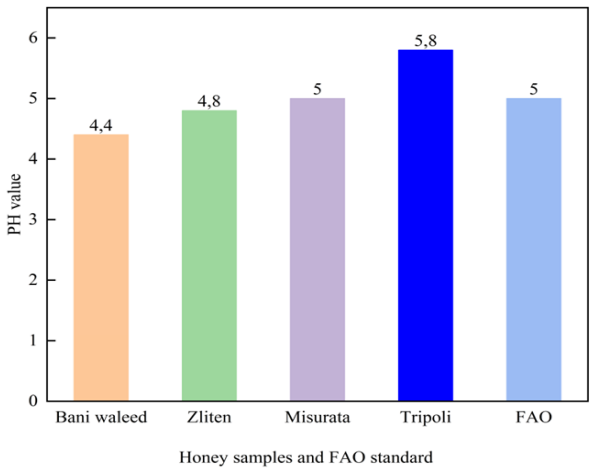

Figure 2. Illustrates the pH values for honey samples and FAO standards.

Figure 2 shows that the pH values for all samples ranged from 4.0 to 6.0. The Bani-Waleed sample had the lowest pH value (4.4), followed by Zliten (4.8) and the Misurata sample (5.0). However, Tripoli had the highest pH value (5.8). When compared with the FAO standard, only the Tripoli sample was higher, and the three others were under the limit and acceptable.

3. 2. Moister content

1 g of each honey sample was weighed in a Teflon container and placed in the oven at 105 °C for 3 hours, and then the ash percentage was measured for each sample.

Table 2. Demonstrates the moister content in honey samples

Honey samples	Moister%
Bani Waleed	16
Misurata	17
Zliten	16
Tripoli	12
FAO	21

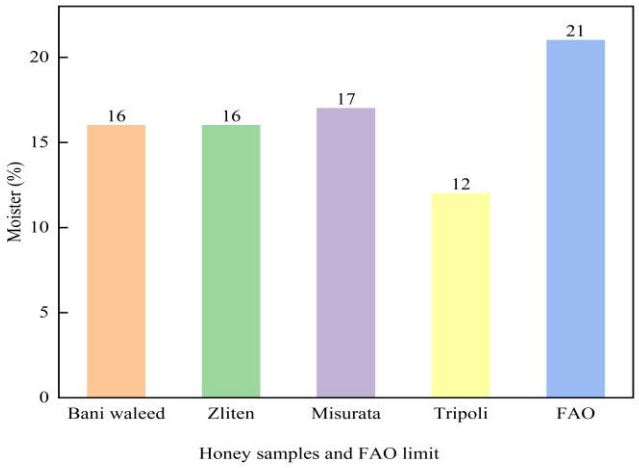

Figure 3. Shows the moister content in honey samples and FAO standard.

It can be seen in Table 2 and Figure 3 that all four honey samples contained less moist than the FAO limit (21%) where the Tripoli sample was the lowest at 12% followed by Bani-Waleed and Zliten samples with 16% while the Misurata sample was the highest among the four samples with 17%. The reason for that might be the hot weather in Libya. The low content of moister makes the storage of honey easier and stands much longer, and that is why Libyan honey is considered one of the best honey in the world (Chou et al., 2020).

3. 3. Electrical conductivity

5g of each honey sample was dissolved in 100 ml of hot distilled water, and an EC600L Conductivity Meter was used.

Table 3. Shows the electrical conductivity values for honey samples and FAO standards.

Honey samples	Electrical Conductivity mS/cm
Bani Waleed	0.32
Misurata	0.33
Zliten	0.5
Tripoli	0.32
FAO	0.8

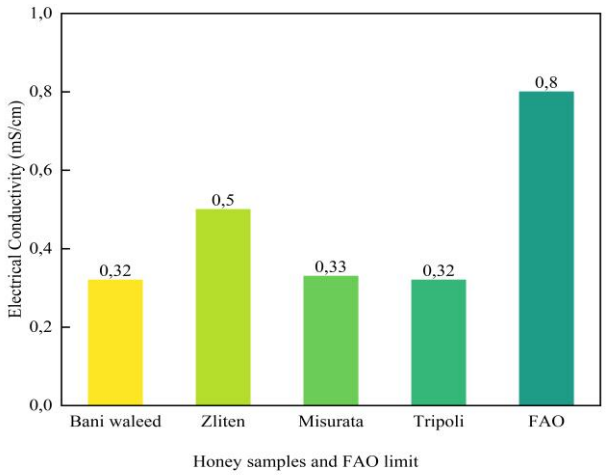

Figure 4. Shows the electrical conductivity for honey samples and FAO standard

According to **Figure 4**, the Tripoli and Bani Waleed samples had the lowest E.C value among the four samples, 0.32 ms/cm, while the Misurata sample was slightly higher, 0.33 ms/cm, and the Zliten sample had the highest E.C value, 0.5 ms/cm. Even though all samples were lower than the FAO standard (0.8 ms/cm), that's a sign of high-quality honey (Gebeyehu & Jalata, 2023; Lim et al., 2022).

3. 4. Ash content

1 g of each honey sample was weighed in a porcelain crucible and placed in the oven at 600 °C for 3 hours then the ash percentage was measured for each sample.

Table 4. Demonstrates the ash content in honey samples and FAO standards.

Honey samples	Ash Content %
Bani Waleed	0.10
Misurata	0.10
Zliten	0.10
Tripoli	0.20
FAO	0.60

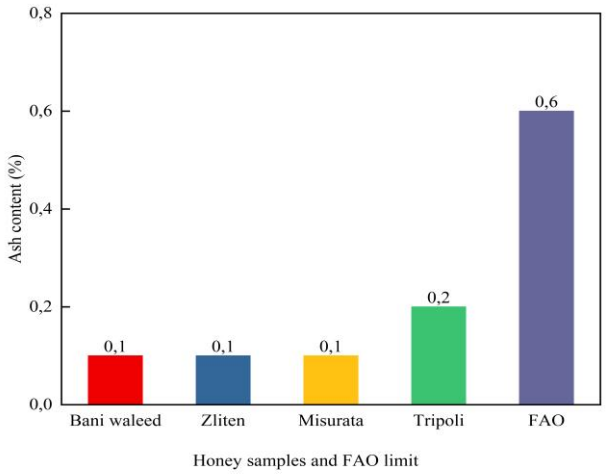

Figure 5. Shows the ash content in honey samples and FAO standards.

It can be seen from **Figure 5** that the Tripoli sample had the highest ash content (0.20%), while the Zliten, Bani Waleed, and Misurata samples had the same ash content (0.10 %). The difference in these results is due to the difference in the type of plant prevailing in the region and the geographical location of each sample. On the other hand, all four samples were significantly lower than the FAO standard (0.80%). As a result, the quality of the honey is considered high, as expected (Gebeyehu & Jalata, 2023; Lim et al., 2022).

3 .5. Heavy metals contents

Table 5. Demonstrates the content of Fe, Zn, and Pb (µg/g) in honey samples and WHO standards.

Honey samples	Zn (µg/g)	Pb (µg/g)	Fe (µg/g)
Bani Waleed	12.8	1.15	37
Misurata	21.7	1.49	50
Zliten	18.6	2.19	40
Tripoli	29.58	1.35	35
WHO	20	2	40

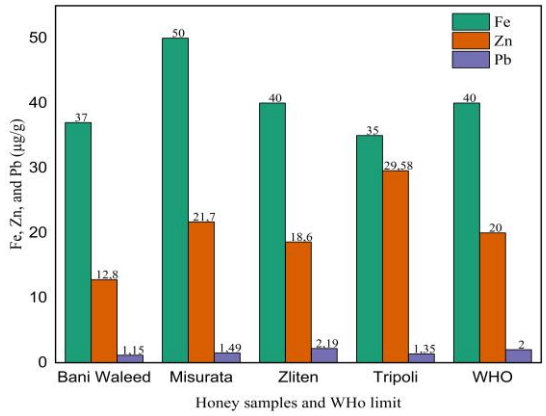

Figure 6. Shows the content of Zn, Pb, and Fe (µg/g) in honey samples and the WHO

The limits bar chart in **Figure 6**. demonstrates the heavy metal contents in the four honey samples, where the X axis shows the average concentration of the three heavy metals (µg/g), and the Y axis represents the honey samples and the maximum level according to the World Health Organization. From the chart above in **Figure 6**, it can be seen that the Bani-Waleed sample had the lower concentration of zinc at 12.80 (µg/g), followed by the Zliten sample with 18.60 (µg/g) and the Misurata sample at 21.70 (µg/g) while the Tripoli sample had the highest content of zinc with 29.58 (µg/g). By comparing zinc content in the four samples with the WHO limit, the Tripoli sample was much higher than the acceptable limit. In comparison, the Misurata sample was slightly higher than the maximum level. On the other hand, Bani-Waleed and Zliten samples were within the acceptable limit (20 µg/g). In terms of lead, the Bani-Waleed sample had the lowest content of lead with 1.15 (µg/g), followed by the Tripoli sample with 1.35 (µg/g) and the Misurata sample with 1.49 (µg/g) and all three samples were within the acceptable limit of lead (2 µg/g) while the Zliten sample was containing the highest concentration of lead among the four samples with 2.1 (µg/g) and that's slightly above the maximum level of lead according to the World Health Organization. Nevertheless, the Misurata sample had the highest iron level among the four honey samples, with 50 (µg/g). That content was much higher than the maximum level of iron 40 (µg/g). However, Bani-Waleed, Tripoli, and Zliten samples were within acceptable standards 37, 35, and 40 (µg/g), respectively. The lead content in this study was lower than the study conducted (Al-Hadar, 2006) on 20 honey samples from different regions of Libya, where the concentration of lead in some samples was 50.0 (µg/g). In addition, the study (Rashed & Soltan, 2004) in samples of honey showed the lead contamination in Egyptian honey was (4.2-9.3 µg/g). This study agreed with the results of (Atrouse et al., 2004) on Jordan honey in about 75% of the samples, where the lead concentration was (0.853-1.234 µg/g). Therefore, the results of this study can be used as a biosensor of environmental pollution (Atrouse et al., 2004; Rashed & Soltan, 2004).

4. Conclusion

This study was carried out on the geographical area extending from Misrata to Tripoli to Bani Walid. This area was chosen due to the large number of beekeepers and the abundant production of honey of all types. Four physicochemical parameters were estimated on honey samples: moisture content, pH, electrical conductivity, and ash content.

The obtained results for the honey samples were compared to international honey specifications. All the studied samples conformed to international specifications and were of high quality. The variation in the result among the four samples reflects the different regions from where the samples were taken. Moisture content in the four samples was very low compared to the maximum allowed content, and due to the low pH, it is possible to store the honey from these areas for a long period without fermentation. The higher the moisture content of the honey, the more likely it is to ferment. The pH values were low for all samples within the acceptable level, and this is why honey can eliminate all microorganisms. Electrical conductivity is one of the most important tests used to measure the quality of honey due to its direct relationship to moisture and ash content. By comparing the obtained results with the FAO standard, honey samples were found to be lower than the maximum level of E.C.

The concentration of zinc in the Bani Walid and Zliten samples was less than the maximum level of 20 (µg/g), while the Misrata and Tripoli samples were higher than the WHO limit. On the other hand, the lead contamination was found to be in the Zliten sample 2.1 (µg/g), which was slightly higher than WHO limit 2 (µg/g), while the other three samples were within acceptable limits. In contrast, the Misurata sample had the highest iron level (50 µg/g) among the four samples and even compared with the WHO limit (40 µg/g), while the other three samples were lower than the maximum level. Honey can be used as a biosensor or an indicator of environmental pollution with heavy metals.

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The author is very grateful to the Department of Chemistry at the University of Bani-Waleed for their assistance in laboratory work.

Competing Interests

The author declares no competing interests.

Abbreviations

AAS: Atomic Absorption Spectroscopy.

EC: Electrical Conductivity.

FAO: Food and Agriculture Organization.

WHO: World Health Organization.

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Rudimentary phytochemical screening and in vivo exploration of brawny hypoglycemic potency of *Aphanamixis Polystachya* (Wall.) parker seed extractives

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ABSTRACT

Aphanamixis polystachya (Wall.) Parker is a sanative herb with colossal corny convenience. This plant contains a wide range of secondary metabolites, which have been linked to numerous medicinal uses. The current investigation aimed to find the phytochemical components and assess the hypoglycemic impact of n-hexane, chloroform, and methanol extracts of *Aphanamixis polystachya* seeds. Phytochemical screening was carried out using qualitative analysis. To measure hypoglycemic activity, hyperglycemic lab rats with glucose and STZ were used. All of the extractives contained the phytochemicals flavonoids, terpenoids, and steroids. After 30 minutes of administration, the n-hexane extract showed a drop of 41.44% in blood glucose levels, while the chloroform extract exhibited the most significant reduction, 47.76%, at a dose of 150 mg/g BW. The fascinating discovery is that the methanolic extract, which contained carbohydrates absent in the other extracts, resulted in a 14.92% increase in blood glucose levels within 30 minutes of treatment. Organic seed extracts can prevent hyperglycemia, which will be a significant argument in favor of the *Aphanamixis polystachya* plant's common uses in traditional medicine to treat diabetes. More research is required to determine the exact mechanism of action, pinpoint the active ingredients, and clarify their structures.

Keywords: *Aphanamixis polystachya*, Phytochemical screening, Hypoglycemic, Hyperglycemia, Oral glucose tolerance test.

1. Introduction

Hyperglycemia, often known as high blood sugar, is an eminent feature of DM, which is a long-standing and immedicable metabolic malady bringing on either superfluous begetting of insulin hormone, waned responsiveness to insulin, or both (Al-Rasheed et al., 2018). A study has found that it significantly increases the chance of developing both communicable and non-communicable illnesses, such as tuberculosis, DM, and cancer (Qiu et al., 2023). Additionally, the coronavirus illness pandemic of 2019 may have raised the likelihood of insulin resistance and hyperglycemia, exacerbating the universal burden of DM (Mirzaei et al., 2021). A recent study reveals that, by 2030, the worldwide economic cost of DM is expected to reach over 2 trillion USD (Bommer et al., 2018). When taken as a whole, hyperglycemia seriously threatens human health, and greater awareness is needed.

Unworthy treatment of DM resulting from persistent hyperglycemia leads to herculean and occasionally internal impressions after a few days. Crucially, it increases the likelihood of retinopathy, nephropathy, nerve damage, and cardiovascular diseases, among other ailments (Mukherjee et al., 2006). The first-line treatment for T2DM is the oral antidiabetic medication MET (Bravard et al., 2021). In patients with type 2 diabetes, MET monotherapy reduces the fasting plasma glucose concentration by around 60–70 mg/dl (Cusi & DeFronzo, 1998). However, according to Inzucchi et al. (Inzucchi, 2002), up to 50% of individuals undergoing MET therapy experience gastrointestinal side effects. The use of natural items as alternative therapies is quickly gaining acceptability and appeal because of the negative impact and expense associated with current anti-T2DM drugs (Dhanabal et al., 2004).

Currently, there is an increased focus on the efficacy of medicinal plants in the traditional medical system to counteract both on-target and off-target untoward effects. Of the estimated 250,000 higher plants, less than 1% have been screened pharmacologically, and even fewer have been screened for DM (Arumugam et al., 2013). Lamentably, the traditional medicinal herbs used to treat DM have not been studied in toto (Fei et al., 2024).

Of great noteworthiness is a vital plant affiliated with the Meliaceae family, *Aphanamixis polystachya* (wall.) Parker is provincially familiar with "Pithraj," "Royna," "Tiktaraj," or "Baddiraj," which is profusely found in the Indo-Bangladesh subcontinent (Basu, 1999; Chopra & Nayar, 1956; Gupta et al., 2010). The literature search has indicated significant biological activity of this plant, including antioxidant, laxative, anti-cancer, insecticidal, antifeedant, thrombolytic, anti-bacterial, anti-rheumatic, anthelmintic, anti-fungal and analgesic properties (Haque et al., 2020; Mishra et al., 2014; H. Snigdha et al., 2016). Despite its strong pharmacological properties, little research has been found on this plant's hypoglycemic effects. Research on hypoglycemic activity is confined to *Aphanamixis polystachya* leaf essences only (Tiwari et al., 2019). Moreover, studies on seed extracts are restricted to conventional applications, including the assessment of insecticidal and antifeedant efficacy (Talukder & Howse, 1993). In the Indo-Bangladesh subcontinent, farmers have historically used *Aphanamixis polystachya* seed oil to protect their skin from the irritants found in contaminated water when harvesting jute. Assiduousness has been taken through this study to explore the therapeutic benefits against hyperglycemia and phytochemical screening of several organic extracts from *Aphanamixis polystachya* seeds.

2. Materials and method

2. 1. Chemicals and reagents

The following reagents were provided by the Department of Pharmacy, University of Rajshahi-6205: n-hexane, methanol, chloroform, Tween-80, Benedict's reagent, Fehling's Solutions A and B, Dragendroff's reagent, and Molich reagents. Glucose was bought from the neighborhood market under the Unilever brand Galaxose-D. Opsonin Pharma Limited, Barishal, Bangladesh, provided MET hydrochloride under the Met brand. STZ was culled from SimSon Pharma Limited, Mumbai, India.

2. 2. Collection and identification of the plant

Spick and span seeds of *Aphanamixis polystachya* were culled from Rajshahi, Bangladesh. They were in good condition and showed no signs of sickness. At a subsequent time, they were housed in the Phytochemistry Laboratory, Department of Pharmacy, University of Rajshahi, Bangladesh, following verification by the Botany department at the same university.

2. 3. Preparation of plant extracts

After rinsing the seeds with fresh water, they were subsequently exposed to sunlight for a few days to facilitate drying. The desiccated embryos were pulverized into a coarse powder using suitable laboratory grinding equipment. A mixture of 300 grams of powdered seeds and 600 milliliters of n-hexane was placed in a reagent container and subjected to maceration for ten days, with remittent jolting. Afterward, the combination was percolated using a Whatman filter paper, followed by an initial coarse filtration through a clean, white cotton material. After drying, the liquid (n-hexane) was removed by evaporation using a rotary evaporator operating at 120 rpm for 15 minutes at a temperature of 50°C. The result was an n-hexane extract (APHE) with a yellow hue, semisolid consistency, pleasant smell, and bitter taste, with an 8.67% yield value of the extractive. The relic segment was subjugated to successive solvent schemes using chloroform and methanol to prepare posterior essences. The identical procedure was employed to consecutively generate the semisolid, fragrant, acrid, brown-colored chloroform, and methanol extractive, APCE (5.33%) and APME (7.33%). Subsequently, the extracts were employed for phytochemical screening and in vivo hypoglycemic efficacy. The extractives were then kept in reserve in a lucid container, which was counterbalanced with an unequivocal aluminum foil in an arid area.

2. 4. Phytochemical screening

Using the procedures outlined in Evans (Evans, 2009) and Ghani (Ghani, 2003), the organic extractives of *Aphanamixis polystachya* seeds underwent several phytochemical group resolution studies in the Phytochemistry Laboratory, Department of Pharmacy, and University of Rajshahi.

2. 5. Hypoglycemic study design

2. 5. 1. Experimental animals

A total of 66 adult male Wistar rats (*Rattus norvegicus*), with a body weight ranging from 150 to 180 grams and an age of two months, were procured from the Animal House of Khulna University, Bangladesh and were perpetuated at the Pharmacology Laboratory of Bangabandhu Sheikh Mujibur Rahman Science and Technology University (BSMRSTU), Gopalganj, for evaluating hypoglycemic efficacy. Every individual rat was given seven days to acclimate to the unfamiliar environment before commencing the experiment. The rats were brought up during the trial with potable water and regular salubrious pellets. Over and above, they underwent natural lighting and darkness cycles for twelve hours each day and were facilitated with boundless ventilation at room temperature. The Department of Pharmacy, BSMRSTU, approved the experimental design and procedures (#bsmrstu16-11/22).

2. 5. 2. Grouping of experimental rats

Out of sixty-six, eleven groups of six male Wistar rats were randomly allocated (Andrade-Cetto et al., 2019). **Table 1** illustrates the number of treatment groups for hypoglycemic activity.

Table 1. Study groups and treatments for *in vivo* hypoglycemic activity.

Study groups	Treatments
TG1	N. Control (Distilled water)
TG2	H. Control
TG3	H.+ Metformin
TG4	H.+ APME
TG5	H.+ APCE
TG6	H.+ APHE
TG7	N. Control (Glucose)
TG8	G.+ Metformin
TG9	G.+ APME
TG10	G.+ APCE
TG11	G.+ APHE

2. 5. 3. Experimental induction of hyperglycemia

Rats who fasted the previous night were given an intraperitoneal injection of 60 mg/kg of the freshly dissolved STZ solution in 100 mm citrate buffer (pH 4.5). The blood glucose concentration was measured 48 hours later using an acceptable glucometer, Bioland G-423 (Bioland, Germany), collecting blood samples attained from piercing tail veins of speculative rats. Any animals with blood glucose magnitudes higher than 13.9 millimoles per liter were classified as hyperglycemic and allowed to participate in the trials (Tiwari et al., 2019).

2. 5. 4. Readiness of reactive medicaments and plant extractives

Guidelines 423 of the Organization for Economic Cooperation and Development dictated that extract containing 150 mg/kg BW should be used to screen hypoglycemic activity after an acute toxicity study (Tiwari et al., 2019). Samples were measured to suspend test samples at 150 mg/kg BW. The extracts were triturated in a single direction by mixing distilled water with a tiny Tween-80 (H. S. H. Snigdha et al., 2016). On the other hand, MET showed high solubility in water and was present as microcrystals. Due to its high efficacy, Metformin was formulated as a solution using distilled water. Each 0.1 ml solution contains 150 mg/kg BW of MET (Islam et al., 2009).

2. 5. 5. Hypoglycemic upshot of the plant extractives

With minor modifications, the hypoglycemic properties of plant extracts were evaluated in TG 1-6 using the methodology outlined by Andrade-Cetto and his colleagues (Andrade-Cetto et al., 2019). Following the induction of STZ, TG2–TG6 were prepared to assess the hypoglycemic effect at rest. The rats were deprived of water for sixteen hours. Glucose levels at the starting point were monitored in every individual rat. To compare the blood glucose levels of the control group with those of other groups receiving STZ, TG1 that was given distilled water was chosen. TG2 was chosen as the hyperglycemic control group; neither MET nor extracts were given to this group. TG3 represents the MET control group, which receives 150 mg/kg BW doses of MET intraperitoneally. The extractives of *Aphanamixis polystachya* seeds- APME, APCE, and APHE were given to TG4-TG6. The subsequent procedure involved extracting blood and quantifying the blood glucose concentration using an advisable glucometer. In this case, the tail vein was pierced at 0, 15, 30, 60, and 120 minutes, succeeding germane administration of the medication and plant extractives.

2. 5. 6. Oral glucose tolerance test (OGTT)

OGTT was conducted using the protocol with some adjustments followed by Islam and his colleagues (Islam et al., 2009). After 16 hours of abstaining from consuming food or drink except for water, TG7–TG11 was selected to participate in the OGTT evaluation. The starting point of blood glucose intensity was obtained by using a convenient glucometer. TG7 was acted to embody the control group, which received glucose solution only. TG8 was dealt with an intraperitoneal dose of MET (150 mg/kg BW). Afterward, a dose of 150 mg/kg BW of the three extracts - APME, APCE, and APHE derived from *Aphanamixis polystachya* seeds was administered intraperitoneally. A pristinely prepared glucose solution (2 ml) was administered to experimental rats of groups TG7-TG11 using an intragastric tube (2 gm/kg BW) following one hour of MET and plant extract treatments. Subsequently, the blood glucose level was assessed using a glucometer. Blood was culled by pricking the tail vein at intervals of 0, 30, 60, 90, 150, and 270 minutes.

2. 6. Statistical analysis

The consequences are reported as the mean ± standard error of the mean or as a percentage collated with the control groups. The statistical analyses were conducted with the aid of Graph Pad Prism software (Version 9.5.1, San Diego, CA, USA). Interrelationships between the means were thoroughly evaluated using one-way ANOVA and t-Student Newman–Keuls post hoc test. Correlations for hypoglycemic tests were calculated using blood glucose level values. Significance was attributed to p values ($p < 0.05$) at a 95% confidence level, while a precise code of behavior of p ($p < 0.0001$) was contemplated as very noteworthy.

3. Results

3. 1. Phytochemical analysis

Plants under investigation included flavonoids, terpenoids, steroids, alkaloids, and carbohydrates, according to a phytochemical screening **Table 2**. Except for tannins, the APME showed flavonoids, terpenoids, steroids, alkaloids, and carbohydrates. Besides carbohydrates and tannins, the APCE exhibited flavonoids, terpenoids, steroids, and alkaloids. Conversely, APHE displayed steroids, terpenoids, and flavonoids.

Table 2. Phytoconstituents of *Aphanamixis polystachya* seed extracts.

Constituent	Name of test	APME	APCE	APHE
Steroid and terpenoid	Libermann-Burchard's scrutiny	-	+	-
	Salkowski's scrutiny	+	+	+
Alkaloid	Mayer's scrutiny	-	+	-
	Hager's scrutiny	+	+	-
	Dragendroff's scrutiny	-	-	-
	Wagner's scrutiny	+	+	-
Phenolic and flavonoid	Zinc-Hydrochloride reduction scrutiny	+	+	+
Tannin	Ferric chloride scrutiny	-	-	-
Carbohydrate	Reducing sugars scrutiny	+	-	-

3. 2. In vivo hypoglycemic activity

3. 2. 1. Effect on STZ-induced investigational rats

Figure 1 presents the effects of MET and three distinct extracts of *Aphanamixis polystachya* seeds, namely APME, APCE, and APHE, on the blood glucose intensity in accustomed and STZ-instigated hyperglycemic probing rats. The data is presented as the mean ± standard error of the mean. Upon comparing the blood glucose levels of the hyperglycemic control group with those of the normal control group, it was seen that the animals of the hyperglycemic control group had consistently high glucose levels over 120 minutes. The standard medication, MET, lowered the glucose by 61.53% after 30 minutes and had a sustained, substantial hypoglycemic impact from 15 to 120 minutes.

The evaluation's outcome shows that two extractives, APCE and APHE, injected intraperitoneally had a hypoglycemic impact that was statistically significant ($p < 0.05$) and comparable to MET. In this case, both extracts, APCE and APHE, are almost equally effective, but APCE is the more potent. Blood glucose levels were lowered by APCE to 22.50%, 47.76%, 38.46%, and 6.97% in 15, 30, 60, and 120 minutes, respectively. Thus, after 30 minutes, APCE resulted in a maximum drop of 47.76% in blood glucose levels. In 15, 30, 60, and 120 minutes, APHE decreased blood glucose levels to 20.66%, 41.44%, 31.53%, and 5.03%, respectively. So, after 30 minutes, APHE reduced blood glucose levels to 41.44%. However, it's important to note that in 5, 30, 60, and 120 minutes, APME raised blood glucose levels to 6.55%, 14.92%, 2.62 %, and 1.55%, respectively.

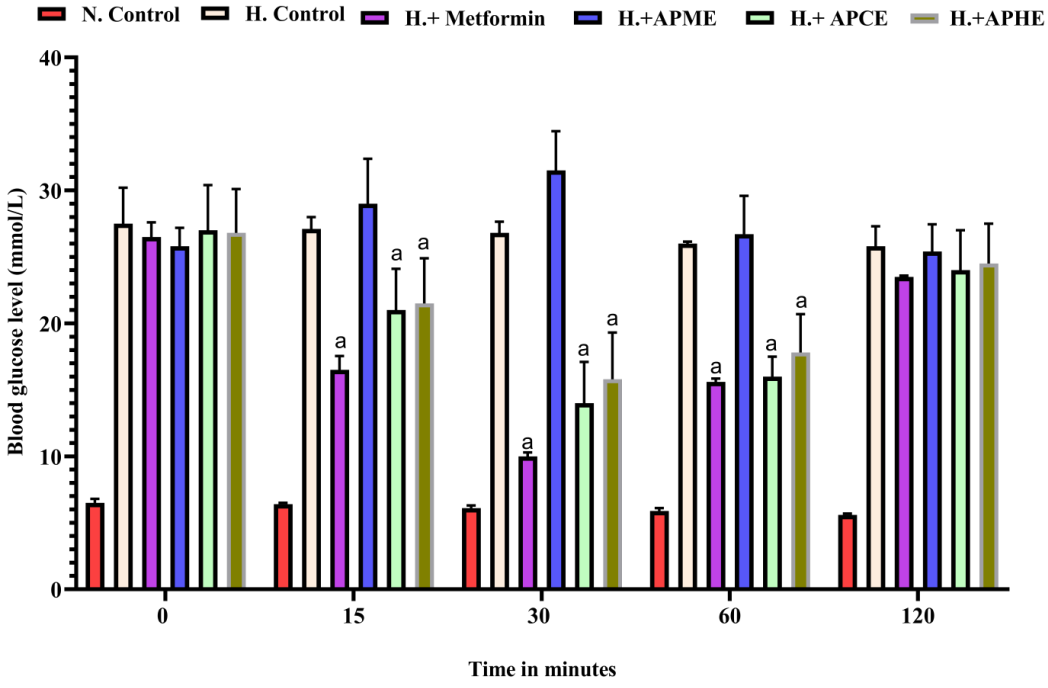

Figure 1. The effect of various fractions of *Aphanamixis polystachya* seeds on STZ-induced hyperglycemia in normal rats. The result is shown as (means ± standard error of the mean (SEM); one-way ANOVA and t-Student Newman–Keuls post hoc test with multiple comparisons at 95% confidence intervals; A significant difference in blood glucose level (mmol/L) is indicated by the letter 'a' when compared to the H. Control (hyperglycemic control) group ($p<0.05$).

3. 2. 2. Effect on glucose-induced rats

In an experiment to induce hyperglycemia, plasma glucose levels increased 1.5–2 times when glucose was consumed intragastrically. Figure 2 shows the effects of three different extracts (APME, APCE, and APHE) of *Aphanamixis polystachya* seeds on blood glucose levels in normal and glucose-instigated hyperglycemia in customary investigational animals. The data is displayed as mean ± standard error of the mean.

The aforementioned experiment clearly shows that the usual medication MET lowered blood glucose levels to 29.41%, 26.66 %, 22.72%, 2.85%, and 1.5% in 30, 60, 90, 150, and 270 minutes, respectively, under the outcomes of OGTT. MET resulted in the most significant reduction of blood glucose levels by 29.41% after 30 minutes.

Blood glucose concentration was lowered by APCE to 23.52%, 20%, and 18% in 30, 60, and 90 minutes, respectively. The blood's APCE concentration falls with time, and after 150 minutes, the blood glucose level diminishes by 2.85 %. In 30 and 60 minutes, respectively, APHE lowered blood glucose levels to 17.64 % and 13.33%. After 90 minutes, the blood glucose level declines by 9.09% while the blood concentration of APHE falls. However, it's mentionable that within 30, 60, 90, 150, and 270 minutes, respectively, APME raised blood glucose levels to 22.72 %, 20%, 9.09%, 6.66%, and 2.94%.

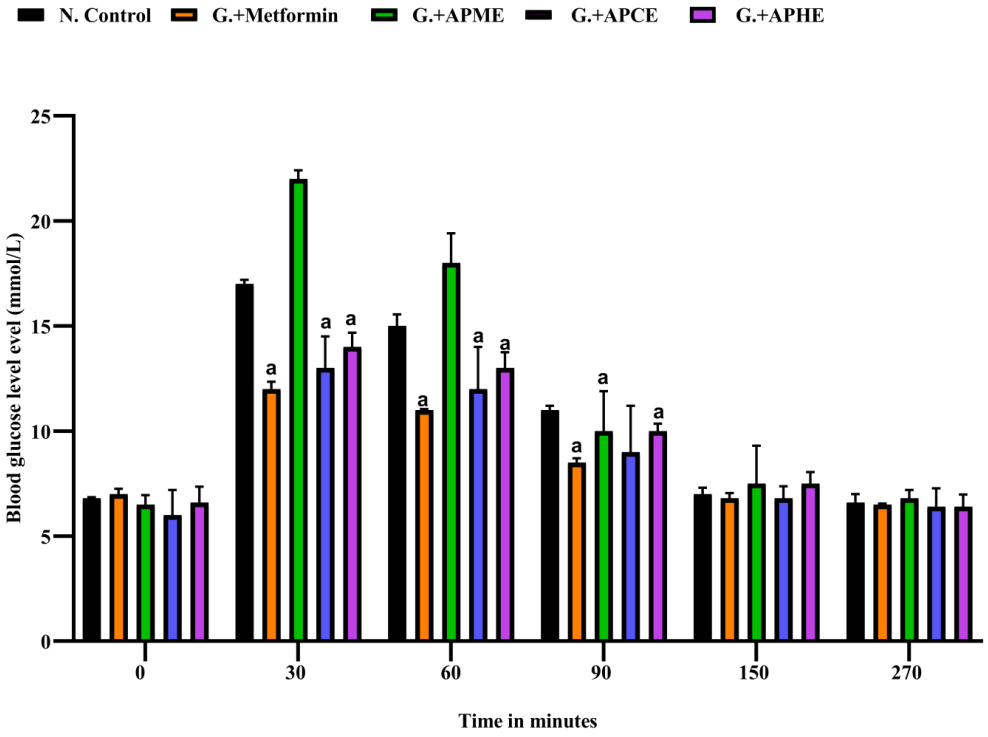

Figure 2. The effect of various fractions of *Aphanamixis polystachya* (Wall.) on glucose-induced hyperglycemia in normal rats. The result is shown as (means ± standard error of the mean (SEM); one-way ANOVA and t-Student Newman–Keuls post hoc test with multiple comparisons at 95% confidence intervals; A significant difference in blood glucose level (mmol/L) is indicated by the letter 'a' when compared to the N. Control (Glucose) group ($p<0.05$).

4. Discussion

A cytotoxin called STZ selectively destroys the pancreatic β-cells, causing an outstanding drop in blood insulin intensities. In the absence of insulin, the liver's ability to absorb glucose will be hindered, leading to a drop in the liver's glycogen levels (Patel et al., 2012). The assessment's repercussions demonstrate that intraperitoneal injection of two extractives, APCE and APHE, at the administered doses of 150 mg/kg BW can resolve this issue, aid in glucose absorption by cells, and facilitate the production of liver glycogen compared to hyperglycemic control animals (Tiwari et al., 2019). Furthermore, these two extracts have a similar pattern of blood glucose decrease to that of the conventional medication MET.

The aforementioned result is consistent with a prior study in which extracts were administered intraperitoneally to hyperglycemic rats, resulting in a considerable reduction in blood glucose levels. Methanolic extract from *Aphanamixis polystachya* leaves has been shown in a previous study to have possible hypoglycemia effects in rats induced by STZ (Tiwari et al., 2019). Furthermore, not much study has been discovered when *Aphanamixis polystachya*'s other parts—aside from its leaves—are used to test for the hypoglycemic effects. In this investigation, it was found that n-hexane and chloroform extracts

of *Aphanamixis polystachya* seeds are powerful hypoglycemic agents when compared to mice treated with MET and hyperglycemic control animals.

Another method by which plant extracts are tested for acute hypoglycemia is by an increase in oral glucose tolerance. This widely used OGTT was initially created to categorize carbohydrate tolerance because the test's results for plasma glucose and insulin represent the capacity of pancreatic cells to release insulin and the tissue's susceptibility to insulin (Stumvoll et al., 2000). The degree of hyperglycemia caused by glucose loading in treated rats appears to have been significantly decreased by the chloroform and n-hexane extracts of *Aphanamixis polystachya* seeds in this investigation compared to control animals. This suggests that chloroform and n-hexane extracts could somewhat postpone the development of hyperglycemia. It is believed that improved glucose tolerance is related to plasma insulin's availability and functionality (Tiwari et al., 2019).

Compared to the standard medication MET at a dose of 150 mg/kg BW, this may have been a significant factor in the extracts' hypoglycemic ability to reduce glucose-induced hyperglycemia in the treated mice, which enhances OGTT outcomes by lowering blood glucose levels and increasing insulin action. In general, MET accelerates glucose transport and glycogen synthesis, raises insulin receptor tyrosine kinase activity, increases the number and affinity of insulin receptors in muscle and adipocytes, and decreases hepatic gluconeogenesis and glycogenolysis through AMPK-dependent and AMPK-independent mechanisms to exert a powerful and complex effect on enhancing blood glucose homeostasis (Rena et al., 2017).

The hypoglycemic activity of *Aphanamixis polystachya* may be due to the presence of tannins, flavonoids, saponins, and sterols in the methanolic leaf extract. These compounds perform through pancreatic β-cell regeneration and decrease blood sugar levels (Tiwari et al., 2019). According to a different study, the primary mechanism by which the phenolic compounds of *Aphanamixis polystachya* produce their hypoglycemic effects. These substances regulate the enzymes linked to glucose metabolism, augment the activity of β-cells and insulin, and encourage insulin release (Hotamisligil, 2006; Hotamisligil et al., 1993).

A phytochemical screening in this work revealed the presence of flavonoids, terpenoids, steroids, and alkaloids in the chloroform and n-hexane extracts of *Aphanamixis polystachya* seeds. Numerous studies showed that in STZ-induced hyperglycemic rats, steroids exhibited intense hypoglycemic action by diminishing tumid blood glucose magnitudes and flourishing insulin intensity (Daisy et al., 2009). The scientific community has taken notice of Proença et al.'s (Proença et al., 2022) study on the hypoglycemic efficacy of flavonoids, copiously present in *Aphanamixis polystachya* (wall.) parker seeds that fire at DPP-4 and PTP1B.

Alkaloids, basic nitrogenous compounds that plentifully exist in *Aphanamixis polystachya* seeds, function similarly to other natural products in regulating glucose metabolism. They do this by either inducing or inhibiting a diversity of aspirant proteins, for instance, glucose transporters, AMPK, sterol regulatory element-binding proteins 1, glucokinase, glucose-6-phosphatase, and acetyl-CoA carboxylase (Muhammad et al., 2021). Thus, phytochemicals have overwhelmed APCE and APHE as potent hypoglycemic agents. It's interesting to note that APME contains carbohydrates. In contrast, the other two extracts did not, and this causes APME to elevate blood glucose levels in both STZ-induced and glucose-induced rats.

5. Conclusion

Aphanamixis polystachya is notable for several naturally occurring bioactive metabolites with remarkable therapeutic potential. Based on the above discussion, we can conclude that *Aphanamixis polystachya* seed extracts are an excellent source of hypoglycemic properties. This is only a preliminary study; additional research is inevitable to examine other physiological, pharmacological, and toxicological parameters along with the isolation of bioactive components that guarantee the genuine causes of the extractives' pursuit and their undistorted demeanor with the least negative impact. With any luck, more research will identify the active phytoconstituent and reveal the structure of the novel compound.

Conflict of Interest

The authors declare that there is no conflict of interest or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

All necessary data generated or analyzed during this study are included in this article. Any additional data could be available from the corresponding author upon request.

Author Contributions

H. M. Shadid Hossain Snigdha conceived the idea, outlined the content, and edited the manuscript; Dr. Md. Ekramul Haque supervised the research work; Md. Tahajul Islam collected information, performed the experiments, and developed the manuscript; MD. Shadin Mostakim analyzed and interpreted the data and wrote the manuscript.

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Abbreviation

AMPK: AMP-activated protein kinase.
ANOVA: Analysis of Variance.
APCE: Aphanamixis polystachya chloroform extract.
APHE: *Aphanamixis polystachya* n- hexane extract.
APME: *Aphanamixis polystachya* methanol extract.
BW: Body Weight.
DPP-4: Dipeptidyl peptidase-4.
DM: Diabetes Mellitus.
G: Glucose.
MET: Metformin.
N: Normal.
OGTT: Oral Glucose Tolerance Test.
PTP1B: Protein Tyrosine Phosphatase 1B.
STZ: Streptozotocin.
T2DM: Type 2 Diabetes Mellitus.
TG: Treatment Group.
USD: United States Dollar

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A study of the effect of volume fraction of Alumina Oxide on the thermal conductivity values of polyester resin particulate composites

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ABSTRACT

This study aims to calculate the thermal conductivity of unsaturated polyester resin when adding aluminum oxide Al_2O_3 as a filler in different quantities of 10%, 20%, and 30% to the resin and to study the effect of these additives on the thermal conductivity (K) of this resin material. The behavior was changed based on Fourier's thermal conductivity law when calculating the resin's K value before and after adding aluminum oxide. The results showed an increase in thermal insulation with an increase in the percentage of aluminum oxide in the resin with a decrease in the thermal conductivity value. The lowest value obtained was 0.23 W/m.c when the percentage of alumina oxide was 30% at the highest applied temperature of 50 °C. This was illustrated through the graphs that summarize the relationship between thermal conductivity and temperature based on different percentages of aluminum oxide.

Keywords: Unsaturated polyester resin, Alumina Oxide, Thermal insulation, Thermal conductivity

1. Introduction

With the increasing importance of energy and its widespread use, using thermal insulation materials has become necessary in buildings to reduce energy use, whether in cooling, heating, or other processes. Thermal insulation is a material or a group of overlapping materials that retard the rate of heat flow by conduction, convection, and radiation when applied correctly. Thermal insulators are defined as materials that reduce or resist heat transfer from outside to inside and vice versa. Reducing the need to use air conditioners, and its use is beneficial in all seasons; it works to maintain the temperature of the building in summer and winter and protects it from heat loss in the winter, so it remains warm and from gaining heat in the summer, so it remains cool or moderate (Wessel, 2001). Thermal insulating materials are classified into three main materials, which are as follows (Bakatovich & Gaspar, 2019): Fibrous insulation materials, such as silica materials, glass, and rock wool, and fiberglass and mineral wool are among the most widely used types. Cellular insulations, such as polystyrene and polyurethane. Granular insulations, examples of which are Calcium silicate, cellulose and expanded polystyrene of heat insulating materials are many, among which are the following: (ASTM, 2013) Glass mineral wool: Mineral glass wool is used as a thermal insulator in steam pipes, hot water lines, and industrial applications, as well as in the aircraft industry. These materials are characterized by their appropriate cost and ability to be used in high-temperature insulation. Calcium silicate is a non-combustible material with a compressive strength of 600 kN/m^2 and is used in steam pipelines and hot water lines, and added as insulators in ships, furnaces, and boilers. Rock mineral wool is widely used in thermal insulation applications. Also, it is used in the industrial and commercial sectors as a fire prevention material in installations and equipment.

One of the characteristics of thermal insulation materials is the ability of the material to be thermally insulated, and the thermal conductivity coefficient usually measures it. The lower the conduction coefficient is, the more the material's resistance to heat transfer. The thermal resistance is inversely proportional to the coefficient of thermal conductivity through the insulating material, which is usually done by all the different means of transmission (conduction, convection, and radiation) (Yousefi & Tariku, 2021).

Any insulation material's thermal characteristics must be examined since they have a significant impact on how heat is transferred within building envelopes. Thermal conductivity, specific heat, thermal diffusivity, thermal expansion, and mass loss are the primary factors that determine thermal characteristics (Yousefi & Tariku, 2021). The primary indicator of a material's capacity to transfer or restrict heat flows through building insulation materials is its thermal conductivity coefficient. Three primary parameters influence thermal conductivity at the macroscopic level: density, moisture content, and operating temperature (Ukponmwan, 1993).

Although traditional building materials are commonly utilized, alternative materials that come from natural sources also have comparable heating performance requirements. Condensation within the sample causes the thermal conductivity to decrease with increasing density, according to a study on hemp fiber insulation materials (Zach et al., 2016). Conversely, when density increases by 2/3, hemp fibers based on concrete notice an approximate 54% increase in thermal conductivity (Collet & Pretot, 2014). In a sheep wool test, it was found that when the apparent density increases from 20 to 40 kg/ m^3, a 50% increase in temperature might result in a 21% drop in heat conductivity (Zach et al., 2012). However, in his cellulose fiber experiment, Sekino found the reverse pattern (Sekino, 2016). From 20 to 110 kg/m^3, the density increases, and the λ values rise by roughly 5%. From 20 to 110 kg/m^3, there is a minor rise in the λ values of around 5%. An indicator of how density influences λ values was developed, known as "apparent thermal conductivity," to help explain this discovery. Thermal conductivity rises as a result of an increase in the number of thermal bridges made by cellulose fibers in the material as its density increases. In an experimental study utilizing three biomaterials, shemp concrete, flax concrete, and rape straw concrete, the impact of moisture on thermal conductivity at various concentrations was found to have the same effect. Research revealed that the dry density might be used to represent the dry thermal conductivity as a linear function of the latter. An additional investigation conducted by G. Balčiőnas et al. (Balčiūnas et al., 2016) proved that the relationship represented by a multiple regression equation and 97% of density

determine the thermal conductivity of hemp shives composites. Additionally, because of the low density of the sapropel binder additive, this specimen showed low thermal conductivity, ranging from 0.055 to 0.076 W/(m.K) within the range of 210 to 410 kg/m^3. Coconut fiber is one of the various natural fiber varieties that has been considered as a lightweight option for composite reinforcement. Three different coconut sample types were studied, and the results showed that as density increased from 30 to 120 kg/m^3, thermal conductivity dropped from 0.052 to 0.024 W/ (m.K) (Bui et al., 2020).

2. Materials and methods

2. 1. Composite materials

A composite material consists of two materials combined with different mechanical and physical properties. The purpose of this combination is to derive new properties that were not available in the original materials. In nature, there are many examples of composite materials, including cellulose fibers with wood material. In industry, reinforcing resins with synthetic fibers is the most common (Mallick, 2007). For the manufacture of a composite material, two materials must be available:

- **Base materials (Matrix Material).**

They are either metallic, ceramic, or resinous materials, which are most widely used for their good mechanical and thermal properties. Resins include phenolic, epoxy, and polyester resin.

- **Reinforcement material.**

There are several methods of reinforcing, including particle strengthening, dispersion strengthening, and fiber strengthening. Examples of the types of fibers used are glass fibers, Kevlar fibers, and glass fibers. Reinforcing by fibers is the most common reinforcement material due to its great strength compared to resin materials (Zach et al., 2013).

2. 2. Unsaturated polyester resin

Unsaturated polyester resin belongs to the group of thermosetting resins, where these resins are not able to be reformed by heat after turning into a solid material as a result of forming long polymeric chains intertwined with each other, which is called cross-linking. It is prepared from a reaction with a dibasic unsaturated acid, and it is required that one or both of the monomers have a double bond in their composition (Malik et al., 2000).

Polyester resin has good thermal properties as it withstands high temperatures (for resins) up to 260° C. Still, it suffers spontaneous disintegration at a temperature of about 300° C, even in the absence of oxygen. It is also characterized by excellent electrical and chemical resistance to solvents, acids, salts, wear, and environmental influences. It is also low in cost but also characterized by weakness and fragility (Mallick, 2007; Malmström & Hult, 1997). Polyester is added to fiberglass for the manufacture of mold structures, aircraft and automobile fuselage components, and other industries.

2. 3. Fillings

Fillings can be defined as metallic materials added to resin materials in different proportions to change their properties to obtain new properties, and one of the properties that require changing and as needed is resistance, stiffness, bladder, thermal, and electrical resistance (Teh et al., 2008). Fillers are added to polyester resin for two purposes: the first one is to reduce cost due to its low cost, and the second one is to strengthen the resin and have high resistance properties. Ceramic materials are considered one of the most important fillers added to the resin and kneaded for high hardness, resistance to wear, and poor conduction of heat. They are widely used in thermal insulators. Among the materials used are silicon oxide (silica), magnesium oxide, alumina, and others (Silva et al., 2012).

3. Experimental work

The following materials were used in this research:

1- Unsaturated polyester resin obtained from Tajoura Plastics Research Center.

2- Alumina, used alumina or aluminum oxide AL_2O_3 - with particle size and purity (95.5% µm10%).

3. 1. Sample preparation

Models are 25 mm in diameter and 4 mm thick. The preparation is done by mixing a quantity of resin after it hardens by adding 2% methyl ethyl ketone peroxide to the precipitate. After that, aluminum oxide is added in different proportions of 10%, 20% and 30% by weight

3. 2. Thermal conductivity measurement:

The Fourier Law can be used to calculate the thermal conductivity coefficient (k):

$$Q = -k \times A \times \left(\frac{\Delta T}{\Delta X}\right)$$

Where:

Q: The amount of heat that passes per unit of time and is measured in (W).

k: Coefficient of thermal conductivity, measured in (W/m.c).

A: Heat flow cross-sectional area, measured in (m^2).

$\left(\frac{\Delta T}{\Delta X}\right)$: temperature gradient relative to distance, measured in ($^oC/m$) .



Figure 1. Thermal conductivity

The curve shown in Figure 2 shows how to calculate the value of the temperature gradient ($\Delta T/\Delta X$) applied in the Fourier equation. (X_1, X_3) represent the distance between the thermometers on both sides of the model, and X_2 represents the thickness of the model (Bergman et al., 2011).

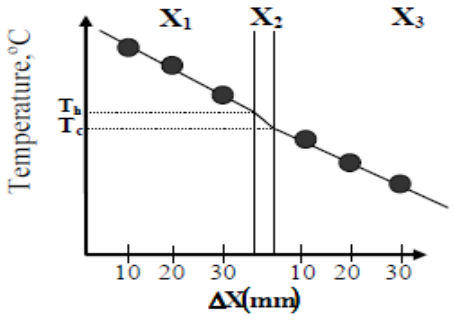

Figure 2. Temperature gradient

4. Results and discussions

Thermal conductivity increases with the increase in temperature, and the reason for this is the vibrations in the internal structure of the resin, which increase with the increase in temperature (Bogomolov et al., 2003). These vibrations begin to decrease when fillings are added to the resin, which works to impede the vibration and thus reduce the value of the thermal conductivity.

Figure 4 represents the thermal conductivity of polyester resin plus (10%) Alumina oxide as the percentage of thermal insulation increases as a result of obstruction. The internal structural vibration of the oxide, in addition to the alumina, is a poor conductor of heat due to its being of ceramic oxides (Zhou et al., 2007).

The thermal insulation value and the percentage of retardation of vibrations increase with the increase in the percentage of added alumina, as shown in Figure 5, which represents the thermal conductivity of the polyester resin in addition to (20%) of the alumina oxide, as the obstacles to heat transfer increase with the increase in alumina oxide minutes (Teh et al., 2008). This behavior continues with the increase in the proportion of alumina oxide, as shown in Figure 6, which represents the thermal conductivity of polyester resin in addition to (30%) of alumina oxide.

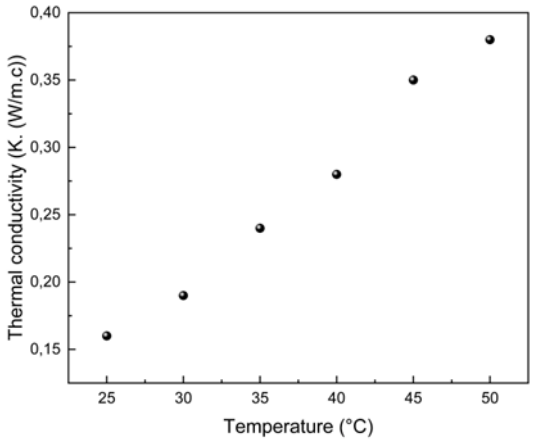

Figure 3. Polyester resin

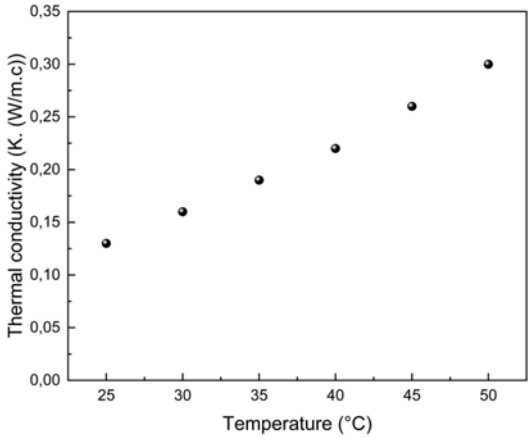

Figure 4. Polyester+10% Al_2O_3

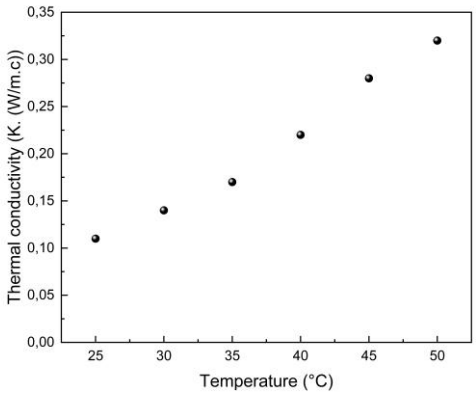

Figure 5. Polyester resin+20% Al_2O_3

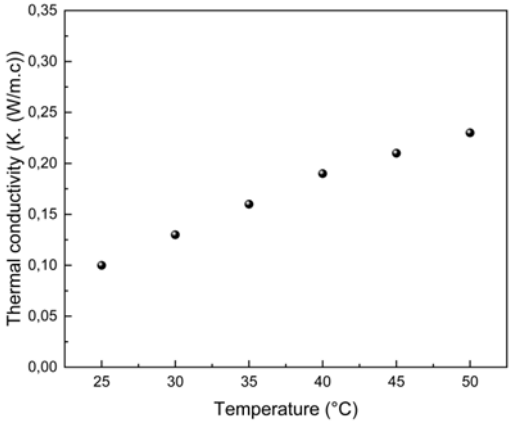

Figure 6. Polyester resin+30% Al_2O_3

5. Conclusion

Through the results obtained from the thermal conductivity test of polyester resin before adding alumina and after adding certain percentages of alumina oxide, a number of conclusions were reached:

1- The thermal conductivity value of polyester resin increases with increasing temperature, and this is attributed to the nature of the resin that can transfer heat.

2- When adding different percentages of alumina oxide, a decrease in the thermal conductivity coefficient of polyester resin was observed, as its value decreased at a rate of 30% more than 20% with the same change in temperature remaining constant.

3- Some other materials can be added, whether natural materials such as palm fibers, wool, thermal images, etc., to the polyester resin material and used as materials for either thermal insulation or heat conduction after studying the experiments and testing the thermal conductivity.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Data Availability

No data was used for the research described in the article.

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Evolution of computed tomography techniques

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ABSTRACT

Recently, computed tomography (CT) scanners, which combine X-rays and computers, have been developed and adopted globally as diagnostic tools. We found it necessary to chronicle the development of CT technology and identify the factors of their widespread application and the sequence of introduction and adoption of installed optical equipment, including the events that caused the advancement of these technologies and their impact on medical services. The twentieth century was full of scientific events and a wealth of information available to scientists and innovators worldwide, challenging the restrictions imposed on the space for technology transfer and the sharing of science and information that may limit coverage. Developments in emerging inventions and innovations. Through this paper, we review the main CT techniques developed. This work focuses on hardware and systematic evolution following the timeline associated with innovations that have contributed to image reconstruction technology.

Keywords: A computerized tomography scan, CT -Tomography, image reconstruction, processing, imaging by sections.

1. Motivation

In 1895, W.C. Röntgen discovered X-rays, which was a real revolution in medical diagnosis due to their ability to give a view from inside the body. Because of its limitations represented in physical properties, scientists focused on studying two-dimensional projections of bones. They found it difficult to diagnose tumors and soft shadow tissue and the inability to determine locations behind solid bones (Shao et al., 2020). This is what prompted researchers to invent "computed tomography" and try to create images of specific cross-sections or "slices" of the body by sending X-rays from multiple angles of the patient (Sosa et al., 2022). Due to the risks of exposure to large doses of radiation and the inability of CT X-rays to distinguish between soft tissues or differentiate between tumors and normal tissues (Müssig et al., 2020), physicist Alan Cormack proposed a theoretical method for tomography in 1963 (Carbonell Carrera & Bermejo Asensio, 2017). Cormack performed calculations to measure X-rays after they passed through the body, determined radiation absorption values, and derived the mathematical formulas necessary to build the supposed image structures in cross-sections (Turkan et al., 2017). Five years later, Godfrey Hounsfield presented a model of the device that closely resembles the theoretical specifications presented by Cormack; without knowing about Cormack's study, he experimented with using computers to display digital data patterns and improve CT X-ray images (Redondo et al., 2013; Turkan et al., 2017). Hounsfield wrote a proposal to build a scanner based on these ideas and later supervised the project to build a primitive medical experiment in 1968 that was effective and prompted him to pursue developing and refining the prototype each time (Kysela & Štorková, 2015; Redondo et al., 2013).

In 1971, he successfully built a head scanner, which was tested at Ambrose Hospital. An experimental diagnosis was performed, and an image of the tumor was successfully obtained (Dunleavy et al., 2009). Soon, head scanners spread from the UK to the US, and their effectiveness was completely confirmed.

Many teaching and research hospitals opened in the US, including Georgetown and Cleveland Clinic (Wei et al., 2015; Ye et al., 2020), so that radiologists receive technical training on devices and equipment and learn about methods of interpreting and analyzing CT images on computer screens. With the advent of 1976, factories for CT scanners and others had emerged.

Medical equipment spreads in France, Germany, Israel, Japan, Mexico, and the Netherlands (Chong et al., 2018; Ford & Minshall, 2019; Kong et al., 2016; McMenamin et al., 2014; Scalfani & Vaid, 2014). By the beginning of 1977, large scanners and CT machines could scan the entire body, were equipped with X-ray detectors, and could rotate around the body more quickly, providing greater accuracy and a faster pace (Codd & Choudhury, 2011; Gerson & Van Dam, 2003; Josman et al., 2008; Ke et al., 2020).

The development of computers, equipment, and software, along with the use of contrast agents, has gradually improved image quality and expanded the scope of radical concept (Ceccaldi et al., 2016; Modesti & Kanaar, 2001; Pinto & Flaus, 2010; Polo & Jackson, 2011). In fact, we found that contrast agents are an independent science that parallels the technical development of optical spaces, which are materials that are ingested or injected and help improve image quality. Further, the high-speed cardiac scanner was introduced in 1983 (Li & Zou, 2005).

Moreover, we note the increasing growth in computed tomography installations in member countries of the Organization for Economic Cooperation and Development, including Belgium, France, Greece, Italy, Netherlands, the US, Israel, the UK, Denmark, and Germany (Lamarche et al., 2010; Mirza-Aghazadeh-Attari et al., 2019; Shibata & Jeggo, 2020; Ström et al., 2004; Wang et al., 2002). At the same time, this field's relative decline and backwardness were clear in countries that do not enjoy such membership. In 1988, the German Siemens devices were developed, helical scanners that make a quick spiral pass along the patient's length (see **Figure 1**), a technology that differs from the traditional "slice by slice" system.

In 1992, the Israeli Elscint devices were developed. when multi-slice scanners increased scanning speeds, these devices were characterized by installing X-ray sources and detectors in rows, imaging several slices simultaneously. According to international standards, the clinical value of Elscint CT devices has decreased despite their superior performance speed due to the low quality of the image.

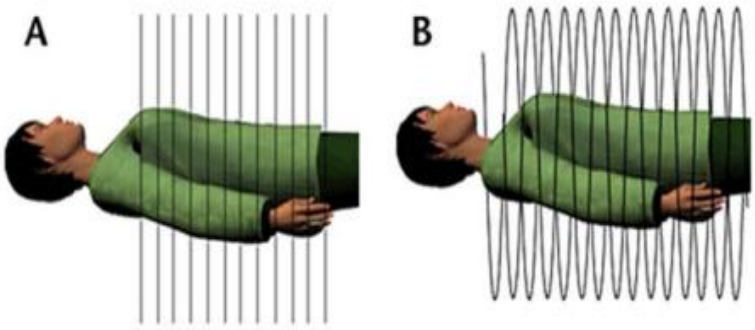

Figure 1. X-ray path in conventional (A) and spiral (B) CT scans.

Recently, experts have aspired to obtain cross-sectional images that combine helical and multi-slice designs (Ünal et al., 2004). Consequently, scanners have been developed that can capture image data four times faster, meaning eight times faster than the old devices.

It is characterized by reducing radiation exposure (Mognato et al., 2009) and supporting diagnostic applications. It performs accurate detection even in exceptional circumstances such as accidents and disasters, including identifying internal bleeding, scanning body and head trauma, and detecting heart and blood problems (Noda et al., 2012).

2. Introduction

Recently, with advances in the development of computers, the application of multi-faceted theories in physics, mathematics, chemistry, electronics, and computers aims to achieve the requirements of technology based on the ideas of computed tomography (Shao et al., 2020) and the scientific consensus on which it is based on mathematical proofs. Beginning with the success of Boheme C. in calculating the distribution ratios of radon gas in a layer of material when the values are integrated, it is found along certain lines that pass through the same layer in 1917 (Shao et al., 2020). It was viewed as essentially a practical reconstruction of the separation of matter for optical reconstruction, which prompted J. Frank, in 1938, to develop the optical back-projection technique to reconstruct X-ray images along a selective axis (Sosa et al., 2022). In 1963, Bracewell worked on creating an algorithm for image reconstruction. It has been approved for use in CT scanners (Müssig et al., 2020). Gabriel Frank obtained a brief patent for this invention in 1938, where the body was exposed to a cylindrical film to form a slice (Turkan et al., 2017), which encouraged Cormack to conduct many tests between 1957 and 1963 and to conduct his experiments and applications for this type of reconstructive tomography (Turkan et al., 2017).

He has achieved significant improvement in radiotherapy planning and developing a method for calculating radiation absorption distributions in the human body based on transmission measurements (Carbonell Carrera & Bermejo Asensio, 2017), and these applications were based on his hypothesis, recording the smallest absorption differences in soft tissue structures. With the practical implementation of G. N. Hounsfield's radon theory in 1972, computed tomography has become one of the most important tools used in the world (Müssig et al., 2020; Sosa et al., 2022). It was not easy to manufacture radiological equipment, but with Hounsfield's invention, laboratory activity shifted from manufacturing records and electronic components, including those required by CT-scanner devices (Antonelli et al., 2015; Redondo et al., 2013). In 1974, the first conventional head computed tomography (CT) device was approved. After that, many similar devices followed until 1972, when a CT scanner was installed for clinical purposes at Atkinson Morley Hospital in London, and the result of the examination performed on the first patient was the discovery of a cystic tumor in the frontal lobe (Redondo et al., 2013; Turkan et al., 2017). This was convincing evidence of the accuracy of CT scans and the effectiveness of CT scans in diagnosing tumors. This technology is considered the most important invention in diagnostic radiology. It was developed by using cylindrical lenses and rotating film technology to conform to the body while scanning, recording, and electronically controlling all components of the X-ray tube located in the

CT machine. Because of all these advantages, both Hounsfield and Cormack received Nobel prizes in medicine in recognition of their efforts in 1979. X-ray technology relies on providing a radiographic image of a three-dimensional (3D) structure; the object image is represented in 2D. However, during the filming process, dimensions and all levels are lost. Parallel X-ray films are perpendicular to each other; thus, an image is a projection of a three-dimensional volume onto a two-dimensional surface. The reason for this is the superposition of structures, which causes the high contrast to disappear. On radiographs, while it is clear in the bones, it appears in the air cavities when imaging the respiratory system. However, asymmetry may also occur in soft tissue areas like blood vessels surrounded by muscles. As for low contras, certain elements (such as iodine and barium), known as contrast media, are used and injected into the bloodstream to reduce energy levels. Through X-rays, blood vessels become visible in the image (Lee et al., 2022). Therefore, computed tomography (CT) technology is capable of evaluating poor radiographic contras. It provides in-depth information. When producing a 2D image of a 2D plane (slice), there is no overlap between structures, and the contrast of the image is improved. Furthermore, on this basis, it is a technology that can produce an image of one level in the body.

X-rays are produced when electrons are emitted from the material in the cathode tube by emission. The electron rays are accelerated and focused into high potential and collide with a target of which it is a part anode (as in **Figure 2**).

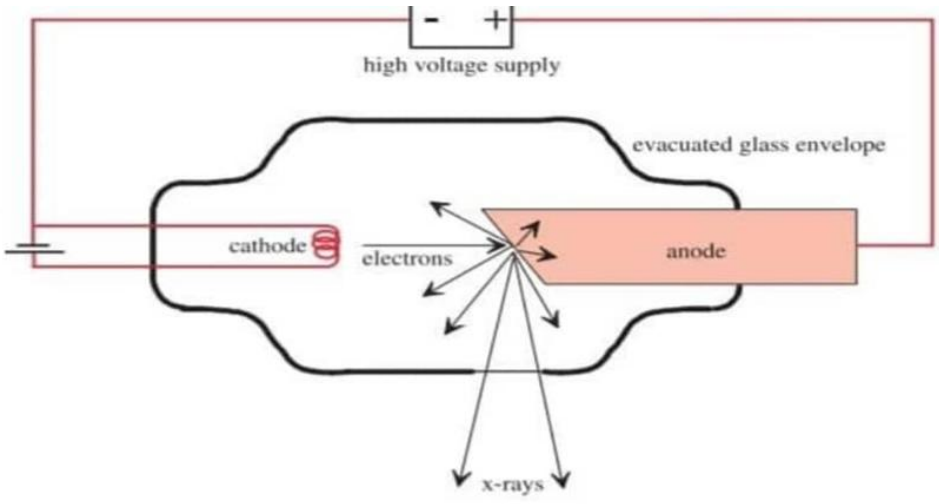

Figure 2. Illustration of X-ray computed tomography (Sosa et al., 2022).

Figure 2 represents a schematic of an X-ray tube. Here, the anode is shown as fixed, and it is noted that X-rays are emitted in all directions parallel to the lead shield (not shown in the figure) to produce and collect the electron beam. X-ray emission occurs due to the sudden deceleration of the ejected electrons on the nuclei or collision of the target electrons, a process called Bremsstrahlung that produces X-rays, followed by characteristic X-rays.

The electron is slowed down by the Coulombic interaction with the electrostatic field of the target nucleus, and when

the electron slows down and loses kinetic energy, transforming into electromagnetic radiation. Finally, the result of the difference in the kinetic energy of an accelerating (or decelerating) charge; as for electromagnetic rays, the amount of this energy emitted depends on how close the emitted electron is from the target kernel. The process includes Bremsstrahlung X-rays, where energy ranges from zero to maximum. As for emitted electrons, they are numerically equal to the electrical energy used to operate the X-ray tube, accelerate the electrons, and are measured in kilovolts. It is called Bremsstrahlung, the name of white radiation because of the broad continuous spectrum of the resulting X-ray energies (Dunleavy et al., 2009; Marnef & Legube, 2017). It also grows characteristic rays of vacant shells.

It arises from throwing an electron at a target atom that is ionized by the emitted electrons. When electrons descend from the outer shells and are filled, the vacuum is released, and the excess energy emanates through X-rays. As for the characteristic X-rays, they are unilateral and dependent on the binding energies of emitted electrons and their type; the atoms in the anode emit

X-rays simultaneously. In the case of tomography, X-ray tubes operating at 100-150 keV are often used because the emitted electron does not lose all its energy in one interaction. This is because it undergoes multiple collisions with the outer electrons of the target atoms, which mainly increases temperature, increasing the belief that only a small percentage of the ejected electrons undergo X-ray production reactions.

Modern photography methods have succeeded in providing a deeper understanding of medical science, exploring different materials, and exploiting the precise information that has developed in anatomy. X-rays are waves of electromagnetic energy that behave similarly to light rays. Shorter wavelengths and the ability to penetrate thick objects are generated during the Bremsstrahlung process when the hysteresis phenomenon occurs, and the primary electron beam is forced to enter the electric field surrounding the nucleus of the atoms in the sample (Marnef & Legube, 2017; McMenamin et al., 2014; Wei et al., 2015; Ye et al., 2020). The emission of K shell electrons is essential due to high energy. X-rays are emitted when an electron is expelled from an internal orbit in the atom.

X-ray tubes are used to create X-ray photons from the electrical energy provided by X-ray generators (Scalfani & Vaid, 2014), and recently, the synchrotron has become a source for producing X-rays `by high-energy electrons orbiting around the synchrotron. Synchrotron rays can be used multiple times. There are several methods and stages of photography (Li & Zou, 2005; Mirza-Aghazadeh-Attari et al., 2019; Wang et al., 2002). In the diagnostic scope, X-rays interact through two main processes that affect the formation of the radiograph. The first is known as the photoelectric effect (photoelectric absorption), and the second is the Compton effect. Clinically, Roentgen images are two-dimensional, in addition to 3D images obtained from computed tomography (CT) machines.

Using X-rays, a technique developed by different attenuation of X-rays in structures, means the composition and density of different tissues are the reasons contrast is obtained through X-ray transmission. It is absorbed into hard tissues, such as bone structures, to a greater extent than surrounding tissues. This paper discusses protocols for applying this technique to achieve acquisition and outlines image reconstruction and restoration methods.

3. Methodology and discussion of previous studies

This study uses the comparative approach that relies on comparison in studying medical imaging. Computed tomography, or CT scan, is a diagnostic medical test that relies on X-rays by creating a three-dimensional image of the body's internal organs from several two-dimensional images taken around a fixed axis of rotation. It is necessary to review the methods of applying medical tests and analyses during diagnosis to control the management of treatment techniques and gain a deep understanding of the operations of image reconstruction. In 1972, Godfrey implemented the theory of work done in tomography technology. During that period, Hounsfield developed a device for measuring radiometric density by conducting many experiments based on Alan Matheson's mathematical theories and MacLeod Cormack's ideas regarding X-rays. Since 1964, and as a result of the success of Godfrey's experiment, examination of bones, blood vessels, and soft tissues has become possible inside the body.

The scanner application is based on a series of two-dimensional X-rays. For multi-angle projections, 3D images or slides are processed and created using a computer. The three-dimensional nature of CT scans affects the provision of detailed information compared to radiographs. Conventional scanners have evolved to confirm absorption contrast predictions. Therefore, it has been adopted as one of the most important methods for imaging hard tissues such as bones. Modern research and studies are working on imaging soft tissues through contrast-enhanced imaging technology and introducing phase and dark fields to measure and photograph soft tissues, such as liver tumors, brain tissue, and lung nodules. The development of X-ray CT scanning systems is based on the application of modern theories in mechanical science, electronics, and computer technology.

To improve data quality and readability, researchers are working to speed up CT scanning times and reduce the resulting images to suit clinical purposes. It is suitable for non-clinical studies and has many applications in discriminating soft and hard tissues in the head, neck, abdomen, and chest, such as liver, lung tissue, fat, and bone, and detecting types of abnormalities such as lesions, tumors and metastases within different organs, thus obtaining information about their sizes, spatial locations, and

texture. Thus, it is necessary to perform a CT scan of the abdomen because it contains many organs of the digestive, urinary, endocrine, and reproductive systems, including the liver and kidneys, pancreas, spleen, digestive system, and the area surrounding these organs, to evaluate lesions, injuries or deformities and to investigate the effects of oncology treatments (Wei et al., 2015).

This procedure is often performed repeatedly to evaluate bone damage or damage to joints and diagnose lesions and fractures. CT scans also provide information about head injuries and study the causes of headaches, dizziness, strokes, and brain tumors. In this case, tests are frequently performed to detect abnormalities and diagnose shortness of breath and unexplained cough, chest pain, fever, and detection of lung nodules, which is a method common in chest CT scans, has been successful in diagnosing small nodules, and progress is made with each new generation of CT scanners.

Due to radiation risks, doctors are working to reduce the dose exposure to radiation distributed during CT scans after modifying the acquisition protocol (Dunleavy et al., 2009). Several researchers have begun to codify CT image reconstruction techniques and propose ways and means for new systems (Ke et al., 2020; Polo & Jackson, 2011). Hence, phase contrast and dark-field X-ray imaging mean the ability to enhance and analyze medical images. Many studies have also been conducted to measure network interference (Redondo et al., 2013) and conclude rates of scattering and refraction of X-rays by the scanned object, thus obtaining phase contrast and dark field. And experiment with several reconstruction and noise reduction methods to improve image quality (Ceccaldi et al., 2016; Polo & Jackson, 2011). It is necessary to note the metrological development in CT scanners, taking into account its standards to avoid deterioration of the quality of images in medical examinations, which means follow-up correction operations, periodic maintenance of devices and equipment, or removing them from service. Instructing the patient to follow safety instructions, such as neutralizing metallic materials, selecting desired positions, and carefully selecting scanner parameters is necessary.

Because they are the most vital factors, tomographic reconstructions depend on the development of computers to increase the efficiency and performance of advanced devices, assuming the attenuation object coefficients measured from a set of projections (transmission) and values, arranging data into a series of parallel beams and the projection at an angle θ, thus deepening the understanding of the inverse problem based on Beer-Lambert's law, describing absorption given by the relation:

$$I = I_0 e^{-\int \mu(x,y) ds} \qquad (1)$$

The intensity is straight, where μ (x, y) indicates the attenuation coefficient specific to each object type and points to the sender. It is also noted that the analytical methods used in reconstruction are a class of image techniques such as CT scan, which is common in commercial scanners and often uses filtered back projection (FBP) and a one-dimensional projection filter. The data is before back projection (2D or 3D), covering the image space (Carbonell Carrera & Bermejo Asensio, 2017; Ford & Minshall, 2019; Shao et al., 2020). Several limitations reduce the performance of the analysis. During reconstruction for medical applications, various scenarios, such as ignoring noise associated with measurements, can be overcome by influence during post-filtering operations. As for iterative reconstruction procedures in a class of algorithms, they begin by assuming the image and then comparing them with the values measured in real-time during operation so that adjustments continue until they are reconciled. As shown in **Figure 3**, after the CT scan is acquired and the projections are measured, a first image estimate is generated, and then the X-ray beam is simulated via the frontal projection. To obtain simulated projection data, compare it with the measured projection data.

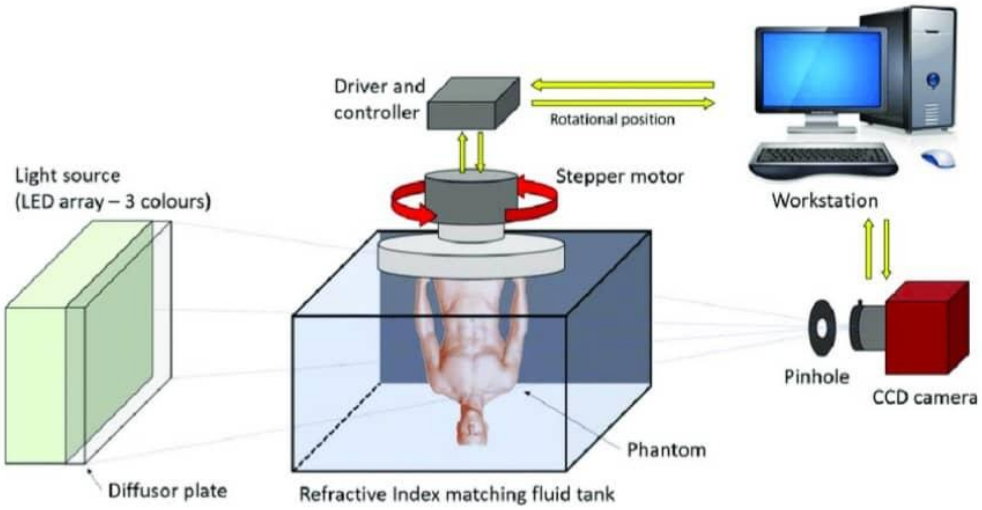

Figure 3. Simplified diagram of iterative reconstruction (Marnef & Legube, 2017).

If there is a difference, image estimates are updated based on spatial features, which is considered a basic procedure (Pinto & Flaus, 2010). As for the Algebraic Reconstruction Technique (ART), the more relevant iterative approach was first applied in practice by Kaczmarz in 1937 (Wei et al., 2015) and used independently by Gordon et al, a reconstruction algorithm is defined as the art of using a set of projections to rebuild a given object. Assuming the original linear problem is AX = Y, it can be written as follows:

$$\sum_{j=1}^{N} a_{ij}\, x_j = y_i, s.t. \quad i = 1,2,\dots\dots, M \;\; and \; j = 1,2,\dots\dots, N, \qquad (2)$$

Where a_{ij} is the weighting parameter that indicates the effect of cell i on the integration line j, x_j.

It is a constant equal to j cell density value, N indicates the total number of cells, and M indicates the total number of rays (Chong et al., 2018; Codd & Choudhury, 2011; Modesti & Kanaar, 2001). In 1984, the Simultaneous Algebraic Reconstruction Technique (SART) appeared and was accompanied by major changes in the standard artistic approach and its impact on projection data Limited. It has been found that reconstruction can be performed in just one iteration, which has been shown in superior performance compared to the ART approach (Gerson & Van Dam, 2003; Ye et al., 2020). Scientists have concluded that maximum likelihood projections (MLEM) assume measurements that are not considered models for the possibility of appropriate conditions and standards for the photon to ensure a reduction in radiation doses.

Probability (PL) has become a way to look at a model's complexity while estimating the bar meters from different models, instead of MLE implementation is simple, where the log-likelihood is imperfect. The range is thus expanded depending on the model and the number of parameters (Sosa et al., 2022).

4. Conclusion

In conclusion, it's clear that Roentgen discovered X-rays, and Hounsfield designed the first clinical CT scanner; many approved methods for X-ray and CT imaging have been proposed. Most included more advanced detail within the confines of the survey. This ensures the continuity of imaging techniques despite the contrast between stage and dark field.

Thus, one may demonstrate that it has the ability to improve medical imaging applications. The development of computers has had a positive impact on the innovation of advanced processing methods, such as tomographic reconstruction methods. Reducing the dose also worked. Use more stringent protocols to develop radiation protection systems and thus expand the scope of CT imaging for medical scenarios. Therefore, CT has become an important technology in the examination, diagnosis, treatment, and study of many conditions, including diseases and deformities.

Finally, we note that the technology of multi-slice and helical computed tomography (CT) scanners, radiation dose adjustment techniques, and image reconstruction algorithms by iterative methods are an addition to the developments of modern scientific research and the importance of a relationship between technology, economic development, and international cooperation. Further, international organizations and institutions to support and codify research work have witnessed great development.

By reviewing previous literature and studies, it is confirmed that there are major trends, methods, and standards that establish the foundation for further development in this field.

Provided that all flows and supporting information are available, and with an insight into the relationship between technology and economics that is already happening, in development, we noticed a lack of cooperation, partnership, and equality between the currents and the absence of a comprehensive model to ensure that progress occurs at a faster rate than it is now. We find it necessary to make some recommendations with the aim of settling the concept of the relationship between technological aspects and the economy.

Due to the influence of economic and environmental conditions on the development of scientific research. We also recommend conducting more research to develop a more detailed conceptual framework that should be carefully tested. Based on our work at the Benghazi College of Medical Technology and the academic and technical program, we offer the following recommendations:

1. It is necessary to work on developing a national strategy for adopting the concepts of the knowledge economy, identifying mechanisms to support scientific research, and providing the Benghazi Medical Technology College with laboratories to ensure the implementation of this strategy.
2. Paying attention to academic and technical research and study centers in order to stimulate innovation, invention, and excellence among researchers and those interested in medical technology and medical imaging projects in a way that serves the development of medical services and supports the economic growth of the country.
3. Through this paper, we notice the advancement of science and excellence in member states of the Organization for Economic Co-operation and Development (OECD), which is an intergovernmental economic organization that includes 35 member states, founded in 1961 to stimulate economic progress and global trade. It also has a notable activity in transferring technology between member states. We recommend that you join Libya, this organization, to achieve a real partnership in medical technology programs and what will bring good and societal development to the country.
4. We recommend forming research groups and spreading team spirit among technical researchers in the medical radiology department to gain in-depth knowledge of the mechanism of forming diagnostic medical radiology images and their dependence on the nature of the energy used in radiological imaging devices. For example, some rely on the X-ray spectrum, and others depend on the use of waves. Ultrasound, magnetic field energy, and radio waves are used in MRI.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Data Availability

No data was used for the research described in the article.

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Assessment of Knowledge and Practice on Prevention of Pressure Ulcer among Nurses in Palestine Cross-Sectional Study

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ABSTRACT

Pressure Ulcers (PUs) are localized skin injuries caused by long-term compression of soft tissue between an external pressure source and a bony prominence. They are one of the iatrogenic causes of extra morbidity for hospitalized patients. This study aimed to assess knowledge and practices regarding preventing PUs among nurses in Palestine. A cross-sectional study was conducted on 430 nurses in various Palestinian hospitals and health centers between February 15, 2024, and April 14, 2024. Convenience sampling was used to collect samples for this study. The collected data were analyzed using the Statistical Package for Social Sciences (SPSS) Version 27. Data analysis included descriptive and inferential statistics. The study showed that 65.61% of participants correctly answered questions about PU prevention. Regarding practice, 55.3% of nurses demonstrated a good level, with an average score of 2.37. Additionally, there was a significant association between demographic variables and levels of knowledge and practice in PU prevention, with P values ranging from 0.01 to 0.05. The study found that male nurses had higher knowledge and practice scores than female nurses, with significant differences in mean scores. The overall level of knowledge and practice among Palestinian nurses was found to be good; however, there is room for improvement in several aspects of both knowledge and practice. Variables such as gender, age, marital status, qualification, and job experience were found to have significant correlations with the level of knowledge and practice among nurses.

Keywords: *Pressure Ulcers, Nurses, Knowledge, Practice, Prevention, Palestine.*

1. Introduction

Hospital-acquired conditions are common, costly, and fatal (Arntson et al., 2021). One of the iatrogenic causes of extra morbidity for hospitalized patients is Pressure Ulcers (PUs). As a result, they may cause longer hospital stays and higher treatment costs. In addition, PUs are a significant issue for healthcare institutions. Beyond the physical difficulties that PUs cause to individuals, they also have a huge financial impact on healthcare systems (Al Mutair et al., 2020).

PUs are a localized skin injury that arises from prolonged compression of soft tissue between a bony prominence structure and external pressures. Friction and shear may also contribute. Millions of people are impacted globally, and the extent and severity of the injury to the skin, underlying tissue, and muscle vary (Gedamu et al., 2021).

Most people who have health problems that make it difficult for them to move or who spend much time in beds or chairs are at risk of getting PUs. Elderly people, those with spinal cord injuries, and people under anesthesia after surgery or trauma are more likely to develop PUs. On the other hand, persons of any age may develop PUs if they are exposed to constant, unrelieved pressure, friction, and shear forces for a prolonged period of time. Many factors, including advanced age, diabetes mellitus, smoking, prolonged immobility, poor nutrition, incontinence, decreased sensitivity, steroid usage, wetness, friction, shear, and pressure, are considered to have contributed to the development of PUs (Getie et al., 2020).

PUs are also a costly problem; treatment for PUs is 2.5 times more expensive than prevention. PUs increase hospital stays from four to thirty days, lower quality of life, and raise pain, morbidity, and death rates (Dalvand et al., 2018).

For a long time, nurses have been concerned about pressure ulcer prevention. Nurses are the first line of care for patients with Pus; therefore, to successfully prevent and treat them and their complications, which, if left untreated, can be fatal, nurses must be knowledgeable about PUs prevention and treatment (Saleh et al., 2019). Globally, nurses are recognized for their ability to tend to hospitalized patients, and the existence or absence of PUs is considered a key indicator of high-quality nursing care (Ingwu et al., 2019).

One of the most important aspects of PUs prevention is risk assessment (RA) (Díaz-Caro & García Gómez-Heras., 2020). One of the most popular RA techniques for developing PUs is the Braden scale (BS), which has been demonstrated to offer the best risk assessment with an acceptable ratio of sensitivity to specificity when compared to other RA measures (Gaspar et al., 2022).

Only a small number of studies, meanwhile, have identified risk factors for both healthcare-acquired PUs and patients with PUs present at admission. Individuals who developed PUs while in the hospital were often identified by their restricted activity level, length of stay, intensive care unit (ICU) admission, or the appearance of one or more PUs during the first skin assessment. PUs were substantially correlated with both older age and a lower Braden score (Olivo et al., 2020).

In 2015, a study of statistics in Palestine found that PUs are very prevalent among inactive patients. Comparatively speaking, 4,033 cases were reported in the West Bank and around 2,312 cases in the Gaza Strip (Eljedi et al., 2015).

The PUs issue poses a serious risk to patients' health due to increased mortality rates, poorer quality of life, longer hospital stays, expensive patient care, disturbed body image, extended recovery times, and a detrimental impact on patients' overall performance (Gedamu et al., 2021).

After heart disease and cancer, PUs-related injuries are the third costliest medical condition, taking up around 4% of Europe's yearly healthcare expenditure. For instance, in 2018, a US study revealed that individuals with PUs had costs that were 22.5% higher than those of other patients (Isfahani et al., 2024).

Diverse research on nurses' understanding of PUs management has produced inconsistent results. The likelihood that nurses will use PUs prevention in practice is significantly influenced by their knowledge of the technique (Saleh et al., 2019).

According to a 2018 study, it's possible that nurses lack sufficient understanding of current clinical practices and are not fully informed of updated treatment guidelines. Occasionally, nurses' actions are guided more by instinct, experience, or habit than by

knowledge (Dalvand et al., 2018). Some studies have indicated that a significant number of nurses cannot recognize PUs preventive guidelines, reduce PUs, or categorize and evaluate PUs risk (Mahmoud Belal & Ali, 2023).

In Palestine, particularly in the West Bank, pressure ulcers are a common issue in hospitals and long-term care facilities. A study conducted on pressure ulcers among patients in the ICU department of a governmental hospital in Palestine reported a prevalence of 33%, with most cases being in Stage I. When Stage I cases were excluded, the prevalence was 7.34%.(Almahmoud, 2018).

The analysis of a Palestinian study in 2019 about Palestinian ICU nurses' knowledge of PUs prevention displayed inadequate knowledge among nurses in this context (Al-Shaikh, 2019). Recent studies on the knowledge and attitudes of nurses in the closed care units about PUs in patients, as well as their prevention and management, are relatively limited (Avgerinou et al., 2022). However, several studies suggested that even though nurses' knowledge and attitudes regarding the prevention of PUs were poor, the management of PUs was relatively acceptable (Avgerinou et al., 2022).

2. Materials and methods

A cross-sectional study was conducted in West Bank hospitals and health care centers from February 15th, 2024, to April 14th, 2024. According to the Palestine Central Bureau of Statistics (2023), there are over 25,000 nurses in Palestine, over 13,000 nurses in the West Bank, and over 12,000 nurses in the Gaza Strip. The targeted population was all nurses, with a total population of over 13,000 nurses.

All nurses working in the closed and open units of all the hospitals and health care centers in the West Bank /Palestine and available during the data collection period were included as the study population for this study. Nurses in the Gaza Strip, nurses who refused to participate in the study, and other medical staff were excluded.

Samples for this study were gathered using convenience sampling. The sample size was determined with a 95% confidence level and a 5% margin of error. The calculated sample size was 374, and after adding a 15% response rate, the final sample became 430.

A standardized, self-administered questionnaire was used to gather data from study participants. The data collection tool was adopted from (Nasreen et al., 2017) . Cronbach's alpha was used to measure consistency for each domain of the questionnaire separately; the knowledge domain scored 0.86, and the practice domain scored 0.81, indicating good reliability for the entire questionnaire. Before data collection, the questionnaire was examined by experts for content validity, thoroughness, and clarity. The questionnaire consisted of three parts with a total of 45 items. First Part (Demographic Data): This part consists of 5 items regarding participants' demographic data of the participant (age, gender, and marital status) and other independent variables (qualification, & and job experience). Second Part (Knowledge Assessment): This part consisted of 20 questions assessing the participants' level of knowledge on PUs prevention. Questions were presented in a 'yes, no, or I don't know' format with a single correct answer. A score of '1' was awarded for each correct answer, and the wrong answer was given a score of 'zero' for a total score of 20. Researchers calculated the average of correct and incorrect answers. Third Part (Practice Assessment): This part consisted of 20 items assessing the participants' practice. The items were presented in an 'always, sometimes or never' format with a score of '3, 2 and 1' awarded for each answer, respectively, with a minimum mean of '1' and a maximum mean of '3'. (Mean Score: 1 - 1.66 = Poor Practice, Mean Score: 1.67 - 2.33 = Fair Practice, Mean Score: 2.34 - 3 = Good Practice).

Data collection started after the approval of the ethical review committee at Modern University College (Ref: muc001/2024). Hospitals and health centers were reached, consent was obtained from each unit's supervisor, and the study's aim was explained to the participants. Informed them that their participation was voluntary and they could withdraw any minute they felt uncomfortable with data collection. It was explained that filling out the form would take 10 minutes or less and that no personal data would be shared. The collected data was analyzed using the Statistical Package for Social Sciences (SPSS) Version (27). After entering the data, it was double-checked for errors or outliers. Descriptive and inferential statistical data analysis was

done**.** In terms of descriptive statistics, the study variables were described using frequency, percentages, mean scores, and Standard Deviation (SD). These metrics are suitable for characterizing the distribution and proportion of categorical variables, such as demographic characteristics (e.g., gender, department, and experience levels) among the 430 nurses. The independent t-test and One-Way ANOVA are chosen for inferential statistics because of their capacity to evaluate group differences. The independent t-test is employed when comparing two groups, and one-way ANOVA is utilized when comparing three or more groups. These statistical tests aid in effectively understanding the relationships and differences between the research variables and are appropriate for the data obtained.

3. Results

The demographic analysis of 430 nurses **(*via* Table 1)** reveals males constitute a slight majority, representing 53.3% (229 individuals). A significant portion of the nurses are married (51.16%, 220 individuals). The group is predominantly young, with 36.5% (157 individuals) falling within the 20-25 age bracket. Regarding qualifications, a significant number hold a bachelor's degree (50.2%, 216 individuals), followed by those with a diploma (25.1%, 108 individuals). In the area of job experience, a wide range of experience levels is present. Many nurses have 1-5 years of experience (36%, 155 individuals).

Table 1. Demographic variables of the nurses (n=430)

Variable		n	%
Gender	Male	229	53.3%
	Female	201	46.7%
Marital status	Single	172	40.0%
	Married	220	51.16%
	Divorced	26	6.04%
	Widowed	12	2.80%
Age group	20-25 years old	157	36.50%
	26-30 years old	106	24.65%
	31-35 years old	73	17.0%
	36-40 years old	63	14.65%
	>40 years old	31	7.20%
Qualification of the participants	Diploma	108	25.10%
	Bachelor's Degree	216	50.20%
	Masters' Degree	96	22.35%
	PhD	10	2.35%
Job experience	Less than 1 Year	108	25.10%
	1-5 Years	155	36.00%
	6-10 years	76	17.70%
	>10 years	91	21.2%

Regarding the level of knowledge on preventing PUs among nurses, **Figure 1** presents data on the average proportions of correct and incorrect responses from participants regarding PU prevention. The majority of participants, 65.61%, provided correct answers, reflecting significant knowledge or awareness in this area. In contrast, 34.39% of the responses were incorrect.

Table 2 Analyzes the frequency and percentages of correct and incorrect answers on PU knowledge among 430 participants, revealing a varied understanding of PU prevention and care.

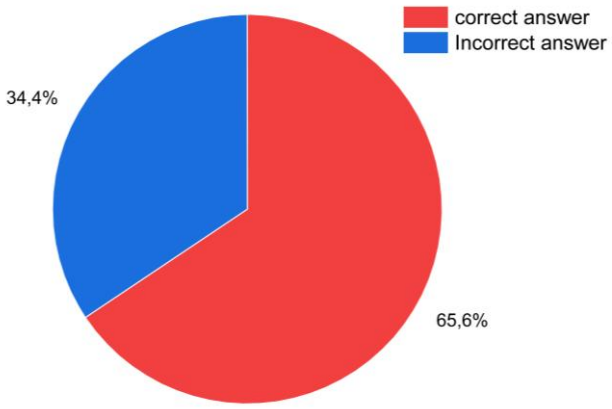

Figure 1. Average of correct and incorrect answers among participants toward the PUs prevention

Analyzing the frequency and percentages of correct and incorrect answers on PU knowledge among 430 participants reveals a varied understanding of PU prevention and care. The highest level of knowledge is shown in the recognition of risk factors for PUs, where 88.1% (379 individuals) correctly identified immobility, incontinence, impaired nutrition, and altered level of consciousness as contributing factors, with only 11.9% (51 individuals) answering incorrectly.

Conversely, the item with the lowest percentage of correct answers, and therefore the most significant misconception, is related to massaging over bony prominences. Only 38.4% (165 individuals) correctly recognized that this practice is not recommended, while a significant 61.6% (265 individuals) believed otherwise.

Other notable findings include a strong understanding of the importance of keeping the skin clean and dry to prevent PU development, with 76.7% (330 individuals) providing correct answers. In contrast, there is less certainty about the appropriate laboratory test for nutritional assessment in PU patients, with only 44.2% (190 individuals) answering correctly that serum albumin is the test of choice and a majority of 55.8% (240 individuals) providing incorrect answers.

Table 2. Frequency and percentages of each item Toward PU knowledge (n=430)

	Knowledge item	Correct Answer		Incorrect Answer	
		n	%	n	%
1.	Risk factors of pressure ulcers include immobility, incontinence, impaired nutrition, and altered level of consciousness.	379	88.1%	51	11.9%
2.	All hospitalized individuals at risk for pressure ulcers should have a systematic skin inspection at least daily and those in long-term care at least once a week.	338	78.6%	92	21.4%
3.	The first sign of pressure ulcer development is an open sore.	233	54.2%	197	45.8%
4.	Hot water and soap may dry the skin and increase the risk of pressure ulcers.	268	62.3%	162	37.7%
5.	It is important to massage over bony prominences.	165	38.4%	265	61.6%
6.	All individuals should be assessed on admission to a hospital for risk of pressure ulcer development.	279	64.9%	151	35.1%

7.	The patient's skin should be clean and dry to prevent the risk of pressure ulcer development.	330	76.7%	100	23.3%
8.	Adequate dietary intake of protein and calories should be maintained during illness.	304	70.7%	126	29.3%
9.	Vitamins C and E are important to maintain skin integrity.	232	54.0%	198	46.0%
10.	Serum albumin test is the appropriate laboratory test for nutritional assessment of pressure ulcer patients.	190	44.2%	240	55.8%
11.	Persons confined to bed should be repositioned every three hours.	266	61.9%	164	38.1%
12.	A turning schedule should be written and placed at the bedside.	311	72.3%	119	27.7%
13.	The head of the bed should be maintained at the lowest degree of elevation, consistent with medical conditions.	299	69.5%	131	30.5%
14.	A person who cannot move themselves should be repositioned every two hours while sitting in a chair.	311	72.3%	119	27.7%
15.	Heel ulcers are prevented by putting a pillow under the patient's legs.	301	70.0%	129	30.0%
16.	Friction may occur when moving a person up in bed.	297	69.1%	133	30.9%
17.	A Braden scale is a risk assessment tool used for assessing pressure ulcers.	239	55.6%	191	44.4%
18.	A low-humidity environment may predispose a person to pressure ulcers.	253	58.8%	177	41.2%
19.	Persons who have incontinence should be cleaned at the time of soiling and at routine intervals.	324	75.3%	106	24.7%
20.	Educational programs may reduce the incidence of pressure ulcers.	324	75.3%	106	24.7%
	Average (20 items)		65.61%		34.39%

Figure 2 details the levels of practice among nurses regarding preventing PUs. The data reveals that a majority of nurses exhibit a good level of practice, with 55.3% falling into this category. A substantial portion, 41.6%, demonstrate a fair level of practice. Notably, only a small minority, 3%, are categorized with a poor level of practice.

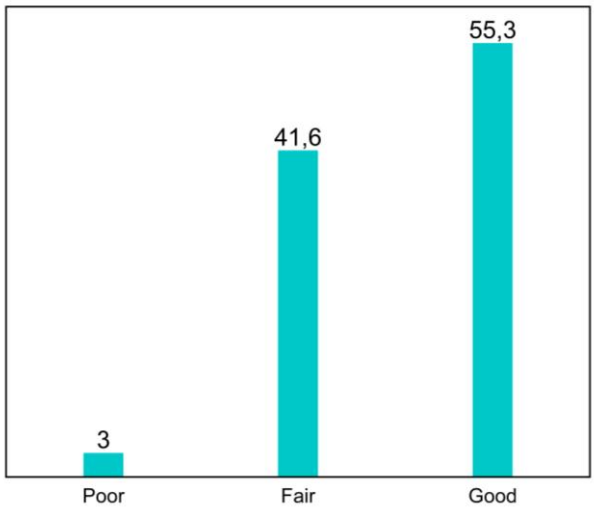

Figure 2. Level of practice on prevention of PUs among nurses

The practice with the highest mean score is "Turning the patient's position every two hours," which achieved a mean of 2.50 and falls within the 'Good' status category. Conversely, the lowest mean score is observed in "Attending seminars for pressure ulcer prevention," with a mean of 1.99, classified under the 'Fair' status. Most of the practices, such as observing how nurses assess risk factors, documenting data related to PU assessment, and using special mattresses, scored within the 'Good' range (mean scores ranging from 2.38 to 2.50). A few items, including performing skin assessment guided by standard care, using an assessment scale, using creams or oils for skin protection, and providing vitamins and food for malnourished patients, fell into the 'Fair' category (mean scores ranging from 2.19 to 2.33).

The overall mean score for the 20 items is 2.37, which is considered 'Good,' indicating that, on average, the nursing practices towards PU prevention are commendable.

Table 3. Mean score for each item toward the practice on prevention of PUs among nurses (n=430)

Practice	Mean	SD	Status
1. Observing how nurses assess risk factors for pressure ulcer development.	2.48	.597	Good
2. Identifying common contributing factors for pressure ulcer development through periodical assessment of the patient's skin.	2.41	.619	Good
3. Performing skin assessment guided by standard nursing care available in the hospital.	2.25	.712	Fair
4. Using an assessment scale to assess pressure ulcers.	2.19	.712	Fair
5. Documenting all data related to pressure ulcer assessment.	2.45	.666	Good
6. Assessing and providing management of pain in patients who experienced pain.	2.46	.638	Good
7. Performing skin care as a routine work of the unit.	2.44	.648	Good
8. Placing the pillow under patients' legs to prevent heel ulcer.	2.44	.640	Good
9. Using or advising caregivers to use creams or oils on patients' skin to prevent damage from urine, stool, or wound drainage.	2.33	.664	Fair
10. Paying more attention to pressure points during cleansing.	2.43	.643	Good
11. Performing lab tests for assessing nutritional status following physicians' instructions.	2.39	.627	Good
12. Providing vitamins and food for malnourished patients.	2.27	.672	Fair
13. Monitoring a protein and calorie diet in bedridden patients.	2.27	.636	Fair
14. Avoiding dragging patients during repositioning.	2.43	.653	Good
15. Using special mattresses to prevent pressure loadings, such as foam or air.	2.39	.651	Good
16. Avoiding massage over bony prominences to prevent pressure ulcer formation.	2.38	.665	Good
17. Turning the patient's position every two hours.	2.50	.621	Good
18. Using air beds for patients who are at high risk for pressure ulcer formation, following a physician’s prescription.	2.46	.638	Good
19. Attending seminars for pressure ulcer prevention.	1.99	.797	Fair
20. Giving advice to the patient or caregiver regarding pressure ulcer preventive care before discharging the patient from the hospital.	2.38	.699	Good
Total Mean Score (20 items)	2.37	.390	Good

Higher mean score means higher good practice
Mean score over 3

Table 4 shows the difference between nurses' demographic variables in terms of knowledge and practice scores. In an examination of 430 nurses, the study measured differences in knowledge and practice regarding PU prevention, revealing significant variances across various demographic categories. Male nurses demonstrated higher knowledge and practice than female nurses, with mean scores of 13.86 and 2.42, respectively, and these differences were statistically significant. When considering marital status, single nurses scored higher in both knowledge and practice than their married, divorced, or widowed peers, and these results were significant as well. Divorced and widowed nurses had notably lower scores in both areas, with widowed nurses scoring the lowest.

Looking at age groups, the youngest (20-25 years old) and the oldest nurses (>40 years old) scored the highest, suggesting that the extremes of the age spectrum were either more knowledgeable or practiced better preventive care. The highest scores were observed in nurses over 40 years old.

Educational qualifications are also correlated with knowledge and practice scores. Nurses with a diploma had the highest practice scores, which was statistically significant compared to those with bachelor's degrees, master's degrees, or PhDs. For knowledge, the trend was similar with diploma holders scoring the highest.

Regarding job experience, nurses with more than 10 years of experience scored higher in both knowledge and practice, with significant differences noted compared to those with less experience.

Table 4. Difference between demographic variables of nurses in terms of both knowledge and practice scores (n=430)

Variable			Knowledge			Practice		
		n	Mean	SD	P-value	Mean	SD	P-value
Gender	Male	229	13.86	4.646	.001*	2.42	.379	.002*
	Female	201	12.28	5.210		2.30	.395	
Marital status	Single	172	13.59	4.477	.001*	2.41	.334	.001*
	Married	220	13.47	5.049		2.39	.402	
	Divorced	26	9.38	5.396		2.04	.418	
	Widowed	12	8.08	3.629		1.94	.310	
Age group	20-25 years old	157	13.44	4.368	.001*	2.42	.334	.001*
	26-30 years old	106	11.47	5.567		2.24	.424	
	31-35 years old	73	12.34	5.475		2.30	.424	
	36-40 years old	63	15.03	4.059		2.46	.350	
	>40 years old	31	15.09	4.109		2.54	.389	
Qualification of the participants	Diploma	108	14.48	3.868	.001*	2.45	.309	.005*
	Bachelor's Degree	216	13.15	4.983		2.37	.388	
	Master Degree	96	11.65	5.628		2.26	.443	
	PhD	10	11.90	5.237		2.32	.497	

Job experience	Less than 1 Year	108	13.17	4.633	.001*	2.39	.383	.001*
	1-5 Years	155	12.87	5.104		2.35	.391	
	6-10 years	76	11.50	5.742		2.24	.415	
	>10 years	91	14.83	3.885		2.49	.343	

Independent t test and One-Way ANOVA

**Significant at p<0.05*

4. Discussion

Even though most nurses demonstrated a good level of knowledge, representing 65.61%, the 34.39% who demonstrated a poor level of knowledge regarding PU prevention can't be considered a small fraction. It's quite a lot, as they are registered nurses and are expected to possess a high level of knowledge. These findings are consistent with results from an Ethiopian study, which found that 54.4% of nurses had good knowledge of preventing PUs. In comparison, 45.6% had poor knowledge (Nuru et al., 2015), and results from a Chinese study found 59% had good knowledge of the subject (Jiang et al., 2020). These findings contradict other studies; for example, a 2014 study in Jordan reported that 73% of nurses lacked knowledge of PUs prevention (Qaddumi & Khawaldeh, 2014). Another study in Egypt found that 63% of nurses had poor knowledge regarding PUs prevention (El Enein & Zaghloul, 2011), while another study in Pakistan revealed that 80% of nurses had poor knowledge regarding PUs prevention (Nasreen et al., 2017). Compared to previous surveys conducted in the region, Palestinian nurses scored among the highest levels of expertise in the Middle East.

According to the survey's results, the majority of nurses practice well; this group included 55.3% of participants and had a mean score of 2.37. These findings are in agreement with other studies conducted in Ethiopia, where 58.5% of nurses had good practice towards PUs prevention and possessed a high degree of expertise in preventing PUs (Tesfa Mengist et al., 2022). This can be attributed to the simulation courses and practical training Palestinian universities utilize to teach nursing students about patient daily care, including skin care and PU care, during their learning years at nursing school. A study on pressure ulcer prevention revealed that nurses with formal training had higher levels of knowledge and practice than those who didn't (Nuru et al., 2015).

These findings are incongruent with another study conducted in Nigeria by Ingwu et al. (2019) and a study in Ethiopia by Nuru et al. (2015), which found that the majority—51% and 51.6% of nurses, respectively—had poor practice levels.

The level of knowledge is quite higher than the level of practice, which was not as expected. This is similar to a study conducted in Pakistan, which revealed the level of knowledge is higher than the level of practice towards PU prevention (Arshad et al., 2022). This particular finding highlights an important point of view that suggests there are barriers preventing nurses from implementing the knowledge they have, which must be investigated. A study conducted in Sweden revealed more than 12 barriers preventing nurses from implementing good pressure ulcer prevention, with lack of time being the leading barrier (Strand & Lindgren, 2010).

The overall mean score for the 20 items is 2.37, which is considered 'Good,' indicating that, on average, the nursing practices towards PU prevention are commendable. However, there remains room for improvement, particularly in enhancing participation in educational programs, which is critical for maintaining high standards of care.

Apparently, there is a significant relationship between nurses' knowledge and practice on preventing PUs and all demographic data mentioned in this study. In terms of gender, the findings show that males demonstrated higher levels of both knowledge and practice on PU prevention. This result is in accord with studies conducted in Palestine and Jordan, where they found a significant relationship between gender and the level of PU knowledge, with male nurses scoring higher than females (Qaddumi & Khawaldeh, 2014; Radwan et al., 2023). In terms of practice, these findings contradict another study conducted in Greece, where they found that the gender of nurses shows no statistically significant difference in terms of knowledge and

practice (Avgerinou et al., 2022). The significant relationship between nurses' knowledge and practice on the prevention of PUs and gender, where males demonstrated higher levels, may be attributed to differences in educational opportunities, workplace roles, and professional development resources.

When considering marital status, in this study, single nurses scored higher in both knowledge and practice compared to their married, divorced, or widowed peers, and these results were significant. Divorced and widowed nurses scored the lowest, with divorced nurses scoring higher than widowed nurses, the least knowledgeable and practiced. This is in accord with another study done in Ethiopia (Tesfa Mengist et al., 2022). This can be attributed to the social challenges they face in their daily lives, as well as the loneliness and loss of emotional support they used to get from their partners. A study conducted in Spain revealed that widowed nurses have higher burnout rates than others, clarifying that a lack of an intimate and supportive marital relationship is detrimental to mental health. On the other hand, marital partners' protection and healing support seem to be beneficial in reducing the emotional stress and anxiety that nursing staff members face when providing patient care. Also, being divorced or widowed as a nurse makes one more prone to emotional exhaustion and burnout (Cañadas-De la Fuente et al., 2018).

In terms of educational qualification, this study has shown that it's correlated with both knowledge and practice, where nurses with diplomas had the highest practice and knowledge scores. These findings are in line with another study conducted in Palestine-Gaza, where diploma holders scored higher than nurses with higher qualifications in terms of knowledge (Radwan et al., 2023). This can be attributed to diploma holders graduating within two years and practicing their job as nurses earlier. Also, being the weakest link and often asked by their colleagues with higher qualifications to do most of the work, they gained experience and were pushed forward to learn more. This finding is incongruent with another study conducted in Ethiopia that showed higher qualifications mean higher knowledge and practice levels (Tesfa Mengist et al., 2022).

On the other hand, findings indicate that there is a relationship between age groups and the knowledge and practice of the prevention of PUs. Nurses over 40 years old demonstrated higher knowledge and practice. Also, nurses with more than 10 years of experience scored higher in practice and knowledge. These findings are in accord with a study conducted in Ethiopia, which indicated that nurses with more than 10 years of experience scored higher knowledge and practice levels than those with less experience (Nuru et al., 2015). Another study conducted in Nigeria indicated that there is a significant correlation between years of experience and levels of knowledge and practice (Ilesanmi & Olabisi, 2014). This could be due to their chances of dealing with different cases with different professionals, pushing them to learn more from them and on their own. This indicates that the more nurses deal with the PUs and the more cases they manage, the amount of knowledge and practice experience they gain increases significantly. As stated in a study conducted in Ethiopia, more years of experience allow nurses to learn even from their own mistakes, making them better at preventing PUs (Nuru et al., 2015).

5. Conclusion

The overall level of knowledge and practice among Palestinian nurses was found to be good; however, there is room for improvement in several aspects, in both knowledge and practice. Variables such as gender, age, marital status, qualification, and job experience were found to have a significant correlation with the level of knowledge and practice among nurses. Further investigation into the cause of the decreased level of knowledge among nurses who scored poorly and the barriers to practice among nurses who scored poorly in practice is needed and remains an area of concern.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request. The datasets generated and analyzed during the current study are not publicly available due to privacy and ethical restrictions but are available from the corresponding author on reasonable request.

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Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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