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Bioactive Compounds of *Salvadora Persica* (Miswak): Extraction, Characterization and Role in Tooth Decay Prevention

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***Abstract*— Miswak (*Salvadora persica*) has been widely recognized for its efficacy in promoting oral health and preventing dental issues. This study aimed to extract, characterize, and evaluate the active compounds in miswak using the maceration method. Chemical analysis reveals that miswak is rich in fluoride, silica, and benzyl isothiocyanate, which contribute to its antimicrobial, antiplaque, and anticariogenic properties. Methods included extracting and evaluating the active compound in miswak using Fourier Transform Infrared (FTIR) Spectroscopy and Ultraviolet-Visible (UV-Vis) Spectrophotometry, and assessing its performance via an eggshell test. FTIR analysis revealed the presence of phosphorus- and calcium-related compounds essential to dental health, including calcium phosphate. Key functional groups, such as P-H at 2323.50 cm^{-1} and Si-O-C at 1087.68 cm^{-1}, were identified in both the powder and extract forms of miswak. Evaporation reduced levels of phosphorus-related compounds, potentially altering their chemical composition. UV-Vis analysis demonstrated higher absorbance at 25× and 75× dilutions in the original miswak than in the prepared miswak, indicating a higher concentration of active substances, as UV-Vis absorbance is determined by the presence of certain chromophoric groups. The electronic transitions observed in the UV-Vis spectra confirmed the presence of functional molecules vital for dental health. Performance tests using eggshells reported that miswak toothpaste protected against acidic environments (e.g., black coffee and carbonated drinks), reduced staining, and highlighted its protective qualities due to its fluoride content. The findings also validated miswak as a natural, cost-effective oral hygiene solution, especially in resource-limited areas.**

***Keywords*— Miswak, Oral health; FTIR, UV-Vis; Natural oral hygiene**

I. INTRODUCTION

Brushing and flossing are part of maintaining good oral hygiene, which is crucial for anybody trying to live a healthier lifestyle. Stores offer a wide variety of oral hygiene products to meet people's everyday oral care needs. In Western culture, an oral hygiene program would not be complete without a toothbrush for cleaning teeth. In contrast, a chewing stick, *Salvadora persica*, is used for brushing in Arabian and African nations [1]. *Salvadora persica* has been the subject of extensive research due to its benefits for dental health [2]. The World Health Organization recommends

Salvadora persica as an extra resource for those without access to dental care supplies [3].

Extensive research has established that *Salvadora persica* can prevent plaque formation. The biofilm layer known as plaque forms on the tooth surface and is composed of bacterial cells, their secretions, and saliva [4]. It is commonly recognized that *Salvadora persica* acts as an antibacterial agent, preventing the growth of several bacteria that cause plaque [5]. A lesion on the tooth's enamel is called dental caries, often caused by persistent plaque buildup. Dental varnishes and glass ionomer cement were two of the restorative methods used to repair broken teeth. Preventing further bacterial colonization at the caries site and promoting enamel surface remineralization are essential for the effectiveness of dental caries treatment. The three constituents of the hydroxyapatite crystal that comprise tooth structure are fluoride, phosphate, and calcium. According to reports, *Salvadora persica* contains these three minerals, suggesting it might help repair dental caries [6].

Some chemical compounds identified in *Salvadora persica* include sulfur, fluoride, butanediamine, and N-benzyl-2-phenylacetamide [7]. The chemical content of *Salvadora persica* can eliminate food debris on tooth surfaces, kill microorganisms, and function as an anti-inflammatory in the oral cavity [8]. *Salvadora persica* contains crystals that serve as ingredients for tooth whitening and plaque removal [9] and has recently become more well-known in Islamic countries, Asia, Africa, the Middle East, and South America, especially in Saudi Arabia [10]. The *Salvadora persica* sold on the market contains phosphoric acid, an active ingredient composed of phosphorus atoms that are helpful for the development of teeth and bones [11].

II. OVERVIEW OF *SALVADORA PERSICA*

Miswak, or *Salvadora persica*, belongs to the Salvadoraceae family and has been used as a toothbrush tree or chewing stick in Islamic cultures, as illustrated in Figure 1 [15]. Miswak (*Salvadora persica*) is a common ingredient in store-bought mouthwashes and toothpastes. It is frequently used as part of oral hygiene regimens. Miswak releases calcium and phosphorus into water and has a fluoride content of almost 1.0 (μg/g) [13]. It has also been observed that the extract of *Salvadora persica* contains a wide range of organic and inorganic components. Phenol compounds, alkaloids, tannins, benzyl derivatives, flavonoids, glycosides, and organic acids were among the organic components. Inorganic compounds include anionic chemicals such as fluoride, chloride, sulfate, thiocyanate, and nitrate [14]. Due to its potent properties, miswak has been used in many forms, including toothpaste, sticks, and extracts. It is also commonly used as a traditional remedy since it is readily available and reasonably priced [15].

Although miswak has been used for a long time, Prophet Muhammad (Peace be Upon Him [PBUH]) emphasized its significance in the early days of Islam. Islam emphasizes the importance of maintaining proper dental and general health. The use of chewing sticks, or miswaks, has been recommended to help reduce halitosis and maintain a clean mouth. Islam was proclaimed by the Prophet Muhammad (PBUH) in words and deeds, through demonstration and observation. The Holy Prophet Muhammad (PBUH) highlighted the significance of several plant species in his sayings, with miswak being the most essential [16].

However, miswak fluid has been widely utilized to cure a variety of ailments, including spleen issues, stomach ulcers, and joint pain [17]. Nonetheless, studies on its use as an antibacterial agent to treat a variety of dental issues, such as gingivitis and implant failure, tissue healing, and plaque removal, are still in their early stages [18].

Figure 1. *Salvadora persica*

III. CHEMICAL COMPOSITION OF *SALVADORA PERSICA*

Miswak's chemical composition contributes significantly to maintaining oral health, making it a valuable substance for dental applications. Each one of these components has a unique combination of medicinal and pharmacological actions. The rootbark is unique for its high chlorine content, with 27.06% of its composition being ash [19]. Benzyl isothiocyanate, which has bactericidal and virucidal properties and acts as a chemopreventive agent, is one of *Salvadora persica*'s main phytoconstituents. It also inhibits the production of carcinogenic and genotoxic chemicals.

In addition, the quantity of benzyl isothiocyanate in *Salvadora persica* root extracts was determined in these investigations along with benzyl nitrile, carvacrol, aniline, benzaldehyde, naphthalene, and lauric, palmitic, and myristic acids. They also included sitosterol-O- glucopyranoside, liriodendrin, syringins, and derivatives of furan and phenol lignin [20]. Volatile oils have a distinct scent, exhibit antimicrobial properties, and stimulate salivary flow [21]. The plant also contains terpene glycosides with cytotoxic properties, such as salvadosides and salvadorasides, as well as flavonoids [22].

Furthermore, miswak's silica and resins abrasively and protectively shield tooth enamel from dental cavities [10]. The bark of the miswak plant contains chlorine, which functions as a dentifrice to eliminate tartar. Antimicrobial compounds, including sulfate and thiocyanate (SCN), are present in miswak. Lactoperoxidase, which is present in saliva, oxidizes SCN in the presence of hydrogen peroxide to produce hypothiocyanite (HOSCN). Hypothiocyanate causes cell harm by blocking bacterial enzymes. The sulfur compounds identified in mustard plants have a strong flavor and aroma and are well-known bactericidal agents [23].

Salvadorine and trimethylamine have also demonstrated strong antibacterial and gingival-stimulating qualities. Combining trimethylamine, sulfur, alkaloid, and resin

molecules has been demonstrated to have antifungal effects. *Salvadora persica* fibers were examined both elementally and morphologically by [9]. Various mineral types present in the fibers were also identified using Energy-Dispersive X-ray Spectroscopy (EDX) and scanning electron microscopy. Rhomboidal crystals are composed of calcium (Ca), sodium (Na), oxygen (O), carbon (C), sulfur (S), and potassium (K); irregular crystals are made up of calcium (Ca), iron (Fe), silicon (Si), and aluminum (Al) (34). The essential oil isolated from the stems of *Salvadora persica* had high concentrations of benzyl isothiocyanate (52.5%), benzyl nitrile (38.3%), carvacrol (3.3%), benzaldehyde (2.5%), aniline (0.7%), and naphthalene (0.6%) according to other studies [24].

On the other hand, several studies have demonstrated that extracts from *Salvadora persica* possess antiplaque, antiperiodontal, anticariogenic, anti-inflammatory, and antimycotic properties [10]. The therapeutic effects of the various parts of *Salvadora persica* are outlined in Table I.

TABLE I.. THE THERAPEUTIC EFFECTS OF DIFFERENT COMPONENTS OF *SALVADORA PERSICA*

Phytocomponents	**Therapeutic Effects**	**References**
Benzylisothiocyanate (BIT)	Anticarcinogenic Antibacterial effects Virucidal effects	[25] [26] [27]
Beta pinene	Antimicrobial activity	[28]
Myrcenol	Antibacterial	[29]
Sabiene	Antimicrobial activity	[30]
Silica	It has abrasive properties that eliminate dental plaque and tooth stains	[31]
Salvadorine (Alkaloids)	Anticancer and antiplaque effets Antifungal properties It has antibacterial and gingival stimulating properties	[32] [33]
1,8-Cineole	Antimicrobial and cytotoxic	[32]
Salvadoraside	Anti-inflammatory	[34]
Isoterpinolene	Antioxidant	[25]
Tannins (Tannic acid)	Inhibition of C.	[35]
Phytocomponents	Therapeutic Effects	References
Benzylisothiocyanate	Anticarcinogenic	[25]
(BIT)	Antibacterial effects	[26]
	Virucidal effects	[27]
Beta pinene	Antimicrobial activity	[28]
Myrcenol	Antibacterial	[29]
Sabiene	Antimicrobial activity	[30]
Silica	It has abrasive properties that eliminate dental plaque and tooth stains	[31]
Salvadorine	Anticancer and	[32]
(Alkaloids)	antiplaque effets	
	Antifungal	[33]
	properties It has	
	antibacterial and	
	gingival stimulating	
	properties	
1,8-Cineole	Antimicrobial and cytotoxic	[32]
Salvadoraside	Anti-inflammatory	[34]
Isoterpinolene	Antioxidant	[25]
Tannins (Tannic acid)	Inhibition of C.	[35]

IV. APPLICATION OF *SALVADORA PERSICA*

Miswak's effectiveness in preventing tooth decay has been extensively studied, and the results reveal that it can be used even without other tooth-cleaning methods. As a result, miswak has a variety of current and prospective applications. For example, by reducing plaque, bleeding, and gingival indices, using chewing gum with miswak extract may enhance periodontal or oral health [45]. This is significant because oral candida infections are known to occur in patients with chronic conditions that compromise immune function, such as diabetes mellitus and renal disease, which are frequently treated with immunosuppressive medication [24].

A. Miswak Chewing Stick

Miswak was identified as a safer and more efficient antibacterial toothbrush than regular toothpaste, particularly fluoride-containing toothpaste [46]. Moreover, compared with a toothbrush, the miswak chewing stick remains an efficient antiplaque agent [47]. According to another study, fluoride treatment of miswak chewing sticks did not significantly alter the amount of plaque removed compared to regular toothbrushes, fluoride-containing or not.

However, it was revealed that the plaque-removal rate with both miswak and a regular toothbrush was comparable [48]. Miswak is equally effective as a toothbrush at removing plaque, according to additional scientific and clinical studies that compared the performance of both tools in this regard [49], [24]. In addition to being an inexpensive oral hygiene tool, chewing sticks have been linked to additional benefits, such as strengthening the jaw and promoting spontaneous saliva flow, both of which are beneficial for oral hygiene in certain nations where toothbrush use is not common [24].

B. Miswak Toothpaste

The outcomes demonstrated that miswak had an overall effect on *Candida* and all microorganisms. Miswak is effective against a variety of oral germs that cause periodontal disease and dental cavities [50]. Both right away and after two weeks of use, miswak was noticeably more effective than regular toothpaste at reducing Streptococcus mutans. This is also explained by miswak's antimicrobial properties [51]. The researchers studied the efficiency of fluoridated toothpaste compared with miswak-infused toothpaste in reducing plaque.

They observed that miswak toothpaste removed plaque far more effectively than ordinary fluoridated toothpaste [52]. The efficacy of a toothpaste containing miswak extract was compared with that of conventional Colgate® toothpaste and the popular herbal toothpaste Parodontax®.

The results reveal that using a toothpaste containing miswak extract, which functions similarly to herbal toothpaste, may be safely used by patients with gingivitis [53]. Moreover, chewing sticks provide oral tissues with mechanical and chemical cleansing that is equal to, if not better than, that of a conventional toothbrush. This alternative suggests that miswak use may successfully and solely replace the conventional toothbrush [54], [24].

C. Miswak Mouthwash and Chewing Gum

Plaque can be effectively removed using mouthwash [55]. However, the traditional mouthwash contains chlorhexidine, which can cause tooth discolouration, oral mucosal irritation, and a terrible aftertaste, among other negative effects [56]. This finding has made the creation of natural mouthwash alternatives necessary. The outcomes indicated that the mouthwash containing miswak was significantly more successful than the two chemical components at removing plaque [57].

Additionally, a study by [45] examined chewing gum manufactured from miswak and revealed that it had a miswak flavor, whether used with or without dental scaling. There was no statistically significant difference in plaque reduction among the groups that used 15 mL of the mixture to wash twice a day.

V. BENEFITS OF *SALVADORA PERSICA*

Miswak has been indicated in experiments to be highly effective at preventing tooth decay, even when no other tooth-cleaning methods are used. On the other hand, by reducing gingival indices, bleeding, and plaque, chewing miswak extract gum may improve periodontal health [19].

Miswak is a mechanical instrument that effectively reduces daily plaque accumulation because it has fibrils similar to those of a toothbrush. Miswak's silica functions as a mild abrasive to help remove stains. *Salvadora Persica* contains vitamins and minerals that promote the remineralization of hard tooth tissues, encourage soft tissue regeneration and healing, and prevent the growth of calculus. These include calcium, chloride, and vitamin C. Several clinical studies have examined the effects of miswak on periodontal and gingival health, indicating that using a miswak five times a day reduced gingivitis on the buccal and lingual surfaces. When used properly, miswak reduces plaque and gingivitis more effectively than tooth brushing, according to the majority of research [58]. Rinsing the tongue with water helps prevent halitosis and remove the white coating [59], [60].

VI. EFFECT OF USING *SALVADORA PERSICA*

A. Antiplaque Effect

Determining miswak's efficacy is crucial, as a significant portion of the global population uses it as the only tool for oral hygiene [61]. Since *Salvadora persica* contains an antibacterial ingredient that inhibits the growth of several plaque-causing bacteria or germs, miswak helps prevent plaque [54]. Dental caries is caused by bacteria growing on enamel, leading to the formation of plaque and other periodontal disorders. Since tannins are present, miswak has an antiplaque impact on oral bacteria [19].

It was determined that when miswak is applied correctly and is preceded by expert education, it reduces plaque and gingivitis more effectively than tooth brushing. When it came to plaque removal from embrasures, the miswak seemed more efficient than a toothbrush, improving interproximal health [24].

B. Anticariogenic Effect

Dental varnishes and glass ionomer cement can be used to treat dental cavities and rebuild the tooth structure. However, for the restoration to be successful, the enamel surface must be better remineralized, and further bacterial colonization at the caries site must be prevented.

According to [62], miswak contains three minerals that make up the tooth structure: fluoride, phosphate, and calcium. These elements imply that miswak can help repair dental caries. According to [63], the incidence of dental caries was much higher among non-users than among miswak users, suggesting that miswak may help prevent dental caries. Previous research had also exhibited that miswak significantly reduced tooth cavities in high school pupils [63], [64].

Miswak extract has strong antibacterial properties against dental-cavity-isolated bacterial species, according to several laboratory investigations [65], [66], and miswak's fluoride concentration has been linked to its anti-decay properties [21]. This explains why caries is more widespread in urban regions than in rural ones, where miswak usage was more prevalent in the past [67]. According to another study, *Salvadora persica* contains bioactive, dual-functioning compounds that inhibit the growth of *Streptococcus mutans (S. mutans)* and limit its colonization and accumulation in dental caries. Furthermore, they said that *Salvadora persica* may inhibit the initial adhesion of cariogenic bacteria and subsequent biofilm formation, thereby slowing the progression of dental caries [48], [24]. The effects of using *Salvadora persica* are outlined in Table II.

VII. LIMITATIONS USING *SALVADORA PERSICA*

Maintaining good oral and dental health protects against discomfort in the mouth and face, and oral diseases continue to rank first among the world's most prevalent illnesses, with serious negative effects on both health and economic performance [70], [64]. Dental cavities, gingivitis, and periodontitis are mostly caused by dental plaque, also known as oral biofilm. It also causes most oral illnesses. Despite being considered preventable, these problems remain widespread. Nonetheless, mechanical and chemical methods of removing tooth plaque are crucial for both preventing and preserving oral health [48], [64].

TABLE II. THE EFFECTS OF *SALVADORA PERSICA*

Effect of *Salvadora persica*	**Findings**	**References**
Antiplaque	Investigated by indirectly reducing the development of plaque and dental cavities, *Salvadora persica* is effective in promoting excellent oral hygiene, according to research on the decrease in periodontal disease incidence in children who use it.	[68]
Anticariogenic	Investigated the effectiveness of propolis, miswak, and chitosan-containing tooth varnishes for remineralizing damaged enamel. Remineralization was substantially greater in chitosan and miswak than in the control varnish.	[69]

Despite this, miswak is considered an inexpensive and sensible method due to its beneficial pharmacological properties that help maintain good dental health. There are several drawbacks associated with its use. The long axis of the miswak bristles makes it difficult for users to reach the interdental spaces and the lingual surface. As a result, users may not be able to precisely and conveniently reach all oral surfaces [8], [64]. Another disadvantage mentioned relates to the regular miswak practice for the anterior teeth. It is said that frequent brushing may damage the tooth's surface appearance and cause significant attrition [71], [64].

In addition, miswak may have a negative effect on teeth and the gingiva if it is used dry and hard. Despite the benefits and lack of cytotoxicity reported in previous studies on fresh miswak, the oral mucosa is negatively affected by frequent use [72], [64]. Considering miswak is an oral hygiene instrument with a sensitive approach, these drawbacks may be overcome through awareness and understanding, by modifying the proper technique and use without negatively affecting it [64].

VIII. SAMPLE COLLECTION AND PREPARATION

The study sample consisted of original miswak (Al Khair Olive Brand) and prepared miswak powder purchased from an online market. Three categories of miswak samples were used: powder, extract, and evaporated extract. Solvents were used in the maceration process to extract compounds from the miswak samples. The miswak extracts are made using absolute ethanol, 95% ethanol, distilled water, and the Attenuated Total Reflectance (ATR) sampling technique in FTIR spectroscopy. Among the tools used in this research are sterile bottles, Whatman filter paper No. 42, a sample container, a knife, a rotary evaporator, analytical scales, measuring flasks, and blenders [11].

IX. *SALVADORA PERSICA* EXTRACTION

To extract active compounds from the original miswak chewing sticks, the miswak skin was peeled and grated. The grated result was then aerated for 7 hours, after which it was dried in an oven. The dried miswak was then ground into a fine powder. Eight grams of powdered miswak were soaked with 80 mL of 95% ethanol (ratio 1:10) in a container. The miswak solution was then closed and left for 24 hours [73]. Next, the miswak extract was filtered through filter paper and placed in a sterile bottle. Miswak extract bottles were refrigerated until the sample was ready for use. The extract was later evaporated at a 1:20 ratio by dissolving 18 g of miswak extract in 360 mL of ethanol and allowing it to stand for 24 hours. After that, the extract was filtered and concentrated using an evaporator to yield a thick concentrate [11].

X. CHARACTERIZATION AND PERFORMANCE TEST OF *SALVADORA PERSICA*

The active compounds extracted from miswak were characterized using Fourier Transform Infrared (FTIR) Spectroscopy and a UV-Visible (UV-Vis) Spectrophotometer. Samples were tested using safe, non-destructive optical techniques [74]. This study used three types of sample tests, namely, the powder sample test, the liquid extract sample test, and the evaporated extract test. The samples were analyzed by ATR, a sampling technique in FTIR spectroscopy, to determine the active compounds in powder miswak. In contrast, the UV–Vis spectrophotometer method was used to determine the amount of the active substance based on absorbance. The active substances in this study were compounds that can be easily separated and bound to other compounds [75], [11].

A. Fourier Transform Infrared Spectroscopy (FTIR) Analysis

A small amount of miswak powder was used with a small spatula, then tested using FTIR. For the FTIR analysis of miswak liquid extract, 2 drops (0.05 cc) were added. Lastly, for the FTIR analysis of evaporated miswak extract, samples were analyzed at concentrations of 100, 500, and 1000 ppm. These variation tests were aimed at studying the possibility of identifying the concentrations of evaporated miswak extract mixed into toothpaste. In the first step, two drops of evaporated miswak extract (100 ppm) were applied. Subsequently, the concentrations of 500 and 1000 ppm extracts were measured alternately using FTIR [11].

B. Ultraviolet-Visible (UV–Vis) Spectrophotometer Analysis

Ultraviolet-Visible (UV–Vis) spectrophotometer analysis was performed to determine the amount of active substance based on the results of FTIR spectroscopy by observing the absorbance values. Organic samples were analyzed using a

spectrophotometer over 200-800 nm. For the miswak liquid extract test, miswak extract was diluted 75× and 25× with absolute ethanol. The first test process was the blank test or background test. Next, a 10× dilution was performed using a micropipette with 1000–100 µL, and the sample was then shaken with 9 mL of absolute ethanol. A 75× dilution was prepared by adding 1.5 mL of the 10× dilution to absolute ethanol, bringing the final volume to 10 mL. The sample was shaken, then placed in a 4 mL test cuvette for UV–Vis analysis. A 25× dilution was performed by dissolving 2.5 mL of the sample and the 10× dilution sample. Samples were diluted with absolute ethanol to a final volume of 10 mL. A total of 4 mL of sample was placed in a cuvette, and UV–Vis analysis was conducted [11].

For the evaporated miswak extract test, 0.01 g of evaporated miswak extract was diluted to 1000 ppm in 10 mL of absolute ethanol. Furthermore, 5 mL of the sample at 1000 ppm was dissolved in 10 mL of absolute ethanol to obtain a concentration of 500 ppm. Lastly, 2 mL of the 500 ppm sample was diluted with 10 mL of absolute ethanol to obtain a 100 ppm sample. All samples were tested using a UV–Vis spectrophotometer as illustrated in Figures 2 and 3 [11].

Figure 2. Tooth Decay Experiment with Eggshells. Left: Egg immersed in a carbonated drink. Right: Egg immersed in black coffee.

The extraction process was conducted to obtain the active substances in miswak, as depicted in Figure 4, whereas the evaporation process aims to isolate the pure substances contained in miswak. These compounds were detected only in trace amounts in the miswak powder spectrum due to the high oxygen and hydrogen content, which masked other compounds that were not dominant in the miswak. Some chemical compounds identified in miswak include sulfur, fluoride, butanediamine, and *N*-benzyl-2-phenylacetamide [77], [78], [11]. These compounds can kill both Gram-positive and Gram-negative bacteria [7], [11].

Figure 3. Half of the surface of a raw egg remaining in its shell (left image), and another surface of the same egg in the same eggshell was covered with half of the miswak toothpaste (right image).

Figure 4. Extraction process of the original miswak (Olive) and the prepared miswak. Left: Original Miswak (Al Khair Olive Brand). Right: Prepared Miswak.

XI. RESULT AND DISCUSSION

Samples were tested using optical techniques that were quite safe and did not damage the test sample [74], [11]. Three types of sample tests were performed: the powder sample test, the liquid extract sample test, and the evaporated extract test. The samples were tested using FTIR Spectroscopy and the UV-Vis Spectrophotometer method. The FTIR analysis was used to identify the active substances in powder miswak, whereas the UV–Vis analysis was used to determine the amount of active substances based on absorbance values. The active substances are compounds that can be easily separated and bound to other compounds [75], [11].

A. Fourier Transform Infrared Spectroscopy (FTIR) Analysis

Similarities have been identified in the spectra of the miswak powder samples in Figure 5. Miswak powder's spectrum analysis demonstrated that the major chemicals in the two types of miswaks were anticipated to produce a P-H ester strain and phosphoric acid group with a wave range of 2425–2200 cm^{-1} in Figure 5 and Table III. Phosphorus-containing groups were identified as the active substances. According to [11], this compound, along with calcium, formed a calcium phosphate compound. Phosphorus and calcium combine to form calcium phosphate, which is involved in the growth and formation of human bones and teeth.

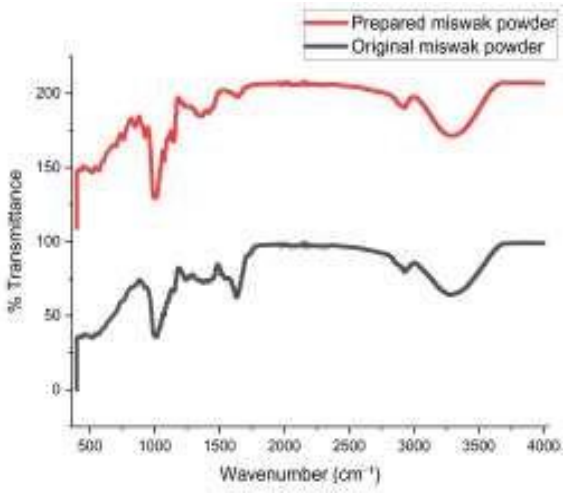

Figure 5. FTIR analysis of original miswak (Al Khair Olive Brand) and prepared miswak powder

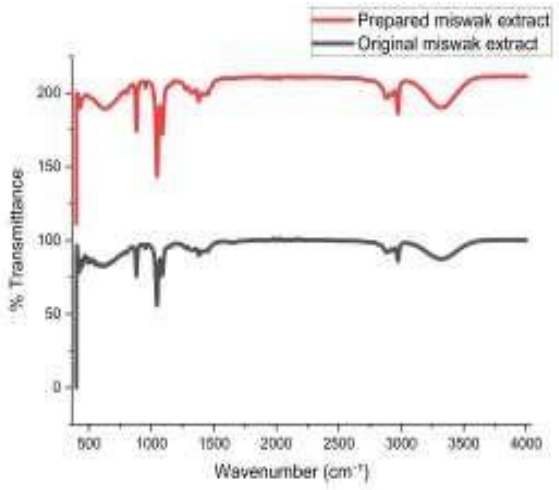

Figure 6. FTIR analysis of original and prepared miswak liquid extract

TABLE III. THE CONTENT OF THE ORIGINAL MISWAK POWDER

Wavenumber (cm^{-1})	Wavenumber range (cm^{-1})	Interpretation	Infrared Absorption
3281.26	3200-3550	Phenol OH strain	Oxygen atoms
2883.95	2900-2700	Aldehyde C=H strain	Oxygen atoms
2323.50	2425-2200	P-H strain and Phosphoric acid	Phosphorus atoms
1631.79	1680-1600	Alkene C=C strain	Aliphatic group
1548.71	1600-1430	C=C strain	Aromatic group
571.77	870-500	P-S strain	Phosphorus atoms

Similarities have been identified in the spectra of the miswak liquid extract samples in Figure 6. Therefore, the analysis focused on the original miswak, which yielded the greatest number of peaks. The miswak liquid extract spectrum did not demonstrate the functional groups of compounds containing phosphorus atoms in the 2425–2200 cm^{-1} wave region, whereas the miswak powder spectrum did. However, Table IV depicts phosphorus atoms at 585.59 cm^{-1}, corresponding to the compound's P-Cl groups, and at 879.77 cm^{-1}, corresponding to the compound's P-O groups. The functional group appeared during the extraction of the miswak powder but was absent from its spectrum.

The FTIR analysis of evaporated miswak extracts revealed no absorption bands for phosphorus-containing compounds at 100, 500, and 1000 ppm in either the original miswak or the prepared miswak (Figures 7 and 8). Given the relatively high wavenumber transmission and the lack of a transmission valley, it can be concluded that no phosphorus-containing compounds were absorbed at 2425–2200 cm^{-1}. This is because recent studies have reported that the hydrogen atom has been eliminated from the phosphoric acid molecule with a P-H functional group. As a result, it stopped producing P-H bonds and eliminated the P-H bond, although both miswaks had the same concentration [11].

TABLE IV. THE CONTENT OF THE ORIGINAL MISWAK LIQUID EXTRACT

Wavenumber (cm^{-1})	Wavenumber range (cm^{-1})	Interpretation	Infrared Absorption
3372.92	3200-3550	Phenol OH strain	Oxygen atoms
2972.78	2850-3000	Aldehyde C-H	Aromatic group
2883.95	2900-2700	Aldehyde C=H strain	Oxygen atoms
1652.31	1600-1430	C=C strain	Aromatic group
1045.02	1275-1000	C-H bending inside	Aromatic group
879.77	1050-870	P-O strain	Phosphorus atoms
585.59	600-300	P-Cl strain	Phosphorus atoms

Due to this, the intermolecular bonds in these two miswak samples were weak, as the phosphoric acid molecule containing the P-H group did not break during the evaporation process of the original miswak, as indicated in Table V. Although the evaporation process exhibited a very small peak, the miswak extract may still be suitable for use in toothpaste formulation testing.

Next, the following clusters were identified in the evaporated original miswak extract as depicted in Table V: (1) Si-O-C groups with compounds that include silicon atoms in the wavenumber 1087.68 cm^{-1}, and (2) group P=S with compounds that contain phosphorus atoms that bind to sulfur atoms in the wavenumber 626.29 cm^{-1}. A study by [11] reported that several chemicals were detected in miswak after extraction and evaporation.

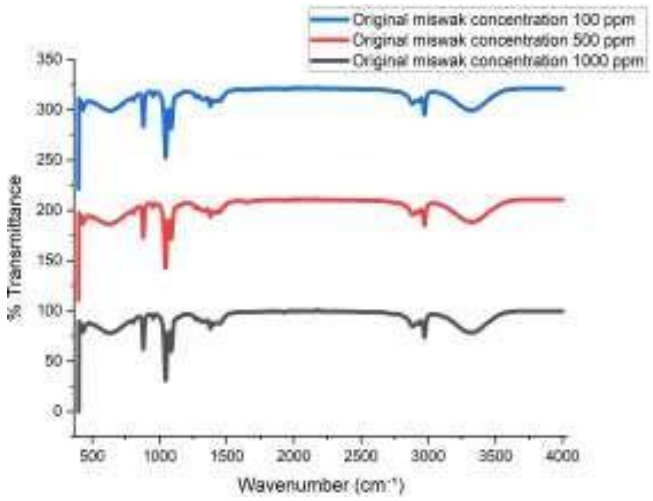

Figure 7. FTIR analysis of evaporated original miswak extract at concentrations of 100, 500, and 1000 ppm

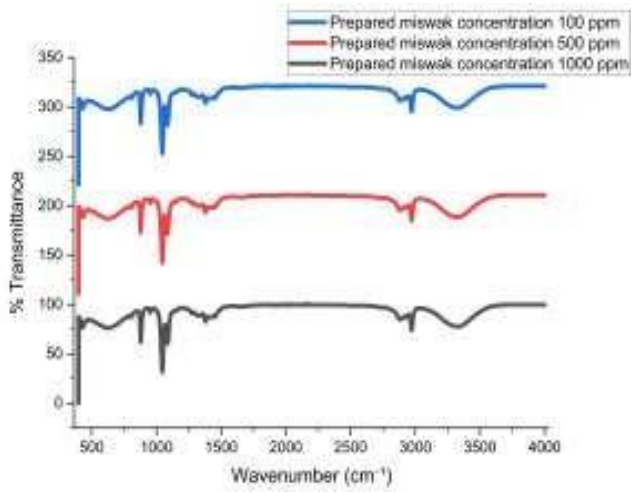

Figure 8. FTIR analysis of evaporated and prepared miswak extract at concentrations of 100, 500, and 1000 ppm

TABLE V. THE CONTENT OF THE EVAPORATED ORIGINAL MISWAK EXTRACT

Wavenumber (cm⁻¹)	**Wavenumber range (cm⁻¹)**	**Interpretation**	**Infrared Absorption**
3325.12	3200-3550	Phenol OH strain	Oxygen atoms
2972.53	2850-3000	Aldehyde C-H	Aliphatic group
2881.67	2900-2700	Aldehyde C=H strain	Oxygen atoms
1454.63	1600-1430	C=C strain	Aromatic group
1087.68	1110-1050	Si-O-C strain	Silicon atoms
952.93	1050-870	P-O strain	Phosphorus atoms
626.29	850-500	P=S strain	Phosphorus atoms

B. Ultraviolet-Visible (UV-Vis) Spectrophotometer Analysis

The miswak extract was tested as illustrated in Figure 9. Compared with other miswaks, the original miswak revealed higher absorbance values than the prepared miswak at 25× and 75× dilutions. Higher absorbance values indicate a greater concentration of active substances within the sample. After evaporation, the molecular bonds in the evaporated miswak extract break during UV-Vis analysis, resulting in multiple absorption peaks. The absorbance value of the original miswak was greater than that of the prepared miswak at a concentration of 1000 ppm (Figure 10). The absorbance value generated increases with miswak concentration. As a result, even more potent compounds are taken up.

Recent studies have reported that UV-Vis spectra are used in quantitative molecular analyses. By applying the Lambert-Beer law to measure absorbance at a specific wavelength, one can determine the analyte concentration in a solution [11]. From this, it was revealed that the original miswak sample exhibited several peaks during evaporation, indicating the presence of more than one electron transition distinct from the active substance. These electronic changes happened as a result of electromagnetic energy being absorbed by atoms or molecules [79], [11]. The movement of electrons between orbitals from lower to higher energy levels is known as an electronic transition [11]. Since all molecules contain electrons that can be excited to higher energy levels, they can all absorb UV–Vis light.

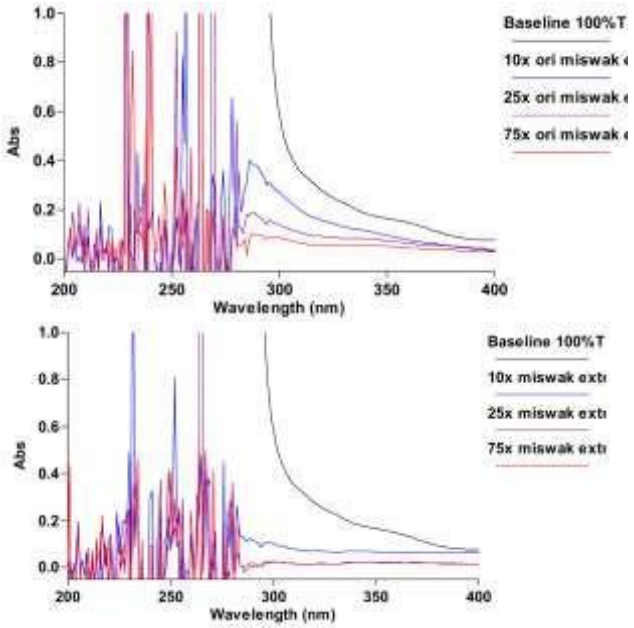

Figure 9. UV-Vis analysis of original and prepared miswak liquid extract at 10×, 25×, and 75× dilution

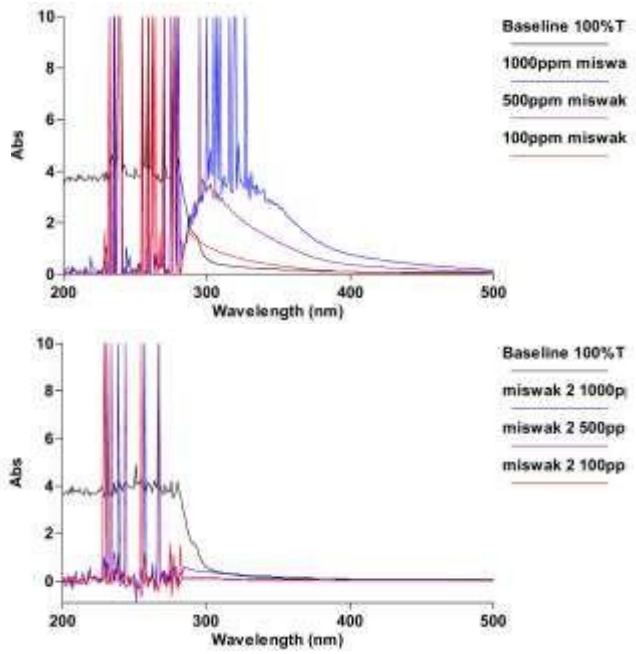

Figure 10. UV-Vis analysis of evaporated original and prepared miswak extract: concentration of 100, 500, and 1000 ppm

XII. EFFECT OF USING MISWAK AND NON-MISWAK

In this experiment, eggshells were used as a substitute for teeth because of their high calcium content. While tooth enamel is a composite of calcium phosphate and calcium carbonate, eggshells consist mainly of calcium phosphate and a composite of calcium carbonate. Both black coffee and carbonated drinks are naturally acidic [76]. After three days of exposure, the results revealed that half-surface eggshells immersed in black coffee or a carbonated drink exhibited visible staining, as illustrated in Figure 11. The acids in the black coffee and the carbonated drink reacted instantly with the calcium carbonate, forming stains on the eggshell surface.

Conversely, when miswak toothpaste-coated eggshells were soaked in black coffee and a carbonated drink, the fluoride in the toothpaste created a barrier that shielded the eggshells from acidic substances, as depicted in Figure 12. Miswak toothpaste's fluoride strengthened the eggshell, preventing it from interacting with the acidic ingredients in black coffee and carbonated drinks. A study by [80] stated that fluoride, a naturally occurring mineral, strengthened the outer layer of teeth and eggshells. The plaque-forming acids produced by bacteria were represented by black coffee and a carbonated drink. Constantly using artificial sweeteners might also lead to plaque. Therefore, fluoride in toothpaste helps protect teeth against acids, cavities, stains, and plaque when brushing is performed properly.

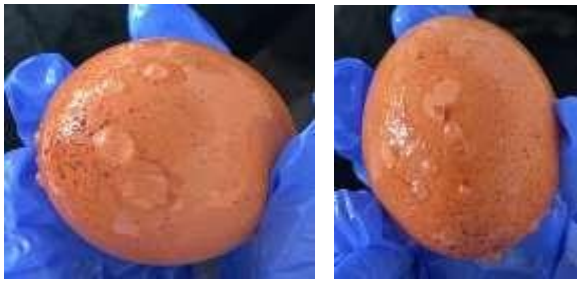

Figure 11. Area of half surface eggshells in black coffee and a carbonated drink. Left: Area of half surface eggshells in black coffee. Right: Area of half the surface of eggshells in carbonated drink

Figure 12. Area of half surface eggshells coated with miswak toothpaste in black coffee and carbonated drink. Left: Half surface eggshells coated with miswak toothpaste in a carbonated drink. Right: Half surface eggshells coated with miswak toothpaste in black coffee

XIII. CONCLUSIONS

According to this study, phosphoric acid, a phosphorus-containing compound, is the active ingredient in miswak and supports the development of teeth and bones. The original miswak exhibited a higher absorbance value and a greater concentration of the active substance than the prepared powder. This study demonstrated that *Salvadora persica*, also known as miswak, contains active compounds that promote oral health. Using techniques such as FTIR Spectroscopy and UV-Vis Spectrophotometry, the research revealed that key components, including fluoride, silica, and benzyl isothiocyanate, play critical roles in antimicrobial, anticariogenic, and antiplaque properties. Additionally, experiments using eggshells as a substitute for tooth enamel confirmed that miswak reduces staining and decay more effectively than non-miswak treatments. These findings validated miswak as a natural and cost- effective alternative to conventional oral hygiene products, particularly in resource-limited settings.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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