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Study of the Physicochemical and Functional Properties of Gum Extracted from Roselle Petals

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Abstract: *The study aimed to extract gum from Hibiscus sabdariffa petals and investigate its physicochemical and functional properties. The extracted gum is classified as a natural gum composed of polysaccharides. The chemical composition analysis revealed that Hibiscus sabdariffa gum contained 6.76% moisture, 3.95% protein, 0.7% fat, 10.5% ash, and 78.2% carbohydrates. The extraction yield of Hibiscus sabdariffa gum using aqueous extraction at pH 7, a temperature of 25°C, a plant-to-water ratio of 10:1 (w/v), and a soaking time of 15 minutes was 10%. The gum was precipitated using ethanol at a gum-to-ethanol ratio of 2:1 (w/w) based on the obtained gum yield. The results of the functional properties assessment demonstrated that the extracted gum exhibited good functional characteristics, including a viscosity of 259.5 cP, water-binding capacity of 4.76 g/g, and fat-binding capacity of 15.67 g/g gum powder. The minimum gelation concentration was 3%, and the gum showed an emulsifying capacity of 74.39%. The foam capacity was 81% at the highest concentration (0.7%), and foam stability increased with gum concentration, reaching a maximum stability of 137% at 0.7% gum concentration.*

Keywords: ***Hibiscus sabdariffa, gums, physicochemical properties, functional properties.***

INTRODUCTION

In recent years, there has been a growing interest in natural food products to promote health and nutrition, as they contain bioactive compounds. These compounds include plant extracts rich in functional components found in fruits, vegetables, and herbs, which have been proven effective in improving food quality and preservation, as well as enhancing flavors and preservatives (1). Hibiscus sabdariffa is one of the plants with high nutritional and health value that has garnered significant attention due to its numerous health benefits for consumers (2). The calyx of Hibiscus sabdariffa contains high amounts of gum and pectin, commonly referred to as mucilaginous polysaccharides, composed of arabinose, galactose, glucose, rhamnose, and smaller amounts of galacturonic acid, glucuronic acid, mannose, and xylose (3).Gums are hydrophilic colloidal substances that dissolve in water, forming viscous gels through swelling or absorption. They consist of polysaccharide units and are found in various plant parts, including roots, leaves, fruits, seeds, and stems. The high water-holding capacity of gums is attributed to the presence of hydroxyl groups, which form hydrogen bonds with water. The amount of water retained by the gum is influenced by the size and shape of its molecules, as well as the presence of hydrophilic functional groups (4).Oil-holding capacity is another important functional property of hydrocolloids, which increases with the length of non-polar chains and the molecular mobility of hydrophobic hydrocarbon groups (5). Foam is a biphasic system consisting of a water phase and an air phase, in which small air bubbles are dispersed in a continuous liquid medium. Foam capacity (or foamability) refers to the ability of the continuous phase to incorporate gas (6).Plant-derived gums play a crucial role in emulsification by aiding in particle suspension, stabilizing emulsions, controlling crystallization, and increasing viscosity (7). Gelation is the process of forming a viscous gel-like material, which is a key functional property of gums (8). Viscosity, which measures a fluid's resistance to internal molecular movement under external forces (9), is a critical factor in understanding the characteristics of different hydrocolloids (10).

MATERIALS AND METHODS

Raw Materials Used in the Study

Hibiscus sabdariffa: Fresh Hibiscus sabdariffa flowers were obtained from the Al-Musayyib region in Baghdad, while dried flowers were sourced from local markets. The flowers were thoroughly washed to prepare them for gum extraction.

METHODS

Aqueous Extraction of Hibiscus sabdariffa Gum

The gum extraction process was carried out following the method described by (11).

Calculation of Gum Yield (Y)

The gum yield percentage was determined using the method outlined by (15), employing the following equation:

$$\textbf{Yield}\ (\mathrm{Y}) = \frac{Drying\ weight\ (g)\ after\ gum\ extract}{Weight\ of\ Hibiscus\ calyces\ (g)\ taken\ for\ extraction\ process} = \times\ 100$$

Chemical Analysis of Hibiscus Gum

The moisture, ash, fat, protein, and carbohydrate contents of Hibiscus sabdariffa gum were determined using standard analytical methods as described by (12).

Functional Properties of Hibiscus Gum

Measurement of Relative Viscosity

The viscosity of the gum powder was measured according to the method described by (13).

Determination of Water and Fat Binding Capacities

Water and fat binding capacities were evaluated following the procedure described by (14).

Determination of Minimum Gelation Concentration and Emulsifying Capacity

The minimum gelation concentration and emulsifying capacity were determined according to the method described by (15).

Foaming Properties

The foam formation capacity and foam stability of the gum were assessed based on the method described by (16).

RESULTS AND DISCUSSION

Gum Yield

The results presented in Table 1 indicate that the percentage yield of gum extracted aqueously from Hibiscus sabdariffa calyces and precipitated using alcohol was 10%. In comparison, (17) reported that the gum content in Hibiscus sabdariffa was 10.2%, while (18) found a slightly lower gum yield of 9.06%. On the other hand, (19) reported a significantly lower gum yield of 5%. (20) Stated that the quantity of extracted gum varies depending on the type of plants and their chemical composition, as well as the impact of the methods used for gum extraction, precipitation, and purification.

Chemical Analysis of Hibiscus Gum

Moisture Content

As shown in Table 1, the moisture content of Hibiscus sabdariffa gum was 6.76%, which is close to the 7.2% reported by (18). In contrast, (21) found that the moisture content of fenugreek seed gum ranged between 7.5% and 10.5%. (21) clarified that moisture content plays a fundamental role in determining the monosaccharide composition and the structure of gum. The variation in moisture content is attributed to differences in hydrophilic sites that retain water molecules within the polysaccharide chain.

Protein Content

The data in Table 1 indicate that the protein content of Hibiscus sabdariffa gum was 3.95%. This value is slightly higher than the 3.4% reported by (18). In contrast, (21) reported a lower protein content in fenugreek seed gum, ranging between 0.78% and 1.5%. The protein content in gum varies due to differences among plant species and variations in environmental conditions, as well as the impact of extraction methods and their varying conditions (22).

Fat Content

According to Table 1, the fat content of Hibiscus sabdariffa gum was 0.7%. This value is higher than the 0.3% reported by (18) but within the range of 0.5% to 1.5% found in fenugreek seed gum by (21). This variation is attributed to differences in extraction methods and estimation conditions (23).

Ash Content

The results in Table 1 show that the ash content of Hibiscus sabdariffa gum was 10.5%. This value is lower than the 13.20% reported by (18) but higher than the 8% found in flaxseed gum by (24). Ash analysis is a general proximate test used to estimate the mineral content of food materials. The ash content resulting from incineration does not necessarily reflect the complete mineral composition, as some elements may be lost due to volatilization during combustion or remain trapped within the material's components after complete oxidation (24).

Carbohydrate Content

As presented in Table 1, the carbohydrate content of Hibiscus sabdariffa gum was 78.2%. In comparison, (19) reported a higher carbohydrate content of 86.56% for Hibiscus syriacus gum, while (24) recorded a carbohydrate content of 76.1% in flaxseed gum. The total carbohydrate content in gum powder depends on its residual protein and fat content after extraction (24).

Table (1): Chemical Composition of Roselle Gum

Composition	Percentage (%)
Gum Yield	10
Moisture	6.76
Protein	3.95
Fat	0.7
Ash	10.5
Carbohydrate	78.2

Each value represents the mean of three replicates.

Functional Properties of Hibiscus Gum

Viscosity

As shown in Table 2, the viscosity of aqueously extracted Hibiscus sabdariffa gum at a 0.5% concentration was 269.5 cP. In comparison, (25) reported that the viscosity of chia gum was 271 cP, while (26) found that bitter almond gum had a higher viscosity of 394 cP. On the other hand, (27) obtained a much lower viscosity of 78.17 cP for okra pod gum. The viscosity of gum solutions increases with decreasing temperature and increasing concentration. A higher concentration leads to the entanglement of molecular chains, contributing to the formation of additional bonds that enhance viscosity. In contrast, an increase in temperature results in a decrease in solution viscosity due to structural changes in the molecular arrangement and alterations in polymer conformation, which affect its ability to interact and bond with other molecules (28).

Water Binding Capacity (WHC)

The results in Table 2 indicate that the water binding capacity of Hibiscus sabdariffa gum was 15.67 g water/g gum powder. In comparison, (24) reported a higher WHC of 16.84 g water/g gum powder for flaxseed gum, while (29) found an even greater WHC of 17.54 g water/g gum powder for tamarind seed gum. Additionally, (30) reported a WHC of 15 g water/g gum powder for garden cress seed gum, which is similar to the value found for Hibiscus sabdariffa gum in this study. The increased ability of gum to bind water is attributed to its polysaccharide content, which is rich in hydrophilic functional groups such as hydroxyl (-OH) and hydrogen (-H) groups. The rise in ambient temperature enhances the gum's water-binding capacity due to the increased activity of these groups resulting from the breakdown of polysaccharides (30). (31) explained that the water-binding capacity of gums plays a crucial role in improving the sensory properties of frozen food products, such as texture and mouthfeel, by reducing the melting rate and promoting the formation of smaller ice crystals.

Oil Binding Capacity (OBC)

As shown in Table 2, the oil binding capacity of Hibiscus sabdariffa gum was 4.76 g oil/g gum powder when tested with sunflower oil. This value is comparable to the 4.65 g oil/g gum powder reported by (32) for garden cress seed gum. However, (29) found a significantly lower OBC of 0.73 g oil/g gum powder for tamarind seed gum when tested with sunflower oil. The fat-binding capacity of gums contributes to retaining distinctive flavors when foods are exposed to high cooking temperatures and enhances the overall taste of the product. The variation in fat-binding ability is attributed to differences in protein content and the presence of nonpolar amino acids, which contain hydrophobic functional groups (33).

Gelation Properties

The results in Table 2 demonstrate that Hibiscus sabdariffa gum formed a gel at a minimum concentration of 3%, with gradual gelation observed at concentrations of 1%, 2%, 3%, 4%, and 5%. At a 7% concentration, the gum formed a stable, unbreakable gel, which remained intact even after 24 hours, indicating its strong gel-forming ability. In comparison, (34) reported that fenugreek seed gum formed a gel at a lower concentration of 1%, while (25) found that chia seed gum exhibited gelation at 2%. (27) indicated that there is a variation in the gelling ability of plant gums depending on their botanical source, which is attributed to differences in their chemical composition.

Table (2): Functional Properties of Roselle Gum

Properties	Roselle gum
Viscosity	269.5 CP
Water holding capacity	15.67
Fat binding capacity using sunflower oil	4.76
Gelation concentration (%)	3 %
Emulsifying capacity (%)	74.39

Each value represents the mean of three replicates.

EMULSIFYING CAPACITY

The results presented in Figure 1 indicate that the emulsifying capacity of Hibiscus sabdariffa gum at different concentrations (0.1%, 0.25%, and 0.5%) was 72.56%, 74.43%, and 76.18%, respectively. The emulsifying properties of plant gums are attributed to their structural composition and surface characteristics, as they contain both hydrophilic and hydrophobic regions, enabling interaction with both oil and water. Additionally, the protein content of the gum plays a crucial role, as these gums form a protective barrier around oil droplets, preventing their coalescence (35). The emulsifying property of plant gums can be utilized as an emulsifier and stabilizer in the production of certain products such as dairy and ice cream (36).In comparison, (37) reported a higher emulsifying capacity of 94.69% for sesame gum (Sesamum indicum). Meanwhile, (38) found that raw fenugreek gum had a lower emulsion stability of 54% at a 4% concentration. Additionally, (25) reported that chia seed gum exhibited an emulsion stability of 74.64% at 85°C, which is similar to the emulsifying performance of Hibiscus sabdariffa gum in this study.

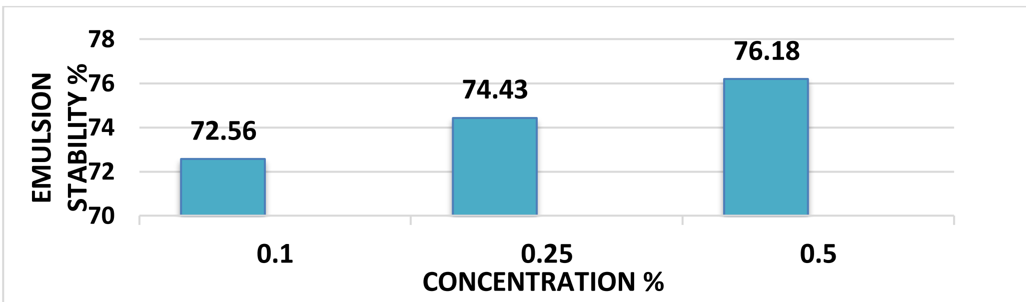

Figure (1) shows the relationship between Roselle gum concentration and emulsion stability.

Foaming Properties (CF)

Figure 2 illustrates the relationship between different concentrations of Hibiscus sabdariffa gum solution and foam capacity. The results indicate that foam capacity decreased as the gum concentration increased (0.1%, 0.3%, 0.5%, and 0.7%) at room temperature, with values of 95%, 93%, 85%, and 81%, respectively. These results are consistent with the findings of (32), which indicated that foam capacity decreased with increasing concentrations of garden cress seed gum. At concentrations of (0.1, 0.3, 0.5, and 0.7), the foam capacity was recorded at (98, 95, 92, and 88)%, respectively. Similarly, (25) reported that the foam capacity of chia seed gum decreased with increasing gum concentrations (0.1, 0.3, and 0.5), with values of (98, 94, and 90) %, respectively. The foam capacity of Hibiscus sabdariffa gum indicates an inverse relationship between gum concentration and foam capacity, as an increase in gum concentration reduces air incorporation during whipping, thereby decreasing foam capacity. Foam plays a crucial role in determining the overall volume of various food products, contributing to a desirable texture and a pleasant mouthfeel, in addition to enhancing flavor, as seen in ice creams, whipped creams, and other aerated products (39). Foam stability is influenced by several factors, including pH, moisture content, molecular weight, temperature, as well as mixing preparation methods and whipping speed (40).

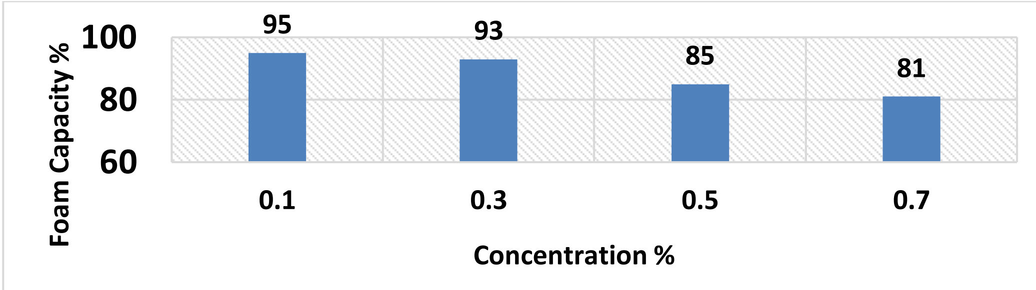

Figure (2) illustrates the relationship between Roselle gum concentration and foam capacity

The results presented in Figure (3) illustrate the relationship between different concentrations of Hibiscus sabdariffa gum (0.1, 0.3, 0.5, and 0.7%) and foam stability (SF) at 25°C. The findings indicate that foam stability increased with higher gum concentrations, reaching (92, 97, 108, and 137)%, respectively. These results align with those reported by (32), which demonstrated that foam stability increased with increasing concentrations of garden cress seed gum (0.1, 0.3, 0.5, and 0.7%), reaching (30, 60, 120, and 160)%, respectively. Similarly, (25) found that foam stability also increased with higher concentrations of chia seed gum (0.1, 0.3, and 0.5%), with values of (30, 33, and 38)%, respectively.

The presence of polysaccharides in gums contributes to enhanced foam stability, which is influenced by viscosity. High viscosity facilitates the formation of a three-dimensional network that prevents air bubbles from coalescing, thereby improving foam stability (37). The high foam stability can be attributed to the presence of components such as starches, pectins, and gums, which increase viscosity and maintain foam stability over extended periods during storage or use. Additionally, colloidal substances form a three-dimensional network that restricts the movement of components within the foam, further enhancing its stability (41).

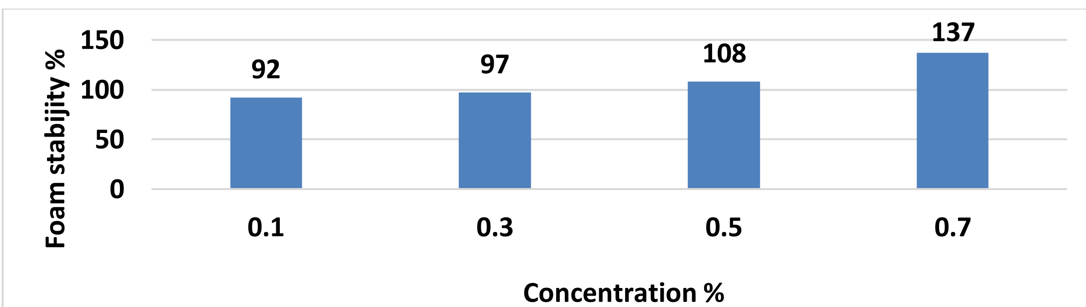

Figure (3) illustrates the relationship between Roselle gum concentration and foam stability

CONCLUSION:

In this study, gum was extracted from Hibiscus sabdariffa (Roselle) flowers at a yield of 10%, and its chemical properties and functional characteristics were analyzed to assess its potential for industrial and food applications. The results indicated that the extracted gum possesses distinct chemical properties, making it a promising material for various applications. Analyses revealed its ability to enhance viscosity, water and fat binding capacity, and emulsification properties, suggesting its potential as a viable alternative to commercial gums. In conclusion, this study highlights the significance of extracting gums from natural sources such as Roselle, offering a sustainable and safer alternative for various industries.

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