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Research Article

Evaluation of Tahini Halva made from Two Varieties of Sesame Seeds with Roasting and Dehulling Treatments

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Abstract

Halva is a confectionery product made from tahini, sugar, and soapwort extract. In the present investigation, eight halva formulations were made from two varieties of Venezuelan sesame (G-150 and DV-9), which were roasted or dehulled. The physical characteristics of the halva formulations obtained were described, such as texture and color, and significant differences were found in those samples that were made from the whole seed of the dehulled seeds. The proximate characterization of the formulations showed that the products have a high protein and fat content (25.96-29.89% and 39.10-35.42%, respectively), so a 100-gram fraction will have a high caloric intake. An untrained panel's sensory evaluation (7-point hedonic scale) yielded an overall acceptability between 6.00 and 5.71. However, some formulations were not highly appreciated by the panelists. The content of antinutritional agents is at safe levels, so it does not threaten the consumer's health. The halvas showed a protein digestibility of 52% for all formulations.

Keywords: Sesame Seeds; Tahini; Tahini Halva; Dehulled

Introduction

Sesame plays an essential role in human nutrition and medicine, pharmacy, industry, and agriculture, but its most important use is obtaining edible oil from roasted or unroasted seeds. Sesame oil has a high proportion of polyunsaturated and monounsaturated fatty acids (linoleic acid (~50%) and oleic acid (~37%) of the lipid fraction, respectively), which results in it being a vegetable oil sensitive to oxidative rancidity [1,2]. Sesame oil has a high proportion of unsaponifiable matter, such as α-tocopherols, sesamol, and sesamin [3]. It has been reported that they have antioxidant properties that safeguard sesame oil's sensorial and nutritional attributes, and they enjoy anti-mutagenic activity against species sensitive to oxidation [4]. On the other hand, protein concentrates obtained from sesame cake present a potential nutritional alternative for human consumption or use as raw material in the food industry as a functional or nutritional ingredient in a wide variety of food products [5]. These lignified compounds, in turn, offer important nutritional characteristics such as cancer prevention and lowering of LDL cholesterol and are precursors of antioxidant biomolecules in the liver [6-8]. Products made with sesame, such as halva, acquire all these attributes. Halva is a confectionery product widely used in various Asian, African, and Eastern European countries for centuries and is available in different forms and flavors. It is a fatty product due to its high tahini content, which contains more than 50% sesame oil. It is usually made from a paste of sesame seeds (tahini), sucrose or inverted sugar, and soapwort extract (Saponaria officinalis) [9]. UNIDO [10] states that halva is formulated with a 1:1 ratio of tahini and nougat, and other ingredients such as nuts, cocoa powder, vanilla, or vanilla extract (if desired) are added. Additives such as citric acid and soya lecithin may be included to safeguard the product's sensory attributes. To achieve characteristic flavors, aromas, and consistency in halva production, foaming agents (gelatin), soy protein extracts, chocolate, cocoa powder, and egg whites can be used [9]. Halva is a high-calorie product, and there is an increasing demand for healthy food products. Halva formulations have been guided by using enriched fibers and nuts containing compounds with biological activity, especially polyphenolic compounds with antioxidant properties [11-13]. The study aimed to evaluate two varieties of sesame seeds to obtain different halva formulations.

Materials and Methods

Seed roasting

Whole or dehulled sesame seeds (0.2 kg) (depending on the type of tahini to be made) were meticulously and precisely roasted using a conduction oven at 400°F for exactly 4 minutes, ensuring the perfect balance of flavor and texture.

Preparation of Tahini for Halva

To obtain the tahini's from the different treatments applied to the sesame seeds, a disc mill was used until a coarse paste was obtained. This paste was then introduced into a wet mill, a traditional and effective method that connects us to the heritage of Tahini production, where its size was reduced for 24 hours. The tahini's were obtained and coded as T1 and T2 for the dehulled-roasted sesame seed varieties G-150 and DV-9, respectively. T3 and T4 for the dehulled-unroasted sesame seeds varieties G-150 and DV-9, respectively. T5 and T6 for the whole-roasted sesame seeds varieties G-150 and DV-9, respectively. T7 and T8 for whole-unroasted seeds. The different formulations are described in Table 1. The tahini's were packaged and stored at refrigeration temperature (4ºC).

Halva preparation

Each tahini was used and standardized according to the parameters required to prepare the different Halva. The ingredients used in the preparation were sucrose, drinking water, and soapwort extract. Calcium chloride was used as an additive to achieve the desired texture, and citric acid was used as a pH modifier. The following were mixed: sucrose, water, soapwort extract, calcium chloride, and citric acid, according to the proportions to be standardized to obtain the nougat (syrup). The mixture was then subjected to heat treatment by conduction until reaching a temperature of 121ºC. Once the desired temperature was reached, the tahini was added and mixed vigorously with the nougat. The mixture was then molded and refrigerated until it completely solidified. Figure 1 shows the technological scheme for the preparation of Halva.

Color parameters

Color parameters were measured using a HunterLab® ColorFlex Spectrophotometer 45°/0° Standards serial number CX-1719 (HunterLab, Inc., Reston, VA). Only the values of the SCE (Specular Component Excluded) considered as these claimed to be more correlated with observations of the human eye. The Spectrophotometer calibrated with the white standard plate (X: 79.45, Y:84.20, Z:88.12, L*:93.54, a*-0.81 y b*:1.58). Results were expressed in terms of L* (lightness component), a* (green to red component), and b* (blue to yellow component). Other essential color parameters were calculated using L*, a* and b* [14].

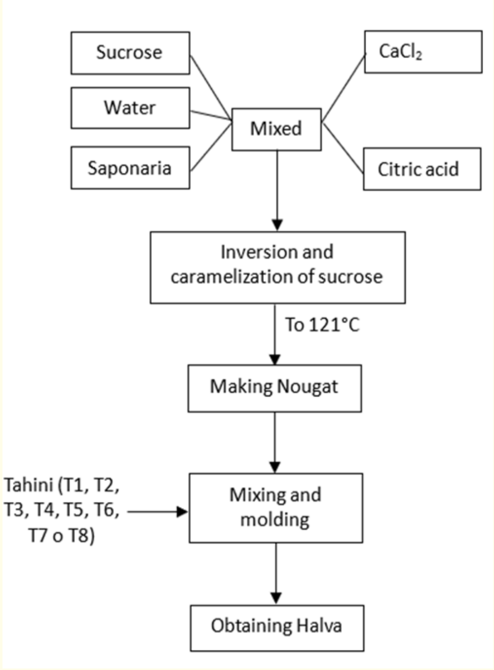

Figure 1: Technological scheme to produce halva.

TPA

The texture profile of halva was analyzed using a texturometer, TA-XT2i (Stable Micro Systems, Surrey, UK), following the methodology of [9,15]. Two compression tests were performed with a set of HDP/BSW blades. The speed conditions during the pre-test and test were 0.5 mm per second. In comparison, the post-test speed was 2 mm per second with a distance of 15 mm. TPA determined texture parameters such as hardness, adhesiveness, fibrousness, cohesion, elasticity, chewiness, and gumminess.

General aceceptability

A survey was conducted through the Google Forms application. Panelists who did not present neophobia to try a new product and liked the taste of sesame and its by-products, allergies, health problems, or special diets were selected. Sample service, the sensory evaluation tests were carried out in the booths of the Sensory Evaluation laboratory of the Institute of Food Science and Technology of the Faculty of Sciences of the Central University. Caracas, Venezuela. The eight formulations were cut into squares with an approximate area of 1 cm2 and served on white cellulose plates. The formulations were named with 3-digit codes with numbers selected from a table of random numbers. The samples were offered with soda crackers and drinking water to cleanse the palate between each sample. The acceptability of the halva formulations was assessed through a verbal hedonic scale so that the panelists could report on the degree of acceptance they had for the formulations. An odd scale of seven (7) points was made, anchored at the extremes with "I dislike it a lot" and "I like it a lot," leaving at the midpoint "I neither like it nor dislike it," with "I dislike it a lot" being equivalent to one (1) and "I like it a lot" being equivalent to seven (7). Two evaluations were made so as not to saturate the panelists. First, they were offered four samples, and they made the evaluation. They were allowed to rest for 30 to 60 minutes and tried the remaining four samples.

Chemical composition and physicochemical analysis

The moisture content (925.10), total ash (923.03), total nitrogen (979.09), titratable acidity, and pH (943.02), lipid extract (920.39) were estimated according to AOAC [16]. Carbohydrates by difference by INN [17]. *In vitro* protein digestibility by [18]. The water activity (aw) was measured in the psychrometric equipment for determining water activity (Aqua Lab, CX2). Antinutritional compounds as described in [19].

Statistical analysis

Statistical analyses were performed using the SPSS [20] (Version 13.0, SPSS Inc., Chicago, IL, USA), where descriptive statistics were calculated and parametric statistical tests such as Student's t-test, ANOVA, and non-parametric tests such as Kruskal-Wallis were performed. All statistics were based on a confidence level of 95%, and $p < 0.05$ was considered statistically significant

Results and Discussion

Tahini preparation

Once the hydrothermal chemical debarking process with potassium hydroxide was carried out, a yield of 90.90 ± 0.70% was obtained. The results obtained demonstrate that the process is efficient. It was observed that the bark can be eliminated at low alkali concentrations and removed with pressurized water, thus obtaining debarked seeds. There are reports of similar yield indices hydrothermal debarking using sodium hydroxide (NaOH) [21,22]. The yield of the roasting process was 95.54 ± 0.53% for the dehulled and whole seeds, while for the dehulled seeds, a value of 93.56 ± 0.78% was obtained. It can be assumed that this weight loss is due to the loss of water and volatile compounds due to the exposure of the sesame seed to high temperatures, added to the occurrence of non-enzymatic browning reactions such as Maillard between proteins and free-reducing sugars and caramelization of the free sugars that release water from the constituents that react at high temperatures, this agrees with Hyeon-wee [23] who characterized the loss of free sugars and amino acids after a roasting process that plays a fundamental role in Maillard reactions. The yield of the grinding process was 85.27 ± 2.67%. The result obtained demonstrated that it is an efficient process. This performance can be associated with the loss of material that occurs when the product adheres to the surface of the mill, as well as the loss of volatile compounds and water that occurs during the grinding process. Codes (Table 1) with odd numbers belong to the G-150 variety, and codes with odd numbers belong to the DV-9 variety. The first four formulations were made with peeled sesame seeds, which were subjected or not to a roasting process, while the last four formulations were made with whole sesame seeds subjected or not to roasting. The roasting process developed interesting (characteristic) flavors and aromas that were transferred to the halvas. In turn, they generated different colors ranging from a cream color characteristic of sesame to brown colors produced by roasting. However, the tahini formulations where the seed was not roasted had flavors and aromas characteristic of sesame. Unlike roasting, the presence of the peel generated acidic and astringent tastes and dark brown and greenish colors. The sesame seed husk's oxalic acid and indigestible fiber probably produce these greenish and brown astringent flavors [24].

Code	Variety	Hull	Roasted
T1	G-150	No	Yes
T2	DV-9	No	Yes
T3	G-150	No	No
T4	DV-9	No	No
T5	G-150	Yes	Yes
T6	DV-9	Yes	Yes
T7	G-150	Yes	No
T8	DV-9	Yes	No

Table 1: Coding for formulated halvas.

Tahini properties

Physical-rheological behaviour of tahinis

Formulations T1 to T6 decreased the resistance to flow (Table 2) as the shear force was increased. That is, the behavior is that of a pseudoplastic non-Newtonian fluid. However, T7 and T8 could not be determined under the same spindle since they saturated at the first speeds. Tahini from sesame seeds with husks presented a higher resistance to shear forces. All maximum and minimum viscosities are in the same order. T5 and T6 (whole) have a higher relative viscosity than those dehulled (T1, T2, T3, and T4). T1 and T2 have a lower relative viscosity than tahini made from the same seeds without roasting. It can be inferred that the differences between viscosities are due to the processes applied to the sesame seeds. Tahini from roasted seeds flowed more and generated less resistance to shear forces than those not roasted. This is probably due to the denaturation of proteins due to the effect of the toasting temperatures. This denaturation decreases the intermolecular interactions that form the emulsion. Likewise, the formulations from whole sesame seeds presented a higher viscosity. It can be inferred that the fiber from the husk generates a more excellent resistance to flow and, therefore, greater viscosity. Some authors have described how the effects of colloidal stability and tahini's rheology depend on the particle size and the heat treatment to which the sesame seed or sesame paste is subjected [25]. Table 2. Relative viscosity range of tahini formulations.

Code	Maximum Relative Viscosity (cp)	Minimum Relative Viscosity (cp)
T1	2,5 x 104 f	2,3 x 103 e
T2	5,1 x 104 e	2,6 x 103 d
T3	6,1 x 104 d	2,9 x 103 c
T4	7,0 x 104 c	2,9 x 103 c
T5	8,7 x 104 a	5,2 x 103 b
T6	8,0 x 104 b	5,4 x 103 a
T7	Nd	Nd
T8	Nd	Nd

Table 2: Relative viscosity of tahini.

Results expressed as an average of 3 replicates with their associated deviation. Superscript letters indicate significant differences between formulations of $p < 0.05$. Nd: Not determined.

Consistency

The formulations made with the G-150 variety (T1, T3, T5, and T7) traveled a greater distance than the tahinis formulated with the DV-9 variety (T2, T4, T6, and T8) (Table 3). The tahinis made with roasted and hulled seeds (T1, T2, T5, and T6) showed a lower resistance to flow compared to T3, T4, T7, and T8. These results showed significant differences between the tahini formulations made. The differences between the resistance to flow and the consistency obtained may be due to the roasting and the fiber content from the husk. As explained above, roasting heat can denature the sesame proteins responsible for generating the surfactant properties that emulsify the tahini and can develop resistance to flow. On the other hand, the fiber content may also generate resistance to flow; those seeds with a shell presented a higher moisture content.

Code	Central route (cm)	Moisture (%)
T1	18.5 ± 0.3a	0.54 ± 0.03
T2	17.5 ± 0.5a	0.71 ± 0.02
T3	15.0 ± 0.4a	0.77 ± 0.03
T4	12.0 ± 0.6a	0.67 ± 0.01
T5	11.5 ± 0.7b	0.62 ± 0.01
T6	11.5 ± 0.3b	0.54 ± 0.01
T7	6.5 ± 0.6c	0.95 ± 0.02
T8	5.0 ± 0.4c	1.12 ± 0.02

Table 3: Route of the different tahinis through the Bostwick consistometer.

Results expressed as an average of 3 replicates with their associated deviation. Superscript letters indicate significant differences between formulations of $p < 0.05$.

Color tahini and Halva

The lightness (L*) of the tahinis varied between the ranges of 70.94 ± 0.12 (for T4) and 37.37 ± 0.23 (for T6), and significant differences were found between the lightness of the formulated tahinis, where the differences were observed between the tahinis that came from different treatments (roasted or dehulled). The parameter a* (red/green) is bounded between the values of 9.77 ± 0.07 and 1.20 ± 0.03, and significant differences were found between the treatments carried out on the sesame seed. It should be noted that the same pattern is monitored in the parameter b* (yellow/blue). However, this was found to be bounded between 19.88 ± 0.30 and 28.04 ± 0.37). The color (Table 4 and Table 5) of tahini is influenced by its main constituent composition and the presence of coloring agents, such as carotene, green pigments, and chlorophyll, whose effect on color is increased by the roasting and peeling processes. A combination of light scattering and absorption phenomena determines the overall appearance of the food. Temperature increases accelerate the Maillard and caramelization reactions that generate the darkening of the seed that is carried over into the tahini.

Code	L*	a*	b*
T1	51.67 ± 0.20b	7.44 ± 0.02a	28.04 ± 0.37a
T2	43.15 ± 0.20b	9.77 ± 0.07b	26.52 ± 0.21b
T3	68.63 ± 0.04a	1.20 ± 0.03c	21.6 ± 0.05b
T4	70.94 ± 0.12a	1.61 ± 0.15c	21.36 ± 0.02bc
T5	44.46 ± 0.06bc	8.20 ± 0.04d	27.28 ± 0.06b
T6	37.37 ± 0.23c	8.62 ± 0.01d	26.87 ± 0.07bc
T7	40.12 ± 0.21bc	4.27 ± 0.03e	19.88 ± 0.30cd
T8	40.42 ± 0.03c	4.24 ± 0.06e	20.17 ± 0.21d

Table 4: Color profile of different tahinis.

Results expressed as an average of 3 replicates with their associated deviation. Superscript letters indicate significant differences between formulations of $p < 0.05$.

It can be inferred that the highest fiber concentration and pigments, such as chlorophyll, are present in the sesame peel. Once this peel is homogeneously distributed after the grinding process, color changes occur in the product; for this reason, an increase in the a* and b* coordinates is observed because plant pigments such as chlorophyll and carotenoids tend to reflect green, yellow, and red-light waves, which are measured by parameters a* and b*. Caramelization and Maillard reactions also influence the increase in these parameters by creating tones and colors associated with yellow and brown. The color change in colloidal dispersions (especially in sesame pastes such as tahini) and how their particle size, constituents, colorants, and production line processes (roasting) generate color changes in the food matrix, which is consistent with the results obtained in this study [25,26].

Code	L*	a*	b*
H1	45.63 ± 0.99b	13.22 ± 0.21a	31.53 ± 1.06a
H2	42.23 ± 3.63bc	8.19 ± 0.48b	21.80 ± 1.32b
H3	61.02 ± 2.26a	2.70 ± 0.16e	22.41 ± 1.00b
H4	58.35 ± 1.34a	1.79 ± 0.36e	19.93 ± 0.20bc
H5	41.15 ± 1.86bc	7.31 ± 0.40c	22.11 ± 1.12b
H6	38.67 ± 3.02c	7.22 ± 0.23c	20.01 ± 1.24bc
H7	39.81 ± 3.57bc	3.72 ± 0.33d	16.54 ± 1.78d
H8	38.71 ± 3.04c	3.94 ± 0.26d	18.10 ± 0.65cd

Table 5: Color profile of different halva formulations.

Results expressed as an average of 3 replicates with their associated deviation. Superscript letters indicate significant differences between formulations of $p < 0.05$.

Figure 2: Color of the different halvas obtained.

Halva formulation

As established by [9,10] commercial halva formulations were made in equal proportions of tahini and nougat, with the addition of citric acid or soy lecithin as permitted additives. For this reason, formulations were prepared where the amount of tahini and sugar were equal, and formulations with expected texture and sensory attributes were achieved. Next, it was decided to standardize citric acid and soapwort extract use. Each ingredient and parameter used is essential in the formulation of halva. This is because it is a complex food matrix, where interactions are achieved after the inversion of the saccharose and, at the same time, a slight caramelization of the same, thus causing interactions between glucose, fructose, and the caramelization products, plus the air incorporated in the mixture with the lipids and proteins of the tahini that have been precipitated by the action of the saponins of the soapwort, thus forming the halva. These interactions can be observed in the results obtained by [27], where it was shown that lipids flow through the food matrix, and it is the set of protein interactions, inverted sugars, saponins, and caramelization products that generate the fragile and delicate structure of the halva. A total of 40 formulations were established, each presenting different characteristics according to the type of tahini used. However, a standardized formula used 63.34% tahini (T1 to T8), 36.06% refined white sugar, 0.25% citric acid, 0.35% calcium chloride, and soapwort extract in 025:1. The temperature used was 123°C. The picture below shows the halva obtained.

Temperature control allowed for the prediction of the degree of saccharose inversion and caramelization. To obtain the fine, hard, and, at the same time, brittle texture of halva, it is necessary to reach a temperature where a hardness more significant than that of gum but less than that of caramel can be obtained. In addition, aeration during mixing incorporates air bubbles into the matrix that generate a finely divided porous structure characteristic of halva. The formulation had the incorporation of calcium chloride, which generated the stability of halva.

TPA Halva

The parameter for fracture ability does not have a defined pattern. Formulations H7 and H8 show greater fracture ability than the others. This behavior is like adhesiveness and cohesiveness. Formulations H5, H6, H7, and H8 showed higher hardness, gumminess, and chewiness values. TPA results (Table 6) for the different halva formulations.

It can be inferred that the variation in hardness, gumminess, and chewiness parameters is due to using the whole seed. Therefore, the shell provides a more significant amount of fiber to the halva formulations that generate a more considerable body in the food matrix, which may generate a greater force of opposition to the deformation of the material that simulates the TPA when generating the first and second bite. However, a defined pattern is not observed in the other parameters because the causes of their variations do not depend on the sesame. This possibly comes from interactions between the sugar and the constituents of the tahini. Texture parameters (especially hardness) vary significantly between commercial halva samples and that it is not easy to standardize a methodology to describe the texture attributes of halva [9].

All halva formulations followed the same pattern of opposition force to material deformation. At first, an increase in the opposition force generated by material deformation at the first bite could be observed. In turn, it is noted that the formulations that started from whole, unroasted seeds (H7 and H8) presented greater resistance than those that did not (H5 and H6), followed by the formulations that used tahini from unroasted, dehulled seeds (H3 and H4) than those that came from roasted, dehulled seeds (H1 and H2). Also, it was found that the formulations tend to adhere between bites and generate a force opposing detachment from the teeth when

Code	Fractur ability (N)	Hardness (N)	Adhesiveness	Cohesiveness (Not unit)	Gumminess (N)	Chewiness
H1	6.38 ± 0.01^{h}	16.28 ± 0.02^{f}	-1.57 ± 0.08^{a}	0.20 ± 0.03^{bc}	3.28 ± 0.12^{h}	65.52 ± 0.12^{h}
H2	8.47 ± 0.03^{e}	15.14 ± 0.06^{g}	-4.43 ± 0.04^{f}	0.24 ± 0.08^{bc}	7.15 ± 1.33^{c}	142.71 ± 0.03^{c}
H3	8.57 ± 0.07^{d}	16.48 ± 0.08^{e}	-2.36 ± 0.05^{b}	0.32 ± 0.17^{a}	5.21 ± 1.12^{e}	104.00 ± 0.09^{e}
H4	8.89 ± 0.05^{c}	13.51 ± 0.06^{h}	-2.85 ± 0.05^{d}	0.33 ± 0.16^{a}	4.40 ± 3.26^{f}	87.91 ± 0.04^{f}
H5	8.25 ± 0.12^{g}	27.97 ± 0.07^{c}	-2.58 ± 0.12^{c}	0.32 ± 0.34^{a}	3.56 ± 2.52^{g}	71.11 ± 0.01^{g}
H6	8.34 ± 0.11^{f}	33.57 ± 0.06^{a}	-5.04 ± 0.16^{h}	0.22 ± 0.99^{c}	7.50 ± 2.01^{a}	149.84 ± 0.10^{a}
H7	11.01 ± 0.08^{a}	28.64 ± 0.10^{b}	-4.67 ± 0.09^{g}	0.26 ± 2.25^{bc}	7.43 ± 1.16^{b}	148.36 ± 0.58^{b}
H8	10.56 ± 0.06^{b}	20.09 ± 0.04^{d}	-3.90 ± 0.06^{e}	0.28 ± 2.29^{ab}	5.58 ± 1.42^{d}	111.53 ± 0.28^{d}

Table 6: Parameters obtained from texture analysis (TPA).

biting. The same behavior was observed but with less hardness in the second bite. The differences between the halva may be due to the treatment given to the sesame seed. Those with a tremendous amount of fiber are harder because the fiber can generate body in the food matrix, and those where the seed was toasted are less hard due to the denaturation of the proteins that maintain the halva emulsion.

Sensory properties

An electronic survey was conducted with the participation of 42 people; those who did not have neophobia, liked sesame, and consumed products made from sesame were selected. Candidates with a special diet or allergies to sesame were filtered, thus discarding 4.76% of the participants. This type of survey is essential when carrying out acceptance tests by inexperienced panels because it is necessary to know the intentions of the panelists when carrying out the sensory evaluation and, thus, avoid errors that alter the results of the sensory acceptance tests. The sensory evaluation comprised a panel of 40 people, of whom 48% were women and the remaining 52% were men. The age groups of the evaluators were 35% between 20 and 28 years, 52.5% between 30 and 60 years, and 12.5% between 61 and 64 years.

The results were obtained through sensory evaluation with a 7-point hedonic scale for the acceptability of products (Table 7 and Figure 3). The results indicate statistically significant differences for all the attributes evaluated, highlighting that in terms of color, H4 had the highest acceptability, followed by H1, H2, and H3, with lower values for H5 to H8. The taste was superior for H1 and H4, with the rest of the panelists' values below those shown for these two halvas. The lowest value was for H8. In this regard, some panelists commented that it was an intense, astringent flavor with a predominance in the mouth that made it difficult to consume. The texture of the halva was more remarkable for H1, and in general, it was superior for the products formulated with G-150. A similar result was obtained for the overall acceptability of the halvas. The results could be correlated with the colors obtained for the halvas, as observed in table 5.

Code	Color	Taste	Texture	Overall quality
H1	5.84 ± 1.22^{ab}	5.59 ± 1.41^{a}	5.97 ± 1.15^{a}	5.97 ± 1.12^{a}
H2	5.87 ± 0.92^{ab}	5.16 ± 1.24^{abc}	5.10 ± 1.11^{abc}	5.16 ± 1.10^{abcd}
H3	5.72 ± 0.99^{ab}	5.38 ± 0.98^{ab}	5.31 ± 1.42^{abc}	5.34 ± 1.07^{abc}
H4	6.16 ± 1.04^{a}	5.48 ± 1.18^{ab}	5.65 ± 1.25^{ab}	5.71 ± 1.00^{ab}
H5	4.56 ± 1.37^{c}	5.13 ± 1.18^{abc}	4.81 ± 1.33^{bc}	4.84 ± 1.19^{bcde}
H6	5.00 ± 1.24^{bc}	4.94 ± 1.21^{abc}	4.77 ± 1.26^{bc}	4.74 ± 1.12^{cde}
H7	3.28 ± 1.28^{d}	4.59 ± 1.24^{bc}	4.75 ± 1.16^{bc}	4.47 ± 1.14^{de}
H8	3.19 ± 1.51^{d}	4.29 ± 1.49^{c}	4.65 ± 1.25^{c}	4.16 ± 1.39^{e}

Table 7: Sensory evaluation through a 7-point hedonic scale.

Forty (40) panelists were evaluated. The average of the results obtained is expressed. Those results that have a superscript obtained significant differences after an analysis of variance with a value of α = 0.05.

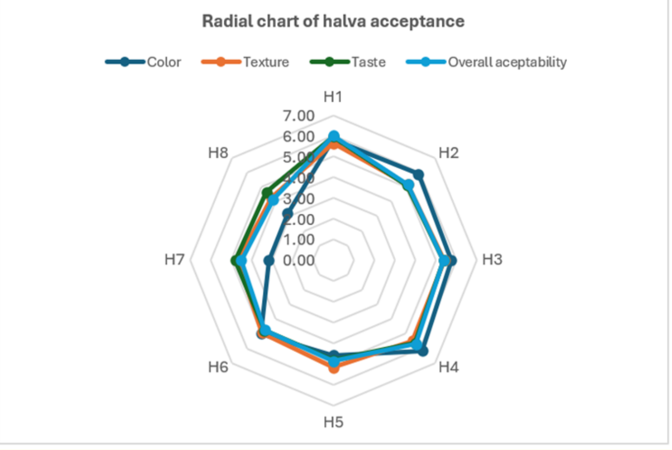

Figure 3: Radial Chart of Halva acceptability.

Generally, the products with G-150 had greater luminosity than those with DV-9, which is a parameter that influences the moment the consumer chooses or accepts to consume any food product. In general, most of the panelists received the Halva formulations positively, especially H1 and H4, where the flavors and aromas of the roasting in H1 reached high levels of acceptance, unlike H4, where the typical sesame flavors were the reasons why the panelists demonstrated their high level of acceptance to this formulation.

Halva was made with G-150, and the panelists commented that it was pleasing from the start, mainly because of its color. This was the evaluator's expectation; it was also less bitter, resembling an excellent quality nougat, although in some cases, it was reflected that it could be pasty for some evaluators. Also, in some instances, evaluators expressed a sensation of residual flavors. In this order of ideas, for halva with DV-9, some panelists indicated that they were more intense, bitter flavors, sometimes with unpleasant colors. In general terms, most evaluators stated a balance of a diversity of colors and flavors, which can be helpful for many types of consumers.

Physicochemical characterization of halvas

Proximal composition

The results showed (Table 8) statistically significant differences between the halva, indicating that the treatments applied to sesame seeds affect the halva's proximate composition. The humidity was between 2.36% (H3) and 3.15% (H8). These values, together with the halva's low water activity, allow us to estimate that the product may be stable over time and also consider that attacks by microorganisms would be infrequent. The moisture content of commercial halva formulations varied between 2.00% and 7.25%, which agrees with the results obtained in this study [9]. The low water activity value in the different formulations can be due to the intrinsic properties of the food matrix. It is inferred that the high contents of carbohydrates and proteins can sequester the water molecules present in the matrix. In addition, it has a low moisture content, which causes the water molecules to interact strongly with the biomolecules in the food. Determining the water activity of a food product is essential since the energy level of the water in the matrix influences the type of deterioration that the food can suffer. Since halva is at a level less than 0.4, it can be established that it is a microbiologically stable and biochemically limited product. That is, the deterioration processes that can occur in this type of product can be due to the intrinsic enzymes of the food matrix and chemical reactions (non-enzymatic darkening and rancidity) of the constituents present in it. A quality parameter for commercial halva should be a water activity less than 0.4 [10]. The protein content varied between 25.96% and 29.89%, and the formulations that used the whole seed had a lower protein content than those that used the dehulled seed. The crude fat content was between 39.10% and 35.42% in the different formulations. The formulations where the seed was toasted had a lower crude fat content than those where the sesame was not toasted. A high protein content and a low crude fat content were found, unlike the commercial halva formulations described in the literature [9,11,28,29]. The climatic conditions during sesame cultivation may have affected the production of triacylglycerides as a reserve energy source, decreasing the crude fat content. It is necessary to emphasize that the crude fat content in the formulations where roasted seeds were used is likely to have decreased because high temperatures can denature proteins. These proteins have surfactant properties that maintain the emulsion of the halva constituents. Therefore, by reducing the capacity to emulsify lipids, they can percolate through the food matrix, causing a phase separation. According to [27], proteins play a prominent role in the emulsification of halva, which can interact with sugars and triacylglycerides. The total ash content between the formulation results ranged from 1.57 to 3.92%, higher than reports found for other types of halva [30]. However, this can be attributed to factors such as the materials used, including different types of sesame. The results of the proximate composition determined that the highest caloric intake of halva was obtained for the H1 formulation, with 577 Kcal/100 g. Halva is a high-fat product that directly affects caloric intake. However, a portion of this product can be between 10 and 20 grams, meaning the energy intake is 10 to 5 times lower and can meet the daily intake requirements for healthy consumers. The halva's pH and acidity were variable. However, they were within the expected ranges, considering that citric acid is used in the formulation. Citric acid can drastically modify the pH if used in proportions higher than those in these formulations.

Antinutritional components

The saponin content (Table 8) was between 17.16 mg% and 18.96 mg% for formulations H1 and H4, respectively. Determining these compounds is essential because saponins are naturally present in sesame seeds and are responsible for the bitter and astringent flavors characteristic of sesame and its products. Toros [31] determined the presence of saponins in sesame flour from Venezuelan varieties (DV-9 and G-150) and described how hydrothermal treatments, especially the hydrothermal debarking process, decreased the saponin content. This study found that the saponin content of the sesame flours used by [31] was higher. Soapwort, a source of saponins, is responsible for the increase in saponin content. Determining the saponin content in food systems is vital because studies [32,33,28] classify saponins as antinutritional agents due to their hemolytic activity. Usually, toxic saponins are thermolabile because they are found in glycosidic forms, and when the extraction is carried out, a large part of them is destroyed. Therefore, we can infer that the low content contributed by saponins is because they were degraded in the preparation process of the halva formulations.

The phytic acid content obtained for the various formulations showed significant differences, indicating that the treatments applied to tahini directly affect the halva. Phytic acid is a component in different food systems of plant origin; it is a chelating agent of minerals such as iron, calcium, and magnesium. Therefore, it is suggested that the presence of phytic acid in products made from sesame seeds has this antinutritional factor. In the case of Venezuelan

Parameter	H1	H2	H3	H4	H5	H6	H7	H8
Moisture*	2.85 ± 0.08^{bc}	2.72 ± 0.06^{cd}	2.36 ± 0.04^{f}	2.94 ± 0.08^{b}	2.47 ± 0.07^{ef}	2.56 ± 0.05^{de}	2.73 ± 0.05^{c}	3.15 ± 0.03^{a}
Dry matter*	97.15 ± 0.08^{de}	97.28 ± 0.06^{cd}	97.64 ± 0.04^{a}	97.06 ± 0.08^{e}	97.53 ± 0.07^{ab}	97.44 ± 0.05^{bc}	97.23 ± 0.03^{d}	96.85 ± 0.03^{f}
Crude protein* (N*6,25)	26.25 ± 0.13^{cd}	26.96 ± 1.12^{bcd}	26.74 ± 1.45^{cd}	29.17 ± 0.79^{ab}	31.11 ± 0.46^{a}	28.35 ± 0.51^{bc}	25.25 ± 0.71^{d}	25.77 ± 0.35^{d}
Crude fat*	39.10 ± 0.10^{a}	38.77 ± 0.03^{b}	38.76 ± 0.02^{b}	37.81 ± 0.04^{d}	35.42 ± 0.01^{f}	36.84 ± 0.02^{e}	38.72 ± 0.02^{b}	38.42 ± 0.01^{c}
Total Ash*	1.84 ± 0.02^{e}	1.73 ± 0.09^{ef}	2.08 ± 0.03^{d}	1.52 ± 0.07^{f}	3.68 ± 0.10^{ab}	3.82 ± 0.08^{a}	3.52 ± 0.08^{bc}	3.41 ± 0.14^{c}
Carbohydrates by difference*	29.96 ± 0.13^{a}	29.82 ± 1.06^{a}	30.06 ± 1.46^{a}	28.56 ± 1.06^{ab}	27.32 ± 0.49^{b}	28.43 ± 0.40^{ab}	29.78 ± 0.74^{a}	29.25 ± 0.35^{ab}
Energy contribution (Kcal/100g)	577 ± 0.88^{a}	576 ± 0.57^{a}	576 ± 0.11^{a}	571 ± 0.56^{b}	553 ± 0.43^{f}	559 ± 0.50^{e}	569 ± 0.12^{c}	566 ± 0.74^{d}
In vitro protein digestibility*	51.78 ± 1.54^{a}	51.84 ± 0.21^{a}	49.08 ± 0.07^{ab}	48.83 ± 1.16^{ab}	45.82 ± 0.58^{bc}	45.57 ± 3.01^{bc}	43.45 ± 1.26^{c}	42.10 ± 2.62^{c}
pH	5.19 ± 0.07^{f}	5.75 ± 0.06^{c}	5.84 ± 0.02^{b}	5.97 ± 0.01^{a}	5.36 ± 0.01^{e}	5.24 ± 0.02^{f}	5.54 ± 0.02^{d}	5.68 ± 0.01^{c}
Titratable Acidity (%)	0.61 ± 0.01^{c}	0.95 ± 0.01^{a}	0.54 ± 0.01^{e}	0.53 ± 0.01^{e}	0.36 ± 0.01^{f}	0.68 ± 0.02^{b}	0.57 ± 0.03^{d}	0.58 ± 0.02^{cd}
Water activity	0.385 ± 0.01^{ab}	0.396 ± 0.01^{a}	0.372 ± 0.01^{bc}	0.371 ± 0.01^{bc}	0.356 ± 0.01^{cd}	0.337 ± 0.01^{d}	0.342 ± 0.01^{d}	0.353 ± 0.01^{cd}
Saponin content (mg%)	17.15 ± 0.02^{d}	18.16 ± 0.57^{c}	18.10 ± 0.07^{c}	18.97 ± 0.06^{b}	19.42 ± 0.04^{b}	20.16 ± 0.04^{a}	20.44 ± 0.07^{a}	20.52 ± 0.03^{a}
Phytic acid content (mg%)	10.58 ± 0.06^{b}	10.67 ± 0.13^{b}	10.93 ± 0.20^{b}	11.89 ± 0.26^{b}	12.71 ± 0.82^{ab}	14.36 ± 0.61^{ab}	12.67 ± 5.75^{ab}	18.37 ± 0.47^{a}
Oxalate content (mg%)	1.09 ± 0.03^{c}	1.10 ± 0.03^{c}	1.12 ± 0.08^{c}	1.12 ± 0.02^{c}	1.21 ± 0.06^{c}	1.21 ± 0.10^{c}	1.48 ± 0.09^{b}	2.10 ± 0.02^{a}

Table 8: Physicochemical characterization of halvas.

Results expressed as an average of 3 replicates with their associated deviation. Superscript letters indicate significant differences between formulations of $p < 0.05$. (*) expressed on a dry basis. N is the calculated nitrogen content.

sesame seed varieties [31] quantified 25.36 mg% in sesame flours for the G-150 variety and 30.85 mg% for the DV-9 variety; however, in this study, lower values were obtained than those reported by [31]. The decrease in content may be due to hydrothermal treatment when dehulled sesame seeds. Hydrothermal treatments contribute to the reduction of phytic acid content because phytic acid is soluble in water. Therefore, the leaching process of phytate ions in water is carried out under the influence of the concentration gradient. The reduction can be attributed to the permeability of the seed crust that has been modified when in contact with water [34-36]; in addition, leaching is favored when it comes to compounds of low molecular weight and ionic character [37].

Differences were recorded between the halva for the oxalate content, attributed to what was indicated above. Oxalate is synthesized in crystals, in structures called idioblasts, located in the cotyledons and the bark of oilseeds [38,39].

After applying the different treatments, the final saponins, phytic acid, and oxalate content were below the lethal dose 50 [40-43]. The acceptable daily intake value is 631-746 mg/day, so it does not threaten the consumer's health [44].

In-vitro protein digestibility

The *in-vitro* digestibility of the various halva formulations was variable, with significant differences for almost all treatments. The Halva's high fat and carbohydrate content may inhibit enzymatic digestion, reducing protein digestibility. Proteins are the primary surfactant in Halva, and because of this, they perform intermolecular interactions with fats and carbohydrates, resulting in a steric hindrance that inhibits rapid enzymatic digestion. By increasing the exposure time during the seed roasting or the tahini temperature during the halva preparation, the proteins can be further denatured and made easier to digest. However, due to the emulsifying properties of proteins in this type of food matrix, finding the desired texture will likely be more complex.

Conclusion

It was possible to produce eight tahini halva from the modifications or treatments applied to the sesame varieties G-150 and DV-9, obtaining for each of them a different chemical, physicochemical, functional, and nutritional composition which can be adapted to the taste of different consumers and promotes moving forward with more studies to achieve the most significant standardization in the production of the product locally. Halva is an essential product that promotes the consumption of sesame and thus takes advantage of the nutritional benefits that it is capable of providing.

Conflict of Interest

The authors whose names are listed in this paper certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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