ISSN: 2347-467X, Vol. 12, No. (2) 2024, Pg. 634-644

Current Research in Nutrition and Food Science

www.foodandnutritionjournal.org

Evaluation of Quality Attributes and Rheological Behavior of Tahini with Addition of Natural Sweetener and Cocoa Liquor

PIEDAD MONTERO CASTILLO, KARINA VIVANCO ZUÑIGA* and DELIBETH CUADRO ALVAREZ

Faculty of engineering, Programme: Food Engineering. University of Cartagena, Cartagena, Colombia.

Abstract

Tahini is a globally recognized creamy paste made from sesame seeds, whose seeds are widely produced in Colombia but little used in the production of products. Therefore, the objective of this study was to evaluate the quality attributes through proximal, microbiological, and sensory analysis, and the rheological behavior of tahini with the addition of natural sweetener, honey, and cocoa liquor as sensory additives, using local crops. A 2X2X2 factorial design with sesame paste, honey concentration, and cocoa liquor as factors were used to prepare tahini. Proximal, microbiological, and sensory analyses were carried out to determine the bromatology, microbiological suitability, and sensory acceptability, respectively. The rheological behavior was studied by shear rate sweep, controlling the deformation $1x10^{-2}$ s^{-1} to $1x10^{-2}$ s^{-1} with a fit to the Ostwald de Waele model. The rheological characterization of the formulations showed that all of them exhibited pseudoplastic flow behavior, with F4 standing out as having a higher apparent viscosity. Finally, formulation F4 showed the best bromatological, rheological, and sensory characteristics, demonstrating that the incorporation of new ingredients can modify traditional tahini to promote its consumption.

Article History

Received: 06 April 2024

Accepted: 29 July 2024

Keywords

Cocoa Liquor;
Creamy Paste;
Innovative Product;
Sesame;
Rheology;
Pseudoplastic.

Introduction

Tahini is a creamy sesame paste made from roasted, hulled, and ground sesame seeds [1] and is one of the most recognized sesame culinary foods worldwide.[2,3,4] It has also long been considered a functional food due to its health-promoting properties.[1] Sesame (*Sesamum indicum L.*) is an oilseed that is widely cultivated in different parts of the world,[5] mainly in the tropical and subtropical regions of Asia, Africa, and South America.[6]

Sesame is considered the "queen of oilseeds" due to its multiple nutritional qualities,[7] such as high protein content, essential fatty acids, antioxidants, minerals; it is also important in medicine due to the presence of bioactive compounds such as sesamolin and

CONTACT Karina Vivanco Zuñiga kvivancoz@unicartagena.edu.co Faculty of engineering, Programme: Food Engineering. University of Cartagena, Cartagena, Colombia..

© 2024 The Author(s). Published by Enviro Research Publishers.
This is an Open Access article licensed under a Creative Commons license: Attribution 4.0 International (CC-BY).

Doi: https://dx.doi.org/10.12944/CRNFSJ.12.2.12

sesamin, which have anti-inflammatory, anticancer and antihypertensive properties, among others.[8,9]

According to the FAO,[10] global sesame production reached 2,376,000 tons in 2022. In Colombia, a wide variety of seeds are grown, with sesame being one of the most representative,[11] with a national production of 3,950.38 tons in 2022. According to the latest data from the Ministry of Agriculture, sesame production in Magdalena was the highest in Colombia in 2022, with a share of 45.07%, followed by Bolivar with 21.97%.[12]

Although sesame has many benefits and large global production, it has not been fully exploited as its use has been mostly limited to the production of edible oil1; however, the most popular form of consumption is whole and roasted.[13, 14] Other uses include the preparation of salads, bars, biscuits, spreads, and the manufacture of bakery products.[15,16]

Of the sesame preparations, tahini stands out, which is mainly used as a food additive, being used as a condiment, seasoning, and butter.[4] Several studies recommend and promote the consumption of this food due to its multiple nutritional qualities,[3, 17, 18] but it is necessary to improve its sensory qualities to promote its consumption as a staple food and not as an additive.

New trends have focused on the consumption of healthy foods with high nutritional and sensory quality,[19] the latter being a challenge for the food industry, which, faced with consumer demands, has opted to incorporate additives of natural origin.[20] Among the natural additive products that stand out the most in the food industry are honey [21] and cocoa derivatives.[22] Honey is a natural sweetener that provides carbohydrates just like table sugar,[23] but it has a higher sweetening power and its assimilation is easier compared to sucrose because it contains short-chain carbohydrates.[24] In Colombia, honey production reached 3,851 tons in 2020,[25] demonstrating the potential use of this bee resource. For several years, have been conducted to evaluate the effects of incorporating other products into tahini or sesame paste; Arslan,[26] investigated the rheological properties of tahini/pekmez blends and observed that the incorporation of pekmez modified the rheological behavior and sensory attributes; Hou,[27] investigated the chemical, rheological and sensory properties of nine different brands of sesame paste, the results showed significant differences in terms of proximate composition and rheological parameters; Tomruk,[28] investigated the rheological properties of sesame paste blends prepared with grape juice concentrate, honey, and sugar syrup. More recently, Saatchi,[29] investigated the effect of using sesame protein concentrate and a conjugated form of the protein with maltodextrin to improve paste rheology.

In this context, the objective of this research was to evaluate the quality attributes through proximal, microbiological, and sensory analysis, and the rheological behavior of tahini with the addition of natural sweetener, honey, and cocoa liquor, using crops native to Colombia in the formulation of the product.

Materials and Methods

Sesame Paste Preparation

The sesame paste was prepared according to the methodology described by Abid,[1] Acevedo,[30] and Alaouie,[31] and with some modifications. Sesame seeds from a local shop in Santa Marta, Magdalena (Colombia) were used. The seeds were rendered suitable by immersing them in water at room temperature for 12 hours and then placing them in a 23% saline solution for five minutes to mechanically separate the hulls. The dehulled and washed seeds were roasted in an oven HE2750-Challerger S.A. at 140°C for 30 minutes and ground in a mechanical disc mill. The tahini obtained was stored in a sterile glass container under refrigeration until use.

Cocoa Liquor Preparation

The methods described by Ramirez,[32] and Pablo,[33] with modifications, were used to prepare the cocoa liquor. Cocoa beans from a local shop in the department of Magdalena, Santa Marta, were used and roasted in a convection oven T043M, Tornado at 110ºC for 25 min. The roasted beans were then crushed and dehulled using a Hamilton Beach coffee grinder to obtain 0.5-0.25 cm pieces (nibs). The nibs were separated from the shell and ground in a mortar and pestle mill, RM-200, Retsch, at a temperature of 40°C until cocoa liquor was obtained. Finally, the cocoa liquor was stored in sterile glass containers and kept refrigerated until use.

Experimental Design and Incorporation of Honey and Cocoa Liquor into Tahini

The tahini with honey and cocoa liquor was developed taking into account the formulations established in Table 1, which consists of a 2x2x2 factorial design to half fraction, in which the following factors were considered: tahini concentration (70 and 80%), honey (30 and 20%) and cocoa (6 and 9%), levels were established by preliminary tests. A total of eight experimental formulations were carried out, four of which were chosen so that the sum of the percentages of tahini and honey was 100%. The procedure was as follows: sesame paste, honey, and then cocoa mass were mixed in a Kitchen Aid mixer, K45SS Classic Stand Mixer, for 3 minutes to obtain a product with a pasty texture. The samples of tahini with added honey and cocoa liquor were packaged in glass jars and pasteurized at 95°C for 10 minutes. They were then stored at 4°C until further analysis.

Table 1. Tahini formulations (%)

Components	Formulations			
	F1	F2	F3	F4
Sesame paste	70	70	80	80
Honey	30	30	20	20
Total	100	100	100	100
Cocoa Liquor	6	9	6	9

Proximal Análisis

The following parameters were determined by the AOAC,[34]: fat by method No. 996.06, protein by method No. 992.15, moisture by method No. 926.01, crude fiber by method No. 991.43, ash by muffle combustion and carbohydrates by the difference in weight. Analyses were performed in triplicate. In addition, the caloric content was calculated using the Atwater coefficients, i.e. for protein 4.0, carbohydrate 4.0, and lipid 9.0.

Microbiological Analysis of The Final Product

Microbiological analysis of the final product was carried out according to the Colombian technical standard NTC 1055 for milled products and pasta.[35] Total and fecal coliform counts, fungal and yeast counts (CFU/g), and total mesophilic aerobic counts (CFU/g) were realized, the latter following the method described in NTC 1273 for honey.[36]

Rheological Characterization

Preliminary tests were carried out on each of the tahini formulations in triplicate. Rheological measurements were performed in a Kinesux Pro rotational rheometer, Malvern Instruments Ltda, using a parallel plate geometry. All samples were allowed to rest for 15 minutes before measurement. A shear rate sweep from $1x10^{-2}$s-1 to $1x10^{2}$ s^{-1} was performed on each sample. The values of the rheological parameters were obtained: apparent viscosity (η), flow index n, consistency coefficient K, and linear correlation of each treatment R^2. The temperature of the samples was kept at 25°C+/-0.01°C and the data were fitted to the Ostwald de Waele model using the Bohlin rheometer software.

Sensory Evaluation

The analysis was carried out taking into account the ICONTEC, [37] The sensory evaluation of all formulations was carried out by a panel of 50 judges, within the age range of 18 to 40 years, regular consumers of sesame and/or cocoa products. The samples were presented in completely clean plastic containers, under the same conditions for all panelists, approximately 15 grams at ambient temperature, with water used between the evaluation of one formulation and another. This analysis consisted of a modified 5-point hedonic scale, where 1= I dislike it very much, 2= I dislike it moderately, 3= I neither like nor dislike it, 4= I like it moderately and 5= I like it very much; 4 basic parameters were evaluated: color, taste, texture and general acceptability.

Data analysis

The statistical analysis was carried out using IBM SPSS Statistics version 23. Descriptive statistics were used to determine the mean and standard deviation parameter evaluated in the proximal and sensory analyses. In addition, analysis of variance (ANOVA) and Tukey's HSD test were performed at a significance level of ($p \leq 0.05$).

Table 2. Proximate analysis of tahini samples added with honey and cocoa liquor

Components %	F1	F2	F3	F4
Fat	32,35 ±0.11 [a]	33,14 ±0.15 [b]	36,53 ±0.17 [c]	38,85 ±0.14 [d]
Protein	13,43 ±0.25 [a]	13,01 ±0.25 [a]	13,83 ±0.13 [b]	14,02 ±0.22 [b]
Ash	1,67 ±0.09 [a]	1,71±0.07 [a]	1,85 ±0.08 [b]	1,90 ±0.07 [b]
Carbohydrates	37,75 ±0.05 [a]	36,85 ±0.08 [b]	34,03 ±0.06 [c]	31,91 ±0.06 [d]
Moisture	11,07 ±0.24 [a]	11,65±0.15 [b]	10,22±0.17 [c]	10,15±0.22 [c]
Fiber	3,16 ±0.03 [a]	3,37±0.04 [b]	3,65±0.05 [c]	3,73 ±0.02[d]
Calories (kcal)	488	493	512	522

Medians within columns followed by the same letter are not significantly different ($p \leq 0.05$)
* *Calories calculated for each 100 g of product

Results and Discussion

Proximal Composition

The results of the proximate analysis of tahini sweetened with honey and cocoa liquor are shown in Table 2. These results show that the formulations have high bromatological values. It was observed that the fat, protein, ash, and fiber contents were directly proportional to the concentration of sesame paste. These results are in agreement with those reported by Sanja, [38] who observed that sesame paste, when added as a supplement to another food matrix, is directly proportional to the nutritional content of the final product. However, the moisture and carbohydrate content was dependent on the proportion of honey, an analysis based on the fact that honey is a highly concentrated solution of sugar in water.[39]

Similar results were found in the literature on the proximate composition of tahini or sesame paste.[27, 38, 40, 41, 42] The consistency of these results with the literature indicates that this product has sufficient nutritional properties for consumption. On the other hand, the caloric value of the samples was found to be in the range of 480 and 525 kcal, USDA,[43] has reported that traditional tahini provides up to 595 kcal per 100g of product. Therefore, it can be said that the tahini obtained in this research has a lower caloric intake and it is considered good and healthy. The results of the proximate analysis of the samples are significant and indicate that the tahini samples have a high nutritional value, as reported by Arab, [44] sesame or sesame products can act on health by preventing degenerative diseases and favoring the organism. Sample F4 stands out with higher values for fat, protein, ash, fiber, and calories, indicating a higher nutritional content compared to samples F1, F2, and F3.

Microbiological Analysis of The Final Product

The microbiological analysis is presented in Table 3. These results show that the microbial counts of all the samples are below the maximum limits allowed by current regulations. This can be attributed to the high percentage of fat, protein, and carbohydrates, as opposed to the low percentage of moisture in the sesame paste, and therefore low water activity, which is an important factor in preventing the growth of microorganisms that cause product deterioration [45]

In addition, the survival of microorganisms is influenced by the temperature parameter, some researchers observed that in tahini and halva, the growth rate was significantly reduced when the products were stored under different conditions, with the result that the development of microorganisms was inhibited at low temperatures.[46] Consequently, these favorable results can be attributed to proper handling, heat treatment, and refrigerated storage conditions. Studies by Kilci,[47]; Szpinak,[48] and Olaimat,[49] showed similar results.

Table 3. Microbiological analysis of formulations F1, F2, F3 and F4

Counting/Formulation	F1	F2	F3	F4	Limit
Mesophilic aerobes (CFU/g)	40	20	20	20	2000
Total coliforms (CFU/g)	<10	<10	<10	<10	<10
Fecal coliforms (CFU/g)	<10	<10	<10	<10	<10
Molds (CFU/g)	3	5	2	2	4000
Yeasts (CFU/g)	3	5	2	2	4000

* Limit according to NTC 1055(NTC, 2014) and NTC 1273(NTC,2023)

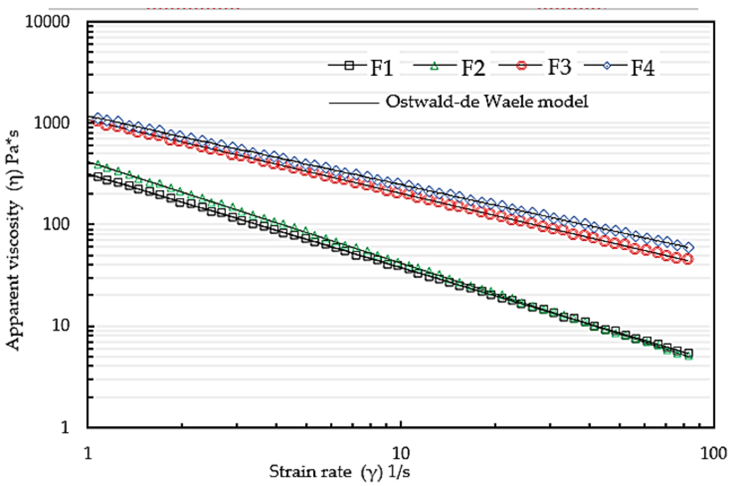

Fig. 1; Reogram adjusted to the Ostwald de Waele model.

Table 4. Rheological flow measurements in the Ostwald de Waele model

Formulation	n	K(Pa*s)	R^2
F1	0,274	2,502	0,9998
F2	0,282	2,720	0,9997
F3	0,342	2,903	0,9978
F4	0,426	3,170	0,9979

Rheological Characterization

Figure 1 shows the superimposed results of the flow curves of formulations F1, F2, F3, and F4 as a function of apparent viscosity and strain rate γ* fitted to the Ostwald de Waele model.

It is observed that the apparent viscosity of all the characterized formulations shows a decrease with increasing strain rate, indicating that shear thinning and non-Newtonian behavior occurred in all the samples analyzed. In studies by Kiani,[50] a decrease in apparent viscosity with increasing strain rate was reported when evaluating the rheological behavior of a sesame paste; similar results were observed by Jin,[40] Acevedo,[51] and Khaji,[52]. This behavior is known as pseudoplastic[53] and, according to other researchers Velasquez-Barreto,[54] is generated when there is a rupture in the polysaccharide molecular network, since the shear rate of the paste during deformation is higher than the rearrangement of the molecules, in addition to being generated by the orientation of the molecules in the direction of flow, which presents a lower resistance to shear forces .[52] Comparing the lines of the reogram, it can be observed that formulation F4 has higher values than the other samples; therefore, it can be said to have the highest apparent viscosity, a behavior that is maintained as the strain rate increases. These results are consistent with those reported by Hou,[27] who reported that the formulation of a spreadable paste with a higher concentration of fats, proteins, and lower moisture content provides a higher reinforcement to the structure of the system, thus increasing its resistance to deformation.

Table 4 shows the flow measurements in the Ostwald de Waele model. The values of the flow behavior index n were less than 1, which is consistent with the previous flow diagram, since according to Acevedo,[51] values less than 1 indicate pseudoplastic behavior, however, these values were below the range (0.77-0.94) reported by Kiani,[50] which can be explained by considering the presence of other components such as cocoa liquor and honey, the latter being the one that is present in more significant proportions in the final product. As reported by Daubert,[55] when the flow behavior index decreases, the material becomes more liquid, this result is observed in the behavior of tahini, since honey, provides a high percentage of water between 13 and 23%,[56] modifies the structure of the matrix, causing a decrease in this rheological parameter by increasing the fluidity.

The consistency index K presented values in the range of 2,502 Pa*s and 3,170 Pa*s in the Ostwald de Waele model. Formulation F4 presented the highest K value. These results are in line with those presented by Jafar,[57] who reported that a higher addition of sesame paste increased the consistency, as well as honey by providing a large content of carbohydrates.[58] When analyzing the linear correlation coefficients of the mathematical model studied, it is observed that they have a minimum R^2 of 0.9978, indicating that the formulations were adequately adapted to the rheological model.

Table 5. Sensory analysis results of tahini sweetened with honey and cocoa liquor addition

Formulation	Color	Flavor	Texture	Overall appearance
F1	4,28±0.07 ^{a}	4,10±0.09 ^{ab}	4,08±0.08 ^{a}	4,22±0.11 ^{a}
F2	4,18±0.07 ^{ab}	4,01±0.09 ^{a}	4,04±0.05 ^{a}	4,14±0.15 ^{a}
F3	4,16±0.08 ^{ab}	4,16±0.07 ^{b}	4,31±0.09 ^{b}	4,42±0.09 ^{b}
F4	4,14±0.06 ^{b}	4,32±0.07 c	4,34±0.06 ^{b}	4,52±0.10 ^{b}

Medians within columns followed by the same letter are not significantly different (p≤0.05)

Sensory Evaluation

The results of the sensory analysis are presented in Table 5. As shown for the color attribute, F1 was the most preferred with a mean of 4.28, this acceptability was mainly dependent on the percentage of cocoa liquor, it was observed that as the concentration of cocoa liquor increased, the samples became darker in color.

The formulation with the highest score in flavor, texture, and overall appearance attributes was F4, this treatment was characterized by containing the highest proportion of sesame paste and cocoa liquor. Similar results were observed in a study by Sanja,[38] when characterizing food matrices containing tahini halvah and cocoa, these showed better sensory properties and acceptability compared to the other ingredients evaluated. Similarly, Akbulut,[59] evaluated the overall appearance of sesame paste mixed with pine honey and found similar results to those presented in this study, attributing the good acceptability to a dilution effect of the sweetness of pine honey on the oiliness of sesame paste, which improves the sensory acceptability of the product. On the other hand, Altay, [60] evaluated the consumer acceptability of the tahini/pekmez mixture and stated that it is highly dependent on the spreadability of other materials, such as bread. These results may explain the results presented in Table 5.

Conclusions

This research showed that making tahini with a natural sweetener and cocoa liquor is an alternative way of using local resources. According to the results, the F4 formulation showed the highest nutritional content and greater sensory acceptability and all samples were microbiologically acceptable. The rheological characteristics showed a non-Newtonian pseudoplastic behavior with a high adaptation to the Ostwald de Waele model in all the formulations studied, with F4 standing out for having the highest values of rheological parameters, which are indicative of the establishment of adequate processing conditions.

These results allow us to affirm that obtaining this tahini based on the F4 formulation could be viable from a technological point of view and that the incorporation of new ingredients can modify the traditional tahini to promote its consumption. In this sense, it is suggested to explore other substitutions for tahini using natural ingredients that take advantage of local crops and diversify this traditional product.

Acknowledgements

The authors would like to thank the University of Cartagena for its financial support through the Seventh Call for the Financing of Research Projects for Undergraduate Seed Groups affiliated to Visible Research Groups (Categorized or Recognized) in the Scienti Platform of the Department of Science, Technology and Innovation - Colciencias and approved by the University of Cartagena.

Funding Sources

The research was funded by the University of Cartagena through the Seventh Call for the Financing of Research Projects for Undergraduate Seed Groups affiliated to Visible Research Groups (Categorized or Recognized) in the Scienti Platform of the Department of Science, Technology and Innovation - Colciencias and approved by the University of Cartagena.

Conflict of Interest

There is no conflict of interest.

Authors' Contribution

This article is the result of the collaborative effort of several researchers with diverse backgrounds and areas of expertise. The individual contributions of each author are detailed below:

- Piedad Montero Castillo: Conceptualization of the study, methodological design and data analysis.
- Karina Vivanco Zuñiga: Conducting experiments, collecting and analysing results.
- Delibeth Cuadro Álvarez: Support in conducting experiments, compilation and analysis of results.

Data Availability Statement

The manuscript incorporates all datasets produced or examined throughout this research study.

Ethics Statement

No human or animal testing was performed. All methods used were non-invasive and data were obtained from public sources and existing databases. Confidentiality of information was assured and permission was obtained for the use of copyrighted material.

References

1. Abib B., Afifi S. M., El-Din M. G. S., Farag M. A. How do cultivar origin and stepwise industrial processing impact Sesamum indicum seeds' metabolome and its paste and in relation to their antioxidant effects? A case study from the sesame industry. *Food Chemistry.* 2023; 420(136134). DOI: https://doi.org/10.1016/j.foodchem.2023.136134
2. Sekhavatizadeh S. S., Afrasiabi F., Montaseri Z. Encapsulation of probiotic Lactobacillus acidophilus ATCC 4356 in alginate–galbanum (Ferula Gummosa Boiss) gum microspheres and evaluation of the survival in simulated gastrointestinal conditions in probiotic Tahini halva. *Brazilian Journal of Microbiology.* 2023; 54(3):1589–601. DOI: https://doi.org/10.1007/s42770-023-01074-3
3. Sumaina G., Abegaz W. B. Tahini: The Magical Condiment. depth Look at its Nutritional and Health Benefits, Ethiopia. *J Food Process Technol.* 2021; 12(859). DOI: https://doi.org/10.35248/2157-7110.21.12.859
4. Labban L., & Sumainah G. The Nutritive and Medicinal Properties of Tahini: A Review. *International Journal of Nutrition Sciences.* 2021; 6(4): 172-179. DOI: https://doi.org/10.30476/IJNS.2021.90294.1123.
5. Kafi, M., Nabati, J., Rezazadeh, EB *et al*. Productividad de sésamo (*Sesamum indicum L.*) de una o varias cápsulas en respuesta a rizobacterias promotoras del crecimiento de las plantas y a la aplicación foliar de silicio, potasio y calcio. *Planta Acta Physiol.* 2022; 44, 103. DOI: https://doi.org/10.1007/s11738-

022-03437-z

6. Dossa K. F., Enete A. A., Miassi Y. E., Omotayo A. O. Economic analysis of sesame (*Sesamum indicum L.*) production in Northern Benin. *Frontiers in Sustainable Food Systems.* 2023; 6, 1015122. DOI: https://doi.org/10.3389/fsufs.2022.1015122
7. Dossou S. S. K., XU F. T., Dossa, K., Rong Z. H. O. U., ZHAO, Y. Z., WANG L. H. Antioxidant lignans sesamin and sesamolin in sesame (*Sesamum indicum L.*): A comprehensive review and future prospects. *Journal of Integrative Agriculture.* 2023; 22(1): 14-30. DOI: https://doi.org/10.1016/j.jia.2022.08.097
8. Wei P., Zhao F., Wang Z., Wang Q., Chai X., Hou G, et al. Sesame (*Sesamum indicum L.*): A comprehensive review of nutritional value, phytochemical composition, health benefits, development of food, and industrial applications. *Nutrients.* 2022; 14(19): 4079. DOI: https://doi.org/10.3390/nu14194079
9. Gebremeskel A. F., Ngoda P. N., Kamau-Mbuthia E. W., Mahungu S. M. The effect of roasting, storage temperature, and ethanoic basil (*Ocimum basilicum L.*) extract on the oxidative stability of crude sesame (*Sesamum indicum L.*) oil. *Food Science & Nutrition.* 2022; 10(8): 2736-2748. DOI: https://doi.org/10.1002/fsn3.2877
10. FAOSTAT. Cultivos y productos de ganadería. 2021. DOI https://www.fao.org/faostat/es/#data/QCL
11. Pérez-Bolaños J.J., Salcedo-Mendoza J. G. Componentes del rendimiento en cultivares de ajonjolí *Sesamum indicum L.* (Pedaliaceae), en el departamento de Sucre (Colombia). *Ciencia y Tecnología Agropecuaria*. 2018; 19(2): 263-276. DOI: https://doi.org/10.21930/rcta.vol19_num2_art:660
12. Minagricultura. Agronet: Área, Producción y Rendimiento Nacional por Cultivo. 2022. DOI: https://www.agronet.gov.co/estadistica/Paginas/home.aspx?cod=1
13. El Hanafi L., Mssillou I., Nekhla H., Bessi A., Bakour M., Laaroussi H, et al. Effects of Dehulling and Roasting on the Phytochemical Composition and Biological Activities of *Sesamum indicum L.* Seeds. *Journal of Chemistry.* 2023. DOI: https://doi.org/10.1155/2023/5394315
14. He S., Pan T., Zhang Z., Wu Y., Sun H., Ma Y, et al. Interactive effect of hot air roasting processes on the sensory property, allergenicity, and oil extraction of sesame (*Sesamum indicum L.*) seeds. *Grain & Oil Science and Technology.* 2023. DOI: https://doi.org/10.1016/j.gaost.2023.02.001
15. Saleem, H., Sadaqat, H. A., Razzaq, H., Farooq, Q. Sesame as functional food. Gastroenterol Hepatol Open Access. 2021; 12(3): 89-92. DOI: https://doi.org/10.15406/ghoa.2021.12.00462
16. Ahmad S., Ghosh P. Benefits of dietary sesame seed and flaxseed to strengthen immune system during COVID-19 pandemic and prevent associated comorbidities related health risks. *Ann Phytomed.* 2020; 9(2): 50-61.DOI: https://doi.org/10.21276/ap.2020.9.2.5
17. Baxevanis G. K., Sakketou E. K. I., Tentolouris N. K., Karathanos V. T., Fragkiadakis G. A., Kanellos P. T. Tahini consumption improves metabolic and antioxidant status biomarkers in the postprandial state in healthy males. *European Food Research and Technology.* 2021; 247: 2721-2728. DOI: https://doi.org/10.1007/s00217-021-03828-5
18. Sakketou, E. K. I., Baxevanis, G. K., Tentolouris, N. K., Konstantonis, G. D., Karathanos, V. T., Fragkiadakis, G, et al. Tahini consumption affects blood pressure and endothelial function in healthy males. *Journal of Human Hypertension.* 2022; 36(12): 1128-1132. DOI: https://doi.org/10.1038/s41371-021-00624-2
19. Banwo K., Olojede AO, Adesulu-Dahunsi AT, Verma DK, Thakur M., Tripathy S, et al. Importancia funcional de los compuestos bioactivos de los alimentos con posibles beneficios para la salud: una revisión de las tendencias recientes. *Biociencia de los alimentos.* 2021; 43: 101320. DOI: https://doi.org/10.1016/j.fbio.2021.101320
20. Saraiva A., Carrascosa C., Raheem D., Ramos F., Raposo A. Natural sweeteners: The relevance of food naturalness for consumers, food security aspects, sustainability and health impacts. *International Journal of Environmental Research and Public Health*. 2020; 17(17): 6285. DOI: https://doi.org/10.1016/j.fbio.2021.101320

21. Miłek M., Ciszkowicz E., Sidor E., Hęclik J., Lecka-Szlachta K., Dżugan M. The Antioxidant, Antibacterial and Anti-Biofilm Properties of Rapeseed Creamed Honey Enriched with Selected Plant Superfoods. *Antibiotics.* 2021; 12(2): 235.DOI: https://doi.org/10.3390/antibiotics12020235
22. Soares T. F., Oliveira M. B. P. Cocoa by-products: characterization of bioactive compounds and beneficial health effects. *Molecules.* 2022; 27(5): 1625. DOI:https://doi.org/10.3390/molecules27051625
23. Atangwho I. J., Ibeneme C. E., Egbung G. E., Ibeneme E., Eno M. A., Nwankpa P. Effect of long-term feeding of the Obudu natural honey and table sugar-sweetened diets on obesity and pro-inflammatory biomarkers in rats. *BMC nutrition.* 2020; 6(1): 1-11. DOI: https://doi.org/10.3390/molecules27051625
24. Veloso M., LABORDE M., Galizio R., DE VILLARREAL A. P., Nuñez M., PAGANO A. M. P. Análisis sensorial del dulzor de mermeladas de ciruelas elaboradas a base de miel como edulcorante. *Alimentos Hoy.* 2020; 28(49): 23-40. DOI: https://acta.org.co/acta_sites/alimentoshoy/index.php/hoy/article/view/552
25. MinAgricultura. Cadena de las abejas y la apicultura. 2020. Link: https://sioc.minagricultura.gov.co/Apicola/Documentos/2020-09-30%20Cifras%20Sectoriales.pdf
26. Arslan E., Yener M. E., Esin A. Rheological characterization of tahin/pekmez (sesame paste/concentrated grape juice) blends. *Journal of food engineering.* 2005; 69(2): 167-172. DOI : https://doi.org/10.1016/j.jfoodeng.2004.08.010
27. Hou L. X., Li C. C., Wang X. D. Physicochemical, rheological and sensory properties of different brands of sesame pastes. *Journal of Oleo Science*. 2018; 67(10): 1291-1298. DOI: https://doi.org/10.5650/jos.ess18109
28. Tomruk D., Devseren E., İlter I., Akyıl S., Koç M, Et Al. Rheological And Sensorial Properties Of Sesame Paste Blends Prepared With Different Sugar Sources. *Gida/The Journal of FOOD*. 2018; 43(1). DOI: https://doi.org/10.15237/gida.gd17091
29. Saatchi A., Kiani H., Labbafi M. Stabilization activity of a new protein–carbohydrate complex in sesame paste: Rheology, microstructure, and particle size analysis. *Journal of the Science of Food and Agriculture.* 2022; 102(12): 5523-5530. DOI: https://doi.org/10.1002/jsfa.11907
30. Acevedo D., Montero P. M., Marrugo Y. A. Caracterización reológica de pastas untuosas artesanal y tecnificada de ajonjolí (Sesamum indicum) cultivado en zambrano-bolívar (Colombia). *Información tecnológica*. 2014; 25(4): 73-78. DOI: https://doi.org/10.4067/s0718-07642014000400010
31. Alaouie Z., AlKhatib A., Khachfe H. M. A quantitative assessment of the microbiological quality of lebanese tahini (sesame paste). *International Journal on Advances in Life Sciences.* 2018; 10(3-4): 127-137.
32. Ramírez, M. J. B., Romero, J. M. V. Características fisicoquímicas y colorimétricas de licores de cacao obtenidos de los clones TCS 06, FEAR 5 Y FSV 41. @ limentech, Ciencia y Tecnología Alimentaria. 2019; 17(1): 40-59.
33. Pablo, R. F., Elevina, P., Romel, G. Características químicas y fisicoquímicas del licor de cacao alcalinizado con: carbonato, bicarbonato e hidróxido de sodio. Evaluation of the chemical and physicochemical characteristics of the cocoa liquor alkalinized with: carbonate, bicarbonate and hydroxide of sodium. Alimentos hoy; Revista de la Asociación Colombiana de Ciencia y Tecnología de Alimentos. 2009; 18(18)
34. AOAC. Manual de Métodos de la AOAC International, 20ª edición, 2021. https://www.aoac.org/: https://www.aoac.org/. 2021
35. ICONTEC, Norma Técnica Colombiana para Productos de molinería, Pastas alimenticias, Bogotá D.C. 2014
36. ICONTEC. Norma Tecnica colombiana para Miel de Abejas, Bogotá D.C. 2023
37. ICONTEC. GTC 293. Análisis sensorial. Metodología. Guía general para la realización de pruebas hedónicas con consumidores en un área controlada. Bogotá D.C. 2018
38. Sanja O, Naira M, Spaho N, Jasmina T, Akagić A, Džafić A. Effects of production and ingredients on tahini halvah quality. *Journal of Food Science and Engineering.* 2015; 5(3):122-129. DOI: http://dx.doi.org/10.17265/2159-5828/2015.03.003

39. Barrera O, Llanos G. Factores que determinan las propiedades fisicoquímicas de la miel de abejas: Revisión Sistemática de Literatura. *Revista Mutis*. 2023; 13(1):1-28. DOI: http://dx.doi.org/10.21789/22561498.1851
40. Jin, L., Guo, Q., Zhang, M., Xu, Y. T., Liu, H. M., Ma, Y. X, et al . Effects of non-lipid components in roasted sesame seed on physicochemical properties of sesame paste. Lwt. 2022; 165:113745. DOI: http://dx.doi.org/10.1016/j.lwt.2022.113745
41. Tounsi, L., Kchaou, H., Chaker, F., Bredai, S., Kechaou, N. Effect of adding carob molasses on physical and nutritional quality parameters of sesame paste. *Journal of food science and technology*. 2019; 56(3):1502-1509. DOI: http://dx.doi.org/10.1007/s13197-019-03640-w
42. Ali, H. S., Badr, A. N., Alsulami, T., Shehata, M. G., Youssef, M. M. Quality Attributes of Sesame Butter (Tahini) Fortified with Lyophilized Powder of Edible Mushroom (Agaricus blazei). 2022; Foods, 11(22):3691. DOI: http://dx.doi.org/10.3390/foods11223691
43. Usda (U.s. Department Of Agriculture. Agricultural Research Service). 2019. Seeds, sesame butter, tahini, from roasted and toasted kernels (most common type). https://fdc.nal.usda.gov/fdc-app.html#/food-details/170189/nutrients Retrieved: January 2023
44. Arab, R., Casal, S., Pinho, T., Cruz, R., Freidja, M. L., Lorenzo, et al. Effects of seed roasting temperature on sesame oil fatty acid composition, lignan, sterol and tocopherol contents, oxidative stability and antioxidant potential for food applications. *Molecules.* 2022; 27(14): 4508. DOI:
45. Deng, L. Z., Sutar, P. P., Mujumdar, A. S., Tao, Y., Pan, Z., Liu, Y. H., et al. Thermal decontamination technologies for microorganisms and mycotoxins in low-moisture foods. Annual Review of Food *Science and Technology.* 2021; 12(1):287-305. DOI: http://dx.doi.org/10.1146/annurev-food-062220-112934
46. Osaili, T. M., Al-Nabulsi, A. A., Aljaafreh, T. F. Use of gamma radiation for inactivating Salmonella spp., Escherichia coli O157: H7 and Listeria monocytogenes in tahini halva. *International journal of food microbiology.* 2018; 278:20-25. DOI: http://dx.doi.org/10.1016/j.ijfoodmicro.2018.04.029
47. Kilci, Z., Çetin, R. U. Determination of Chemical and Microbiological Quality in Commercial Tahini Halva Samples. *Turkish Journal of Agriculture-Food Science and Technology.* 2022; 10:2982-2987. DOI: http://dx.doi.org/10.24925/turjaf.v10isp2.2982-2987.5684
48. Szpinak, V., Ganz, M., Yaron, S. Factors affecting the thermal resistance of Salmonella Typhimurium in tahini. *Food Research International*. 2022; 155:111088. DOI: http://dx.doi.org/10.1016/j.foodres.2022.111088
49. Olaimat, A. N., Osaili, T. M., Al-Holy, M. A., Al-Nabulsi, A. A., Obaid, R. S., Alaboudi, A. R, et al. Microbial safety of oily, low water activity food products: A review. *Food Microbiology.* 2020; 92:103571. DOI: http://dx.doi.org/10.1016/j.fm.2020.103571
50. Kiani, H., Saatchi, A., Haghshenas, M., Jaafari, N., Labbafi, M. The Effect of Milling Process and Particle Size Distribution on the Rheological Properties and Structure of Sesame Paste. *Iranian Journal of Biosystems Engineering.* 2019; 50(3): 695-703. DOI:
51. Acevedo, D., Marrugo, Y., Montero, P. Evaluación de las propiedades reológicas de pastas de ajonjolí artesanal y tecnificada. Revista U.D.C.A *Actualidad & Divulgación Científica.* 2013; 16(1):245-251. DOI: http://dx.doi.org/10.31910/rudca.v16.n1.2013.880
52. Khaji, F., E Mousavi, Z., Kiani, H., Razavi, S. H. The investigation of probiotics viability, physicochemical and rheological properties of a probiotic dessert based on sesame paste (Tahini). *Journal of Food and Bioprocess Engineering.* 2021; 4(2):105-111.
53. Zhao, Y., Li, Y., Liu, Q., Chen, Q., Sun, F., Kong, B. Investigating the rheological properties and 3D printability of tomato-starch paste with different levels of xanthan gum. *International Journal of Biological Macromolecules.* 2024; 257:128430. DOI: http://dx.doi.org/10.1016/j.ijbiomac.2023.128430
54. Velásquez-Barreto, F. F., Velezmoro, C. Propiedades reológicas y viscoelásticas de almidones de tubérculos andinos. *Scientia Agropecuaria.* 2018; 9(2):189-197. DOI: http://dx.doi.org/10.17268/sci.agropecu.2018.02.03
55. Daubert, C. R., Foegeding, E. A. (2010).

Rheological principles for food analysis (pp. 503-516). Springer New York, USA.

56. Nolan, V. C., Harrison, J., Cox, J. A. Dissecting the antimicrobial composition of honey. *Antibiotics*. 2019; 8(4):251. DOI: http://dx.doi.org/10.3390/antibiotics8040251
57. Jafar M. M., Enayat-Allah N., Abdolkhalegh G., Tandis K. Rheological behavior of different phases of grape molasses after storage: Effect of concentration and temperature. *Journal of Food Processing and Preservation.* 2019; 10.1111/jfpp.14013, 43, 8. DOI: http://dx.doi.org/10.1111/jfpp.14013
58. Tafere, D. A. Chemical composition and uses of Honey: A Review. *Journal of Food Science and Nutrition Research.* 2021; 4(3):194-201. DOI:http://dx.doi.org/10.26502/jfsnr.2642-11000072
59. Akbulut, M., Saricoban, C., Ozcan, M. M. Determination of rheological behavior, emulsion stability, color, and sensory of sesame pastes (tahin) blended with pine honey. *Food and Bioprocess Technology.* 2012; 5(5):1832-1839. 1832—1839 DOI:http://dx.doi.org/10.1007/s11947-011-0668-6
60. Altay, F., Altay, I. Tribology of pekmez (grape molasses)-tahin (sesame paste) *mixtures.* Gıda, 2018; 43(4):582-590. DOI: http://dx.doi.org/10.15237/gida.gd18026