A novel mayonnaise-type dressing added with avocado pulp and oil as health ingredients processed with ultrasound

Rosa Isela Guzmán-Gerónimo a, Rosa Carmina Ayala-Tirado b, Remedios Mendoza-López c, Yolanda Cocotle-Ronzón d and María Del Socorro Herrera-Meza e

aLaboratorio de Innovación de Alimentos, Instituto de Ciencias Básicas, Universidad Veracruzana, Xalapa, México; bCentro de Investigación y Desarrollo de Alimentos, Universidad Veracruzana, Xalapa, México; cInstituto de Química Aplicada, Universidad Veracruzana, Xalapa, México; dFacultad de Ciencias Químicas, Universidad Veracruzana, Zona Universitaria, Xalapa, México; eInstituto de Investigaciones Psicológicas, Universidad Veracruzana, Xalapa, México

ABSTRACT

In this study, avocado pulp and oil were added to mayonnaise type-dressing to produce a healthy and microbiologically safe product with improved sensory properties. First, oil avocado was obtained by solvent-free ultrasonic-assisted extraction and centrifugation. The mayonnaise type-dressing was formulated with avocado pulp and oil and then treated with ultrasound. Chemical and sensory qualities were determined in the oil. Microbiological quality, color and sensory analysis were carried out in the mayonnaise type-dressing along a storage period under refrigeration. The avocado oil yield was 64% with an outstanding emerald green color. The avocado oil quality agreed with Mexican Official Standards. Oleic, palmitic, palmitoleic and linoleic acids were found to be the major fatty acids in avocado oil. The mayonnaise-type dressing showed a reduction of the microbial load without the need for thermal pasteurization, and the green color was stable during storage. Color, odor and flavor were sensorially evaluated as “like much.”

RESUMEN

En el presente estudio, la pulpa y aceite de aguacate se usaron para elaborar un aderezo tipo mayonesa, resultando en un producto saludable y microbiológicamente seguro con propiedades sensoriales mejoradas. El aceite de aguacate se obtuvo mediante extracción asistida por ultrasonido y centrifugación sin solventes. El aderezo tipo mayonesa se formuló con pulpa y aceite de aguacate, y fue tratado con ultrasonido. En el aceite se determinó la calidad química y sensorial. Se encontró que los ácidos oleico, palmitico, palmitoleico y linoleico son los principales ácidos grasos del aceite de aguacate. La calidad microbiológica, sensorial y el color se evaluaron en el aderezo tipo mayonesa durante el almacenamiento en refrigeración. El rendimiento de aceite de aguacate fue del 64% y posee un color verde esmeralda. La calidad del aceite de aguacate coincidió con la normatividad mexicana. El aderezo tipo mayonesa mostró una reducción de la carga microbiana sin necesidad de pasteurización, así como el color verde del aderezo tipo mayonesa fue estable durante el almacenamiento. El color, olor y sabor fueron evaluados sensorialmente como “me gusta mucho.”

1. Introduction

Nowadays, there is a growing interest in food products developed from avocado (Restrepo et al., 2012). One of the potential commercial products is mayonnaise type-dressing, where avocado pulp provides vitamins A, C, E, B1, B2 and B6, as well as minerals like potassium, magnesium, phosphorus and calcium, together with monounsaturated fatty acids. Avocado oil is also rich in oleic acid, antioxidants, and phytosterols (Flores et al., 2019). Among the biological properties of avocado, a reduction of total cholesterol, LDL cholesterol and plasma triglycerides has been reported by other authors (Carvajal-Zarrabal et al., 2014). In addition, a recent report showed that consumption of avocado pulp improved cardiovascular and autonomic recovery after exercise in humans (Sousa et al., 2020). Given the above, in this research avocado pulp and oil were considered as bioactive ingredients for the development of a new mayonnaise type-dressing. An important consideration in product development is formulation. According to the Official Mexican Standard NMX-F-341-S-1979 a mayonnaise type-dressing is defined as a food product used to flavor other foods and should not contain less than 50% of mayonnaise or the corresponding amount of edible vegetable oils and egg yolk in any form and may contain other ingredients and food additives Mexican Norm (NMX), 1979). The vegetable oil content should not be less than 33% of the total weight, and egg content should not be less than 4%. Additional flavor will be given by vinegar, sugar, salt, and spices. All of the above was considered in the development of the product described in the present study (Moustafa, 1995). It is known that avocado-based products represent several technological challenges, such as enzymatic browning, lipid oxidation and pigment degradation, which influence the resulting color and flavor. Traditional thermal treatments are widely used in the food industry because they guarantee safe products (Pasha et al., 2014); however, when processing avocados they may oxidize lipids and affect the color. Therefore, alternative processing techniques, such as microwave, high pressure, and pulsed light, combined with food...
additives have been used to preserve the quality of avocado products (Aguiló-Aguayo et al., 2014; Guzmán et al., 2002; López-Malo et al., 1998). The food industry has explored the application of alternative technologies to preserve the nutritional and sensory qualities, as well as the microbial stability of avocado products (FAO: 2004). Ultrasound is a low cost, non-conventional technology that is also environmentally friendly (Gallo et al., 2018), since it requires less energy to process products such as mayonnaise and dressings, where cavitation produced by acoustic waves generates the emulsion (Chemat et al., 2011).

Other reports point out that ultrasound represents an alternative green technology in the extraction of avocado oil, where the mechanical effects of ultrasound create a greater disruption of the fruit cellular structure, enhancing oil extraction (Clodoveo et al., 2013; Sicaire et al., 2016). Given the above, in the present study we explored the potential application of ultrasound in the processing of avocados. The aim of the present work was to evaluate the physicochemical properties and microbiological quality of a mayonnaise type-dressing containing pulp and avocado oil processed with ultrasound.

2. Materials and methods

2.1. Samples

Avocados (Hass variety) with 16% ethereal extract were purchased at a local market in Xalapa, Veracruz, Mexico. Fruits were selected according to size, uniformity of color, with a good general appearance and no physical defects. The rest of the ingredients used in the formulation were bought at a local market in Xalapa city.

2.2. Extraction of avocado oil

The conditions for avocado oil extraction with ultrasound were established in the first part of the present work. For this purpose, 80 g of avocado mash was placed into a 100 mL glass beaker, then the ultrasound probe (13 mm) was submerged to a depth of 25 mm into the mash, and the ultrasound processing was carried out at a frequency of 20 kHz and 750 W (Ultrasonic processors with temperature controller, Cole-Palmer Instrumental Company, VCX-750, USA 80%, 30 min). The sample temperature was controlled at 40°C. Afterwards, the processed mash was centrifuged at 8228 g for 20 and 40 min at 40°C. The oil was collected and 0.03% of vitamin E was added as antioxidant, in accordance with Mexican Official Standards.

2.3. Mayonnaise type-dressing preparation

The mayonnaise type-dressing containing ground avocado pulp (29%) and oil (36.9%) was prepared with salt (1.45%), sugar (2.9%), lemon juice (9%), vinegar (0.74%), mustard (1.16%), whole egg (17.4%), xanthan gum (0.35%), vitamin E (0.02%) and spices (1.08%). The ingredients were mixed using an ultrasonic homogenizer (Cole-Palmer Instrumental Company, VCX-750, USA) at a frequency of 20 kHz and a potency of 750 W at 60% for 10 min. EDTA was added to the mix. Later, the mayonnaise type-dressing was transferred to a glass jar previously pre-sterilized until analysis.

The pH value of the sample was 4. Avocado mayonnaise type-dressing was stored during 15 days at 4°C ±1°C According to the Mexican Food Equivalent System (Pérez-Lizaur et al., 2014), which establishes daily recommendations for food products, the suggested portion size of avocado mayonnaise type-dressing is 5 g. The nutritional value of this portion is: proteins (0.1 g), lipids (2.1 g), carbohydrates (0.3 g), vitamin A (1.1 μg), vitamin C (0.2 mg), folic acid (0.1 μg), vitamin E (1 mg), potassium (0.6 mg), sugars (0.2 g), sodium (29.8 mg), calcium (0.4 mg), selenium (0.2 μg), cholesterol (3.2 mg), saturated fat (0.2 g), polyunsaturated fat (0.3 g), monounsaturated fat (1.4 g), energy (Kcal 19.5).

2.4. Chemical analysis

Avocado oil was characterized according to the Official Mexican Standard NMX-F-052-SCFI-2008 Fats and Oils/avocado oil (Mexican Norm (NMX), 2008). The contents of free fatty acids (as oleic acid), % moisture, % volatiles, color, relative density at 25°C (water), peroxide index (meq/kg), % insoluble matter, % unsaponifiable matter, refraction index, iodine index (cgl2/g) and saponification index (mg KOH/g) were tested. The mayonnaise type-dressing was analyzed for total acidity as acetic acid (%) and pH, according to the Official Mexican Standard NMX-F-341-S-1979 for mayonnaise dressing.

2.5. Fatty acid profile analysis

Fatty acids were esterified according to the technique proposed by Egan et al. (1981) using 14% BF3 in methanol. The analysis of fatty acid profile was made with a gas chromatograph (Agilent Technologies, model 6890N, Net Work GC system), coupled to a mass spectrometer (Agilent Technologies model 5975 inert XL) and equipped with DB-5 column (Agilent Technologies) of 60 m × 0.25 mm × 0.25 μm. The temperature of the injector was 250°C (Split ratio of 50:1). A temperature program of 150°C was used, holding 5 min with a gradient of 30°C/min until reaching 210°C followed by a temperature increase to 213°C with a gradient of 1°C/min. The carrier gas was helium (1 ml/min). Mass spectra were obtained by ionization by electron impact at 70 eV. Identification of individual compounds was made with the database HP Chemstation-NIST 05 mass spectral search program, version 2.0d. A mix of standards was used (Sigma-Aldrich, catalogue number 18,920-1AMP).

2.6. Color analysis

L*, a* and b* colorimetric parameters in avocado oil and mayonnaise type-dressing were determined with a colorimeter (Hunter Associate Laboratory, Inc., Reston, Virginia, USA). Hue angle (h) was calculated using arc tan (b*/a*)+180 and chroma (C*) was calculated using [a*² + b*²]1/2. All determinations were performed in triplicate.

2.7. Microbiological analysis

In order to determine the microbial quality of the mayonnaise dressing, the contents of aerobic mesophiles, coliforms, mold, yeasts, Salmonella and E. coli were evaluated.
according to the Official Mexican Standard NMX-F-341S-1979. Results were reported as colony formation units (CFU).

2.8. Sensory analysis

Avocado oil and mayonnaise type-dressing were sensory evaluated using a bench top test, with 20 judges and a hedonic test on a scale of 7 points, from "like much" to "dislike much" (Pedrero & Pangborn, 1989). The parameters evaluated were odor, flavor and color.

2.9. Statistical analysis

Data were analyzed with a linear analysis of variance (ANOVA) and a Tukey mean comparison test (p ≤ .05). The Minitab 16 software was used to perform the analyses.

3. Results and discussion

3.1. Avocado oil analysis

Several aspects should be considered in the development of an avocado mayonnaise type-dressing. A key ingredient is the oil, as it greatly contributes to the sensory properties of the final product. In the present work, we started with an oil yield of 64%, which corresponded to a treatment time of 30 min and amplitude of 80%, centrifugation at 40°C and 8000 rpm for 40 min. Similar data were reported for avocado oil extracted with high-frequency ultrasound (Martínez-Padilla et al., 2018). In the present study low-frequency ultrasound was used; however, 35% of the oil was obtained after 20 min of centrifugation. It was also noted that the conditions of the centrifugation process affected the oil yield. Ultrasound facilitates oil extraction due to cavitation forces, where the implosion and explosion of bubbles in the medium during ultrasound processing produce a physical disruption of the cell wall of the oil-containing cells (Xuan et al., 2017).

Temperature is another important factor (Yang et al., 2020). Previous studies reported that avocado oil should be obtained from a high-quality fruit at temperatures lower than 50°C without the use of solvents, and these conditions were also considered in the present study.

In the same way, the extraction process improves as the ripeness of the fruits is more advanced. Ortiz et al. (2003) mention that this fruit is considered ripe when the minimum content of lipids in the pulp is of 15%. In the present study, avocados were ripe with a 16% ethereal extract.

It is well known that high values of free fatty acids indicate that the oil is easily susceptible to oxidation. Regarding the quality parameters, avocado oil showed lower values of free fatty acids (0.39) than those established by the Mexican standard (Table 1), which indicates a high quality of the product. It agrees with previous data reported in extra virgin avocado oil obtained by ultrasound-assisted aqueous extraction (Xuan et al., 2017). The values of moisture and volatile matter (%), relative density, peroxide value, percentage of insoluble matter, saponification index and smoke point were also within the reference values of the Mexican standards. The peroxide value is used to measure the oxidative state of oils. Previous studies indicate that avocado oil obtained from puree previously sonicated at high frequency had a peroxide value higher than 10 meqO₂/kg, which is higher than the one established by the Mexican standard (Martínez-Padilla et al., 2018). A low free fatty acids content and peroxide value indicate the high quality and stability of avocado oil.

Regarding saponification index, avocado oil produced in this study showed a high value of 190.1 mg KOH/g, which is a measure of oil purity. Smoke point was of 204°C and according to the literature (Wong et al., 2010), a virgin avocado oil has a value of approximately ≥200°C (Table 1).

On the other hand, the color of avocado oil was emerald green. Previous reports indicate that cold-pressed avocado oil from Hass cultivar has an emerald green color (Qin & Zhong, 2016). In addition, the colorimetric parameter a* showed negative values, indicating a green color (Table 2), which is within the reported values for cold pressed avocado oil, ~5 to ~7 (Wong et al., 2008). Given the above, we can observe that the avocado oil obtained of avocado mash processed with ultrasound retained the color characteristics of the fresh pulp. In the sensory analysis, the color and flavor of avocado oil were evaluated as “like much” and “like moderately,” respectively.

The fatty acid profile of avocado oil (Table 3) showed a high content of oleic acid (70%), which is a desirable quality due to its high oxidative stability and health benefits in the prevention of coronary heart disease (FDA, 2018). Similar data has been reported in avocado oil obtained by ultrasound-assisted aqueous extraction (Xuan et al., 2017).

---

### Table 1. Chemical characterization of avocado oil extracted using solvent-free ultrasonic-assisted extraction.

| Parameters                      | Mexican normativity | Avocado oil values |
|---------------------------------|---------------------|--------------------|
| Free fatty acid %               |                     |                    |
| (as oleic acid)                 | 1.5                 | 0.39 ± 0.0        |
| Moisture and volatile matter, % | 0.5                 | 0.12 ± 0.0        |
| Relative density at 25 °C        | 0.91                | 0.92 ± 0.0        |
| Peroxide value, meq O₂/kg        | 10.0                | 9.96 ± 0.4        |
| Insoluble impurities, %         | 0.2                 | 0.09 ± 0.01       |
| Saponification value mg KOH/g   | 177                 | 198 ± 0.17        |
| Smoke point                      | 204 °C              | 206 ± 1 °C        |

The results were expressed as a mean value with standard deviation.

### Table 2. Parameters color of avocado oil.

| Parameters | Avocado oil |
|------------|-------------|
| L*         | 9.19 ± 1.4  |
| a*         | -3.64 ± 1.1 |
| b*         | 12.08 ± 1.3 |
| H*         | 106 ± 4     |
| C*         | 12.6 ± 3.2  |

The results were expressed as a mean value with standard deviation.

### Table 3. Fatty acid profile of avocado oil obtained by using and solvent-free ultrasonic-assisted extraction.

| Fatty acid         | (%)         |
|--------------------|-------------|
| Palmitic acid (16:0)| 15.6 ± 1.4  |
| Palmitoleic acid (16:1)| 7.3 ± 0.6  |
| Searic acid (18:0)  | 1.11 ± 1.1  |
| Oleic acid (18:1)   | 70.8 ± 0.8  |
| Linoleic acid (18:2)| 5.19 ± 0.34 |
| Linolenic acid (18:3)| -            |

The results were expressed as a mean value with standard deviation.
On the other hand, linolenic acid was not detected, it has been reported that avocado oil contains from 0% to 2% of this acid. Trans fatty acids were not detected. Data obtained for the fatty acid profile was in accordance with those established by the American Oil Chemists Society (AOCs) for avocado oil. Given the above, we can say that avocado oil extracted by application of ultrasound technology can be used as a healthy ingredient. Several studies have shown that foods rich in oleic acid, such as avocado oil, may have health benefits, and recent evidence suggests that the biological properties of avocado oil include anti-inflammatory activity (Carvajal-Zarrabal et al., 2014).

### 3.2. Physicochemical and microbial analysis of mayonnaise type-dressing

The second part of this research was to elaborate a novel avocado mayonnaise type-dressing processed with ultrasound. It was recently reported that two main approaches should be considered in the production of healthy mayonnaise, which are the use of fat replacers, or/and the addition of functional ingredients. In the present work, avocado pulp and oil were added to mayonnaise type-dressing as bioactive ingredients. Mayonnaise traditionally contains 70–80%, oil; however, there is a current market trend to lower oil contents, and therefore the percentage of oil in the avocado mayonnaise type-dressing was of 35.9%. In addition, the calorie content of the avocado mayonnaise type-dressing was similar to that a light commercial mayonnaise product currently sold in Mexico (Procuraduría Federal del Consumidor [PROFECO], 2021). On the other hand, the nutritional value of this novel dressing is improved by the contents of vitamin A, C, E and folic acid.

As mentioned above, product development with avocado pulp is a technological challenge due to its high lipid and chlorophyll contents, as well as the potential for enzymatic browning. A low pH is an important factor that influences the color and microbial load of mayonnaise-type dressings and, in the case of products derived from avocado, should be kept under 5 in order to inactivate polyphenoloxidase (Guzmán et al., 2002), an enzyme that causes enzymatic browning of avocado pulp. The avocado mayonnaise type-dressing had a pH value of 4 and 0.5% acidity, which are within the range established by the Official Mexican Standard NMX-F-102.

Another well-known parameter in food development is color since the first contact with the consumer is usually visual. In the case of avocado products, the green color must be preserved. In the present research, the a* parameter showed values between −14.8 and −11.0, it was superior at the acceptability region reported by López-Malo et al. (1998) (below a* = > −47) in avocado puree. Hue angles of the mayonnaise type-dressing were in the range of 108–104° during storage, placing it in the green region on the color space (Figure 1). The chroma of the color, which measures how much color is present, showed a reduction at the end of the storage period (Table 4). In addition, the lightness (L*) of avocado mayonnaise type-dressing, which has an impact on the perceived appearance of the product, showed a value of 71.8 at the start of the storage period. A previous work about a mayonnaise formulated with xanthan gum at 0.5% reported a decrease of L* values at higher amplitudes (Kumar et al., 2021).

In the present study, the ultrasound amplitude was of 80%. In addition, a desirable opaque color has been reported in mayonnaise processed with ultrasound, and it was attributed to pyrolytic degradation of the interfacial layer due to the ultrasound processing (Tiwari et al., 2010).

In order to obtain an acceptable microbial stability, the pH has to be kept at approximately 4.0. The microbial analysis shows that the mayonnaise type-dressing at days 0 and 15 complied with the limits established in the Mexican standards regarding mold, yeast, and aerobic mesophiles, while E. coli and Salmonella were negative (Table 5).

In addition, acidity is also an important factor in the formulation of mayonnaise-type dressing, which influences microbial load, particularly in the inhibition of bacterial and yeast growth (Levine & Fellers, 1940). Vinegar was used as an ingredient in the formulation of avocado mayonnaise type-dressing due to its antibacterial action on E. coli and Salmonella (Entani et al., 1998), which is attributed to the hurdle effect of the organic acids present in the vinegar (Zhu et al., 2012). In addition, a recent report showed that ultrasound treatment significantly decreased the microbial load in low-fat mayonnaise without any chemical preservative (Tavakoli et al., 2021).

**Figure 1.** Color and hue angle of mayonnaise type-dressing added with avocado pulp and oil.

**Table 4.** Parameters color of mayonnaise type-dressing added with pulp and oil avocado.

| Parameters | Day | 1 | 15 |
|------------|-----|---|----|
| L*         |     | 71.8±1 | 69.3±2 |
| a*         |     | −14.8±1 | −11.0±1 |
| b*         |     | 46±2   | 43.8±2 |
| h°         |     | 108±2  | 104±3 |
| C*         |     | 48.3±2 | 45.1±2 |

The results were expressed as a mean value with standard deviation. The data with different letters are significantly different (p < .05)
It has also been reported that ultrasound improves the inactivation of microorganisms, which is attributed to a physical process called acoustic cavitation.

Sensory analysis is another important consideration in the development of a food product, avocado-based mayonnaise was evaluated as “like much” regarding color, odor and flavor, while texture was evaluated as “like moderately.” It has been reported that sensory characteristics closest to traditional mayonnaise have been obtained by adding food gums such as xanthan gums at 0.1–5% (Bortnowska & Makiewicz, 2006; Kumar et al., 2021). In the present work, xanthan gum was used at 0.35% to prepare a low-fat mayonnaise type-dressing and that avocado mayonnaise type-dressing exhibited no phase separation during storage by visual evaluation (data not shown).

It has been reported that xanthan gum is used in mayonnaise manufacture as stabilizer and emulsifier, it increases the viscosity and prevents the phase separation (Depree & Savage, 2001; Naji et al., 2012). Generally, as the oil content of the dressing increases, less xanthan gum is employed for stabilization. Kumar et al. (2021) reported that xanthan gum at 0.5% had a positive impact on the stability of emulsion of mayonnaise processed with ultrasound.

On the other hand, the effect of ultrasonication in the emulsion stability of mayonnaise has been reported in previous studies, for example, a recent study showed that sonication of low-fat mayonnaise at 20 kHz and 750 W increased its stability (Tavakoli et al., 2021). In addition, Kumar et al. (2021) showed that ultrasonically processed mayonnaise at 20 kHz and 500 W had higher storage stability than a market sample.

It is noteworthy that the development of a healthy product with avocado pulp and oil accepted by consumers is possible. This suggests a potential application of ultrasound technology in the development of novel and healthy food products.

4. Conclusions

Ultrasound is a potential technology to develop mayonnaise type-dressing added with healthy ingredients such as pulp and oil avocado, resulting in a product with sensory qualities accepted by consumers, as well as a safe product during storage under refrigeration. This is the first report to produce novel mayonnaise type-dressing added with avocado pulp and oil.

Acknowledgements

Rosa Carmina Ayala Tirado is grateful to the graduate program in Food Science from CONACyT by the scholarship granted (2016).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The work was supported by the Consejo Nacional de Ciencia y Tecnología (712289).

Author contributions

Investigation, R.I.G.G., R.C.A.T.; Methodology, R.I.G.G., R.C.A.T., R.L.M., Y.C. R.; Formal analysis, R.I.G.G., R.C.A.T., R.L.M.; Data curation, R.I.G.G., R.C.A.T.; Conceptualization, R.I.G.G.; Supervision, R.I.G.G., R.L.M., Y.C.R., M.S.H. M.; Writing – original draft, R.I.G.G, M.S.H.M.; Writing – review and editing, R.I.G.G., M.S.H.M.; Project administration, R.I.G.G.

ORCID

Rosa Isela Guzmán-Gerónimo http://orcid.org/0000-0001-6112-5075
Rosa Carmina Ayala-Tirado http://orcid.org/0000-0002-4704-2879
Remedios Mendoza-López http://orcid.org/0000-0002-6441-4558
Yolanda Cocotie-Ronzón http://orcid.org/0000-0003-0435-2495
María Del Socorro Herrera-Meza http://orcid.org/0000-0003-0838-470X

References

Aguiló-Aguayo, A., Oms-Oliu, G., Martín-Belloso, M., & Soliva-Fortuny, R. (2014). Impact of pulsed light treatments on quality characteristics and oxidative stability of fresh-cut avocado. LWT - Food Science and Technology, 59(1), 320–326. https://doi.org/10.1016/j.lwt.2014.04.049
Bi, X., Hemar, Y., Balaban, M. O., & Liao, K. (2013). The effect of ultrasound on particle size, color, viscosity and polyphenol oxidase activity of diluted avocado puree. Ultrasound Sonochemistry, 27, 567–575. https://doi.org/10.1016/j.ultrasonch.2015.04.011
Bortnowska, G., & Makiewicz, A. (2006). Technological utility of guar gum and xanthan for production of low-fat inulin-enriched mayonnaise. Acta Scientiarum Polonorum Technologia Alimentaria, 5(2), 135–146.
Carvajal-Zarrabal, O., Nolasco-Hipólito, C., Aguilar-Uscanga, M. G., Melo-Santiesteban, G., Hayward-Jones, P. M., & Barradas-Dermitz, D. M. (2014). Avocado oil supplementation modifies cardiovascular risk profile markers in a rat model of sucrose-induced metabolic changes. Disease Markers, 38, 36425. https://doi.org/10.1155/2014/386425
Chemat, F., Zill-E-Huma, & Kamran, M. K. (2011). Applications of ultrasound in food technology, processing, preservation and extraction. Ultrasound Sonochemistry, 18(4), 813–835. https://doi.org/10.1016/j.ultrasonch.2010.11.023
Clodoveo, M. L., Durante, V., La Notte, D., Punzi, R., & Gambacorta, G. (2013). Ultrasound-Assisted extraction of virgin olive oil to improve the process efficiency. European Journal of Lipid Science and Technology, 115(9), 1062–1069. https://doi.org/10.1002/ejlt.201200426
Depree, J. A., & Savage, G. P. (2001). Physical and flavour stability of mayonnaise. Trends in Food Science & Technology, 12(2001), 157–163. https://doi.org/10.1016/S0924-2244(01)00079-6
Egan, H., Kirk, R., & Sawyer, R. (1981). Chemical Analysis of food. Churchill Livingston (8a ed.). Pearson.
Entani, E., Asai, M., Tsujihata, S., Tsukamoto, Y., & Ohta, M. (1998). Antibacterial action of vinegar against food-borne pathogenic bacteria including Escherichia coli O157:H7. Journal of Food Protection, 61(8), 953–959. https://doi.org/10.4315/0362-028x-61.8.953
FAO. (2004). Avocado postharvest operation. Food and Agriculture Organization of the United Nations. Lidia Dorantes, Lidia Parada, Alicia Ortiz.
FDA. (2018). Completes review of qualified health claim petition for oleic acid and the risk of coronary heart disease. https://www.fda.gov/food/csfa-constituent-updates/fda-completes-review-qualified-health-claim-petition-oleic-acid-and-risk-coronary-heart-disease

De la G. R. AZUAGUA. 1979. Estudio del efecto de la congelación sobre la calidad de la aceituna. Materiales de la Universidad de Granada. Serie Biología. 2: 1-45.
Flores, M., Saravia, C., Vergara, C. E., Avila, F., Valdés, H., & Ortiz-Viedma, J. (2019). Avocado oil: Characteristics, properties, and applications. *Molecules*, 24(11), 2172. https://doi.org/10.3390/molecules24112172

Gallo, M., Ferrara, L., & Navigli, D. (2018). Application of ultrasound in food science and technology: A perspective. *Foods*, 7(10), 164. https://doi.org/10.3390/foods7100164

Green, H. S., & Wang, S. C. (2020). First report on quality and purity evaluations of avocado oil sold in the US. *Food Control*, 16, 107328. https://doi.org/10.1016/j.foodcont.2020.107328

Guzmán, G. R., Dorantes, A. L., Hernández, U. H., Hernández, S. H., Ortiz, A., & Mora, E. R. (2002). Effect of zinc and copper chloride on the color of avocado puree heated with microwaves. *Innovative Food Science and Emerging Technologies*, 3(1), 47–53. https://doi.org/10.1016/S1466-854X(01)00053-4

Kha, T. C., Nguyen, M. H., Roach, P. D., & Statthopoulos, C. E. (2015). Ultrasound-Assisted aqueous extraction of oil and carotenoids from microwave-dried Gac (Momordica cochininchensis Spreng) *Ani*. *International Journal of Food Engineering*, 11(4), 479–492. https://doi.org/10.1515/ijfe-2014-0200

Kumar, Y., Roy, S., Devra, A., Dhiman, A., & Prabhakar, P. K. (2021). Ultrasoundonation of mayonnaise formulated with xanthan and guar gums: Rheological modeling, effects on optical properties and emulsion stability. *LWT-Food Science and Technology*, 149, 111632. https://doi.org/10.1016/j.lwt.2021.111632

Levine, A. S., & Fellers, C. R. (1940). Inhibiting effect of acetic acid upon microorganisms in the presence of sodium chloride and sucrose. *Journal of Bacteriology*, 40(2), 255–269. https://doi.org/10.1128/JB.40.2.255-269.1940

López-Malo, A., Palou, E., Barbosa-Canovas, G. V., Welter-Chanes, J., & Swanson, B. G. (1998). Polyphenoloxidase activity and color changes during storage of high hydrostatic pressure treated avocado puree. *Food Research International*, 31(8), 549–556. https://doi.org/10.1016/S0963-9966(99)00028-9

Martínez-Padilla, L. P., Franke, L., Xu, X. Q., & Juliano, P. (2018). Improved extraction of avocado oil by application of sono-physical processes. *Ultrasound Sonochemistry*, 40(Pt A), 720–726. https://doi.org/10.1016/j.jsuc.2017.08.008

Mexican Norm (NMX) (1979). NMX-F-341-S-1979. Aderezo con mayonesa. Normas mexicanas. Dirección general de normas.

Mexican Norm (NMX) (2008). Aceites y grasas- aceite de aguacate-especificaciones en cuanto a contenido de ácidos grasos libres. Normas mexicanas. Dirección general de normas.

Mostafa, M. (1995). Salad Oil, mayonnaise, and salad dressings in D. R. Erickson (Ed.), *Practical handbook of soybean processing and utilization* (pp. 314–338). AOCS Press. https://doi.org/10.1007/8978-9-353513-63-9.00022-X

Naji, S., Razavi, S. M. A., & Karazhiyan, H. (2012). Effect of thermal treatments on functional properties of cress seed (Lepidium sativum) and xanthan gums. *Food Hydrocolloids*, 28(1), 75–81. https://doi.org/10.1016/j.foodhyd.2011.11.012

Ortiz, M. A., Dorantes, L., Galindo, J., & Guzmán, R. I. (2003). Effect of different extraction methods on fatty acids, volatile compounds and physical and chemical properties of avocado (Persea americana Mill) oil. *Journal Agricultural Food Chemistry*, 51(8), 2216–2221. https://doi.org/10.1021/jf0207934

Pasha, I., Saeed, F. M., Sultan, T., Khan, M. R., & Rohi, R. (2014). Recent developments in minimal processing: A tool to retain nutritional quality of food. *Critical Reviews in Food Science and Nutrition*, 54(3), 340–351. https://doi.org/10.1080/10408398.2011.585254

Pedrozo, F. D., & Pangborn, R. (1989). Evaluación Sensorial de los Alimentos (1st ed.). Alhambra Mexicana S.A. de C.V.

Pérez-Lizaur, A. B., Palacios-González, B., Castro-Becerra, A. L., & Flores-Galicia, I. (2014). *Sistema Mexicano de Alimentos Equivalentes* (4 ed.). FNS.

Procuraduría Federal del Consumidor. (2021). https://www.profeco.gob.mx/revista/RevistaDelConsumidor_527.Enero_2021.pdf

Qin, X., & Zhong J.-A. (2010). Review of extraction techniques for avocado oil. *Journal of Oleo Science*, 65(11), 881–888.

Restrepo, D. A. M., Londoño-Londoño, J., González-Alvarez, D. J., Benavides, P. Y., & Cardona, B. L. S. (2012). Comparación del aceite de aguacate variedad Hass cultivado en Colombia, obte- nido por fluidos supercrticos y métodos convencionales: Una perspectiva desde la calidad. *Revista Lavadorista de Investigación*, 9(2), 151–161.

Sicai, A.-G., Vian, M. A., Fine, F., Carre, P., Tostain, S., & Chemat, F. (2016). Ultrasound induced green solvent extraction of oil from oleaginous seeds. *Ultrasonics Sonochemistry*, 31, 319–329. https://doi.org/10.1016/j.jsuc.2016.10.011

Sousa, F. H., Valenti, V. E., Pereira, L. C., Bueno, R. R., Prates, S., Akimoto, A. N., Kaviain, M., Garner, D. M., Amaral, J. A. T., & Abreu, L. C. (2020). Avocado (Persea americana) pulp improves cardi- ovascular and autonomic recovery following submaximal running: A crossover, randomized, double-blind and placebo-controlled trial. *Scientific Reports*, 10(1), 1–12. https://doi.org/10.1038/s41598-020-67577-3

Tavakoli, K., Karami, M., Bahramian, S., & Enamifar, A. (2021). Production of low fat mayonnaise without preservatives: Using the ultrasonic process and investigating of microbial and physicochemical properties of the resultant product. *Food Sciences and Nutrition*, 9(5), 1–10. https://doi.org/10.1002/fsn3.2227

Tiwari, B. K., Muthukumarappan, K., O'Donnell, C. P., & Cullen, P. J. (2010). Rheological properties of sonicated guan, xanthan and pectin dispersions. *International Journal of Food Properties*, 13(2), 223–233. https://doi.org/10.1080/10942910802317610

Wong, M., Ashton, O., Requejo-Jackman, C., McGhie, T., White, A., Eyres, L., Sherpa, N., & Woolf, A. (2008). Avocado oil: The color of quality in the color quality of fresh and processed foods (328) (1st ed.). ACS. https://doi.org/10.1021/bk-2008-0983.ch024

Wong, M., Requejo-Jackman, C., & Woolf, A. (2010). What is unre- fined, extra virgin cold pressed avocado oil? *Inform*, 27(4), 189–260.

Xuan, T., Hean, C., Hamzah, H., & Ghazali, H. (2017). Optimization of ultrasound-assisted aqueous extraction to produce virgin avocado oil with low free fatty acids. *Journal of Food Process Engineering*, 41(2), 1–9. https://doi.org/10.1111/1jfe.12656

Yang, S., Fullerton, C., Hallett, I., Oh, H. E., Woolf, A. B., & Wong, M. (2020). Effect of fruit maturity on microstructural changes and oil yield during cold-pressed oil extraction of ‘Hass’ avocado. *Journal of the American Oil Chemists’ Society*, 97(7), 779–788. https://doi.org/10.1002/aocs.12362

Zhu, J., Li, J., & Chen, J. (2012). Survival of Salmonella in home-style mayonnaise and acid solutions as affected by acidulant type and preservatives. *Journal of Food Protection*, 75(3), 465–471. PMID: 22410219. https://doi.org/10.4315/0362-028X.JFP-11-373