Original Article
Food Science and Technology
ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
DOI: https://doi.org/10.5327/fst.00410

Effects of different dehydration methods on the color, nutritional, and functional characteristics of okara

Bruna Méris Grigoleto da SILVEIRA[1*], Rubén BERMEJO-POZA[2], Jesús de la Fuente VÁZQUEZ[2], Thiago Gentil RAMIRES[3], Elisa Helena Giglio PONSANO[1]

Abstract

Okara, a by-product of soybean (*Glycine max* L.) processing, is rich in nutrients, including proteins, fibers, lipids, minerals, and bioactive compounds. However, its high moisture content (70–80%) makes it susceptible to spoilage. This study investigated the effects of four drying methods (using equipment such as a conventional electric oven, a microwave oven, a forced air convection oven, and a homemade dehydrator) on the color, microbiological safety, nutritional composition, percentage yield, and technological properties of dehydrated okaras. The following analyses were performed: yield, microbiological (*Escherichia coli* and *Salmonella* sp.,) characteristics, proximate composition, fatty acid profile, La*b* color, water absorption index (WAI), oil absorption index (OAI), and emulsifying activity (EA). No pathogenic microorganisms were detected. Microwave drying resulted in the lowest yield (4.2%) but produced the highest protein concentration (38.4%), making it ideal for enhancing the nutritional value of food products. Conventional oven and microwave drying showed the highest EA (47.1% and 46.5%, respectively), indicating their suitability for emulsified product applications. Conversely, homemade dehydrator was suitable for gel and bakery product formulations (WAI, 6.2%). Additionally, homemade dehydrator caused minimal color changes (L, 78.4; a*, 4.5; b*, 25.0), making it preferable for applications in which the color retention in okara-enriched food products is crucial.

Keywords: soybean by-products; drying; functional properties; nutritional composition; okara.

Practical Application: Drying okaras improves shelf life, storage, transportation, and marketing.

1 INTRODUCTION

Soybean (*Glycine max* [Merrill] L.) is considered one of the oldest foods in the world and holds significant global interest due to its versatile applications in human and animal nutrition and its economic value in both national and international markets (Hirakuri & Lazzarotto, 2014). Brazil is one of the largest soybean producers globally. According to data from the Companhia Nacional de Abastecimento, the soybean production in Brazil for the 2022/2023 crop year was 154.6 million tons (Brasil, 2023).

Okara is the residue obtained after the extraction of the aqueous fraction generated during the production of soybean hydrosoluble extract (HSE), also called "soymilk," and tofu (Ostermann-Porcel et al., 2017). A significant amount of okara is produced annually worldwide, but only a small fraction is fully utilized (Li et al., 2019). Okaras have a high nutritional value owing to their protein, fiber, lipid, and mineral contents and bioactive components (Kamble et al., 2019; Kamble & Rani, 2020; Vong & Liu, 2016). However, its high moisture content (70–80%) makes it prone to deterioration, which complicates its use as an ingredient in food product development (Guimarães et al., 2020). As a result, it is often discarded, leading to nutrient waste and environmental burden (Vong & Liu, 2016).

Reducing the water activity of foods enhances preservation by decreasing deterioration reactions, such as microbial growth, chemical browning, and enzymatic activity (Dala-Paula et al., 2021a). One of the most effective methods for preserving the integrity of okaras is drying (Guimarães et al., 2018; Pinto & Castro, 2008), as it provides greater convenience for use, improved transport conditions, as well as chemical and microbiological stability during storage (Berghout et al., 2014).

The use of proteins as natural emulsifiers has emerged as an excellent alternative to synthetic stabilizers, in line with the food industry's efforts to reduce ingredients and produce healthier and more sustainable products (Loi et al., 2019; Mozafarpour et al., 2019; Taneja et al., 2015). Plant proteins, such as those found in soybeans, are viable options for food stabilization due to their promising physicochemical and technological properties (Chen et al., 2019; Mozafarpour et al., 2019).

However, thermal treatments aimed at preserving okaras for further utilization may affect the nutritional and technological

Received: 11 Oct., 2024.
Accepted: 31 Oct., 2024.
[1]*Universidade Estadual Paulista "Júlio de Mesquita Filho", Faculty of Veterinary Medicine, Department of Production and Animal Health, Araçatuba, SP, Brazil.*
[2]*Complutense University of Madrid, Faculty of Veterinary Medicine, Department of Animal Production, Madrid, Spain.*
[3]*Universidade Tecnológica Federal do Paraná, Apucarana, PR, Brazil.*
*Corresponding author: brunagrigoleto@gmail.com
Conflict of interest: nothing to declare.
Funding: CAPES/DS.

properties of the soybean proteins, which requires investigation prior to their use as an ingredient in food formulations. Hence, the purpose of this study was to evaluate the effects of different okara drying methods on the yield and microbiological (*Escherichia coli* and *Salmonella sp.*), nutritional (proximate composition and fatty acids), technological (water absorption index [WAI], oil absorption index [OAI], and emulsifying activity [EA]), and color characteristics of the dehydrated products.

2 MATERIALS AND METHODS

2.1 Raw material, experimental design, and treatments

Raw okara was sourced from the production of soy HSE by the Central Municipal School Feeding Program of Birigui (SP, Brazil) and contained (on a wet basis) 81.04% moisture, 6.53% proteins, 0.97% lipids, and 0.73% minerals, as determined by the methodologies outlined by the Association of Official Analytical Chemists (AOAC) (Horwitz & Latimer, 2006). The okara was stored at -20°C and thawed at a controlled temperature of 10°C for the analysis and application of the drying treatments.

For the definition of the treatments, the most accessible commercial equipment were selected: a conventional electric oven, a microwave oven, a forced air convection oven, and a homemade dehydrator. Various dehydration tests were conducted on okaras using each equipment, with variations in time, temperature, and stirring frequency, until the final product achieved uniform granulation, ease of handling, and minimal visual color change. Thus, the four treatments were defined and repeated four times each, maintaining a 1-cm bed height for all methods (completely randomized design). The treatment procedures were as follows:

- T1: Dehydration in a conventional electric oven

  Wet okaras (500 g) were spread in trays lined with culinary silicone mats and placed in a conventional electric oven at 150°C for 50 min, with stirring at 25 min.

- T2: Dehydration in a microwave oven

  Wet okaras (500 g) were placed in a glass plate previously sanitized with 70% alcohol and submitted to microwave drying for 40 min (at 70 W), with stirring every 10 min.

- T3: Dehydration in a forced air convection oven

  Wet okaras (500 g) were spread in trays lined with culinary silicone mats and dried in a forced air oven at 105°C for 4 h, with stirring every 1 h and 30 min.

- T4: Dehydration in a homemade dehydrator

  Wet okaras (500 g) were spread on trays lined with culinary silicone mats and dried in a homemade dehydrator at 70°C for 2 h, with stirring every 30 min.

2.2 Dehydration yield

The dehydration yield for all treatments was determined by the following formula (Equation 1):

$$(\text{dried okara weight})/(\text{wet okara weight}) \times 100 \quad (1)$$

2.3 Microbiological analysis

The presence of *E. coli* and *Salmonella* sp. was investigated in the dried samples following the methodologies specified by the Normative Instruction No. 161/2022 for "texturized vegetable proteins with or without added ingredients" (Brasil, 2022), using the procedures described by the American Public Health Association (APHA) (Downes & Ito, 2001). Analyses were performed in duplicate.

2.4 Proximate composition determination

The total protein, lipid, ash, and fiber contents of the dried samples were determined using AOAC methodologies (Horwitz & Latimer, 2006). The moisture content was measured using an infrared moisture analyzer (Marte Científica; Model ID50 – AUTO Mode). Metabolizable carbohydrates (CHOAVLDF) were calculated by difference. All analyses were performed in duplicate.

2.5 Technological properties

The technological properties of the dried samples were evaluated following the methodology of Seibel and Beléia (2009), with adaptations:

- WAI: One gram of the sample was mixed with 10 mL of distilled water at room temperature in pre-weighed centrifuge tubes. The tubes were continuously stirred for 30 min using a Titer Plate Shaker (Barnstead International, Dubuque, USA) at 75 rpm and room temperature, and then centrifuged at 1000 g for 10 min using a 5500 A centrifuge (Revan Instrumentos Científicos, Campinas, Brazil). The supernatant was discarded, and the wet sediment was weighed. The WAI was calculated as wet sediment weight/dry matter weight, expressed in g of water absorbed/g of dry matter;
- OAI: The same technique used for WAI was applied, substituting distilled water with commercial soybean oil. The OAI was calculated as wet sediment weight/dry matter weight, expressed in g of oil absorbed/g of dry matter;
- EA: An amount of 0.5 g of the sample, 5 mL of distilled water, and 5 mL of commercial soybean oil were mixed and emulsified in a 100-mL beaker using a TE 102 Turratec stirrer (Tecnal, Piracicaba, Brazil) for 1 min at 18,000 rpm. The suspension was centrifuged in graduated tubes at 400 g for 10 min using a 5500 A centrifuge (Revan Instrumentos Científicos, Campinas, Brazil), and the volume of the emulsified layer and the total volume were measured to determine EA (expressed as a percentage) using the Equation 2:

$$\text{EA} = (\text{volume of the emulsified layer} \times 100)/\text{total tube volume} \quad (2)$$

2.6 Color determination

The color of the dried samples was evaluated instrumentally in the CIELa*b* color space using a MiniScan XE Plus

colorimeter (Hunter Lab, Reston, USA), where a* values ranged from green to red, b* values ranged from blue to yellow, and L values ranged from 0 (black) to 100 (white).

2.7 Fatty acid analysis

Fatty acid methyl esters (FAMEs) were prepared using the methods described by Cabezas et al. (2023) and Lee et al. (2012). First, a solution of 10% acetyl chloride mixed in methanol and toluene was heated at 70°C for 120 min. Afterward, 6% potassium carbonate and toluene were added, and the mixture was centrifuged at 1,500 g for 5 min. The organic layers containing the FAMEs were separated into individual vials and stored at -20°C for subsequent analysis. The FAMEs were analyzed by gas chromatography with flame ionization detection (Perkin-Elmer Autosystem-1:A, Massachusetts, USA) using an Omegawax™ 320 capillary column (30 m × 0.32 mm i.d., 0.25 µm film thickness) with polyethylene glycol as the stationary phase (Supelco, Bellefonte, USA). The samples were injected (1.0 µL) in split mode with a split ratio of 1:50 and helium as the carrier gas at a constant flow of 9 psig. Detector and injector temperatures were set at 255 and 250°C, respectively. The oven temperature program was 150°C for 1 min, increasing at 6°C/min to 190°C, then increasing at 1°C/min to 210°C, and holding for 23 min. Individual FAMEs were identified by comparing their retention times with those of a standard FAME mixture. The results were expressed as percentages. The fatty acid analysis was conducted at the BIANDOCARNE research group laboratory, in the Department of Animal Production of the Faculty of Veterinary Medicine of the Complutense University of Madrid.

2.8 Statistical analysis

Preliminary tests for normality and homogeneity of variance were conducted using the Shapiro-Wilk and Bartlett tests, respectively. Data were analyzed by one-way analysis of variance, with treatment as a fixed effect, and Tukey's test was used for mean comparisons ($p < 0.05$). Statistical analyses for proximate composition, functional properties, color, and yield were performed using the R software (R Core Team, 2022). Fatty acid data were analyzed using GraphPad Prism v. 9.1 (GraphPad Software, La Jolla, CA, USA).

3 RESULTS AND DISCUSSION

3.1 Microbiological analysis, proximate composition, yield, and color

E. coli and *Salmonella* sp. were not detected, indicating that the dried okaras were microbiologically safe. The proximate composition of the dried okara samples and treatment yields are presented in Table 1.

The microwave drying treatment (T2) was the most effective for moisture removal, resulting in the lowest yield, along with T3. Although the electric oven treatment (T1) provided a product with higher moisture content compared to T2, it produced a visually better product with easier handling. The moisture contents reported in the literature are also quite variable due to the different drying methods, times, temperatures, and equipment used, which complicates comparisons (Cantuária et al., 2008; Ostermann-Porcel et al., 2017).

The microwave-dried okara also exhibited the highest protein concentration, making it an excellent candidate for use in food preparation such as breads, cookies, and pasta, thereby increasing the nutritional value through protein enrichment. The varying lipid contents found in the analysis can be attributed to the extent of lipid extraction by the solvent (ethyl ether), which might have been influenced by structural changes induced by the drying methods applied.

The fiber content remained unchanged across the different drying methods, likely due to the extensive digestion used in its determination, which eliminates interfering substances and provides a more consistent result. If okaras dried by any of the tested treatments are incorporated into food formulations as functional ingredients, it could contribute to products labeled as a "source of fiber" or "high in fiber," provided they meet the required levels of 3 g/100 g and 6 g/100 g, respectively (Brasil, 2012). Studies evaluating the effects of microwave drying on okaras have reported products with 34.6% protein, 3.4% ash, and 21.1% carbohydrates (Ostermann-Porcel et al., 2017), and 8.9% lipids (Guimarães et al., 2020).

Table 1. Proximate composition (mean ± standard deviation) and treatment yields of okara samples dried by different methods (on a wet basis).

Component %	Treatments				*p*-value
	T1	T2	T3	T4	
Temperature	150°C	–	105°C	70°C	
Power	–	70 W	–	–	
Time	50 min	40 min	4 h	2 h	
Moisture	19.31 ± 5.081^{a}	4.29 ± 0.365^{c}	12.69 ± 1.258^{b}	25.75 ± 11.249^{a}	0.010
Proteins	28.70 ± 1.698^{b}	38.42 ± 3.658^{a}	32.73 ± 1.226^{ab}	27.36 ± 4.644^{b}	0.001
Lipids	4.93 ± 0.313^{c}	9.96 ± 1.560^{b}	12.71 ± 0.379^{a}	11.41 ± 1.388^{ab}	0.001
Ash	3.08 ± 0.278^{c}	3.98 ± 0.064^{a}	3.52 ± 0.058^{b}	2.99 ± 0.686^{c}	0.014
Fibers	12.88 ± 1.811	15.19 ± 0.944	14.72 ± 1.563	13.33 ± 2.971	0.332
CHOAVLDF[1]	21.58 ± 3.763^{b}	30.06 ± 3.199^{a}	23.31 ± 1.134^{b}	24.08 ± 6.598^{b}	0.056
Yield (%)	25.91 ± 2.424^{a}	17.02 ± 1.480^{b}	17.85 ± 0.585^{b}	26.33 ± 4.779^{a}	0.001

T1: conventional electric oven; T2: microwave oven; T3: forced air convection oven; T4: homemade dehydrator; [1]Metabolizable carbohydrates calculated by difference; [a, b, c]Means within a row followed by different letters differ significantly according to Tukey's test at a 5% significance level.

3.2 Technological properties

The technological properties of the okara samples dried by different methods are presented in Table 2.

As expected, the okaras dried in the home dehydrator (T4) exhibited the highest WAI. This is likely because the lower temperature used in this treatment better preserved the structural conformation of the proteins, as this property is affected by thermal denaturation (Dala-Paula et al., 2021c). Based on this, T4 is the most suitable when the goal is to use okaras as an ingredient in food products in which gel formation is desired, such as in pastes and jellies, meatballs, sausages, and burgers; in baked goods such as bread, cakes, and cookies; and in the new niche of plant-based foods (Bastos, 2021; Devide et al., 2019; Leite Júnior et al., 2013; Yoshida et al., 2014).

The WAI is one of the hydration properties of proteins and is related to the availability of the hydrophilic groups of amino acids to bind with water molecules and form gels (Priulli, 2020). However, other okara components, such as fibers and polysaccharides, can also influence this parameter as they also have water-absorbing capabilities (Ahmed et al., 2018; Mateos-Aparicio et al., 2010).

The highest OAIs were found in the okara samples obtained from treatments T3 and T4, suggesting their potential use in baking products due to the influence that lipids can have on the flavor, texture, and shelf life of the products (Priulli, 2020).

The EA measures the capacity of proteins to form emulsions by adsorbing at the oil/water interface (Lin et al., 2020). This property is related to the solubility of proteins and, therefore, to the presence of hydrophobic and hydrophilic groups in their constituent amino acids (Chandra & Samsher, 2013). The results from this study indicate that the drying methods T1 (electric oven) and T2 (microwave) are the best for obtaining dried okaras suitable for preparing emulsified products, such as dressings and mayonnaise.

3.3 Color determination

The color parameters of the dried okara samples using different methods are presented in Table 3.

The okaras obtained by T4 exhibited the lowest a* and b* values and the highest L value (although not differing from T2), indicating better color preservation, likely due to the low drying temperature and air circulation, which are characteristic features of the homemade dehydrator.

The color changes observed in T1 may be associated with the Maillard reaction, a non-enzymatic reaction that is temperature-dependent and occurs between reducing sugars and amino groups of amino acids or proteins, resulting in the formation of brown pigments (melanoidins) (Muliterno et al., 2017). Given the presence of proteins and reducing sugars in okaras and the temperatures used for drying, the occurrence of this reaction was expected, potentially compromising hydrophilic amino acids (lysine, arginine, and histidine) while preserving hydrophobic amino acids (Dala-Paula et al., 2021c). This reaction can impact the nutritional properties of foods, especially the essential amino acid lysine. Therefore, the preservation of color can be associated with the preservation of nutritional and functional values (Dala-Paula et al., 2021c). Generally, a 10°C increase in the temperature doubles or triples the rate of the Maillard reaction, meaning that in order to obtain a product with less browning, drying temperatures should remain between 50 and 70°C (Perussello et al., 2012), as used for T4 in the dehydrator.

3.4 Determination of saturated and unsaturated fatty acids

The total amount of polyunsaturated fatty acids was not affected by the drying treatments of okaras (Table 4), which represents a favorable result, since soybeans are a source of omega-6

Table 2. Technological properties of okara samples dried by different methods.

Technological properties	Treatments				*p*-value
	T1	T2	T3	T4	
Temperature	150°C	–	105°C	70°C	
Power	–	70 W	–	–	
Time	50 min	40 min	4 h	2 h	
WAI (g)	4.36 ± 0.198^{b}	4.44 ± 0.220^{b}	5.06 ± 0.295^{b}	6.25 ± 0.870^{a}	0.001
OAI (g)	1.77 ± 0.042^{b}	1.72 ± 0.026^{b}	1.86 ± 0.051^{a}	1.95 ± 0.210^{a}	0.057
EA (%)	47.10 ± 2.192^{a}	46.57 ± 3.719^{a}	31.70 ± 2.439^{b}	11.09 ± 0.141^{c}	0.001

T1: conventional electric oven; T2: microwave oven; T3: forced air convection oven; T4: home dehydrator; WAI: water absorption index; OAI: oil absorption index; EA: emulsifying activity; [a, b, c]Means within a row followed by different letters differ significantly according to Tukey's test at a 5% significance level.

Table 3. Instrumental color parameters of okara samples dried by different methods.

Parameters	Treatments				*p*-value
	T1	T2	T3	T4	
Temperature	150°C	–	105°C	70°C	
Power	–	70 W	–	–	
Time	50 min	40 min	4 h	2 h	
Lightness (L)	73.06 ± 1.702^{c}	76.28 ± 1.348^{ab}	75.63 ± 1.224^{bc}	78.41 ± 0.681^{a}	0.001
Redness (a*)	7.48 ± 0.866^{a}	6.55 ± 0.544^{a}	6.90 ± 0.447^{a}	4.56 ± 0.262^{b}	0.001
Yellowness (b*)	29.45 ± 1.763^{a}	29.72 ± 0.993^{a}	31.03 ± 0.515^{a}	25.04 ± 0.830^{b}	0.001

T1: conventional electric oven; T2: microwave oven; T3: forced air convection oven; T4: homemade dehydrator; [a, b, c]Means followed by different letters in the rows differ from each other, according to Tukey's test, at a 5% significance level.

Table 4. Fatty acid composition of okara samples dried by different methods (on a dry basis).

Fatty acids %	Treatments				*p*-value
	T1	T2	T3	T4	
Temperature	150°C	–	105°C	70°C	
Power	–	70 W	–	–	
Time	50 min	40 min	4 h	2 h	
Saturated	17.92 [b]	18.50 [ab]	18.87 [ab]	21.29 [a]	0.004
Monounsaturated	24.76 [b]	25.18 [ab]	25.01 [ab]	26.87 [a]	0.002
Polyunsaturated	57.65	56.15	53.70	50.16	0.008

T1: conventional electric oven; T2: microwave oven; T3: forced air convection oven; T4: homemade dehydrator; [a, b]Means followed by different letters in the rows differ from each other according to Tukey's test, at a 5% significance level.

polyunsaturated fatty acids that are essential for humans and need to be consumed in adequate amounts through diet (Dala-Paula et al., 2021b; Izar et al., 2021). Thus, the use of dehydrated okaras as an ingredient in food products may represent a nutritional enrichment due to their increased protein content and the presence of important polyunsaturated fatty acids, beneficial to health.

4 CONCLUSION

All the drying methods for okaras provided microbiologically safe products. The microwave treatment resulted in a lower yield but produced an okara with a higher protein concentration, making it suitable for the nutritional enrichment of food formulations. Drying using a conventional oven or a microwave oven produced okaras more suitable for the development of emulsified products, whereas homemade dehydrator drying was the most appropriate for the preparation of gels and baked goods. Additionally, drying with a homemade dehydrator caused minimal color changes in the product, making it suitable for applications where the original color of food formulations needs to be preserved.

REFERENCES

Ahmed, H., Satheesh, H. N., & Dibaba, K. (2018). Functional, physical and sensory properties of cookies prepared from okara, red teff and wheat flours. *Croatian Journal of Food and Science and Technology*, *10*(1), 23-32. https://doi.org/10.17508/CJFST.2018.10.1.05

Bastos, A. (2021). *Pesquisa viabiliza o uso de subproduto da soja como ingrediente para alimentos plant-based*. Embrapa. Retrieved from https://www.embrapa.br/busca-de-noticias/-/noticia/65266022/pesquisa-viabiliza-uso-de-subproduto-da-soja-como-ingrediente-para-alimentos-plant-based

Berghout, J. A. M., Boom, R. M., & Van Der Goot, A. J. (2014). The potential of aqueous fractionation of lupin seeds for high-protein foods. *Food Chemistry*, *15*(159), 64-70. https://doi.org/10.1016/j.foodchem.2014.02.166

Brasil (2012). Agência Nacional de Vigilância Sanitária. Dispõe sobre o Regulamento Técnico sobre Informação Nutricional Complementar (RDC n. 54, de 12 de novembro de 2012). *Diário Oficial da República Federativa do Brasil*.

Brasil (2022). Agência Nacional de Vigilância Sanitária. Estabelece os padrões microbiológicos dos alimentos (Instrução Normativa n. 161, de 6 de julho de 2022). *Diário Oficial da República Federativa do Brasil*.

Brasil (2023). Companhia Nacional de Abastecimento. *Acompanhamento da safra brasileira de grãos: safra 2022/23 (versão 9)*. Retrieved from https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos

Cabezas, A., De la Fuente, J., Dıaz, M. T., Bermejo-Poza, R., del Olmo, D. M., Mateos, J., Llanes, N., & Jimeno, V. (2023). Effect of the inclusion of rumen-protected amino acids in the diet of growing beef cattle on animal performance and meat quality. *Frontiers in Animal Science*, *4*, 1269775. https://doi.org/10.3389/fanim.2023.1269775

Cantuária, C. C., Ribeiro, S. C. A., Ribeiro, C. F. A., Pakr, K. J., & Araúdo, A. F. (2008). Perfil sensorial de pães de forma enriquecidos com okara. *Revista Brasileira de Produtos Agroindustriais*, *10*(2), 111-120. https://doi.org/10.15871/1517-8595/rbpa.v10n2p111-120

Chandra, S., & Samsher, L. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, *8*, 4849-4852. https://doi.org/10.5897/AJAR2013.6905

Chen, M., Lu, J., Liu, F., Nsor-Atindana, J., Xu, F., Goff, H. D., Ma, J., & Zhong, F. (2019). Study on the emulsifying stability and interfacial adsorption of pea proteins. *Food Hydrocolloids*, *88*, 247-255. https://doi.org/10.1016/j.foodhyd.2018.09.003

Dala-Paula, M. B., Gozzi, P. W., Kringel, H. D., Peloso, F. E., & Custódio, B. F. (2021a). Água. In: M. B. Dala-Paula (Ed.), *Química & bioquímica de alimentos* (pp. 15-16). Universidade Federal de Alfenas.

Dala-Paula, M. B., Gozzi, P. W., Kringel, H. D., Peloso, F. E., & Custódio, B. F. (2021b). Lipídeos. In: M. B. Dala-Paula (Ed.), *Química & bioquímica de alimentos* (pp. 69-106). Universidade Federal de Alfenas.

Dala-Paula, M. B., Gozzi, P. W., Kringel, H. D., Peloso, F. E., & Custódio, B. F. (2021c). Reações de escurecimento não enzimático em alimentos. In: M. B. Dala-Paula (Ed.), *Química & bioquímica de alimentos* (pp. 228-235). Universidade Federal de Alfenas.

Devide, C. J., Pedrão, R. M., Seibel, F. N., & Assis, R. Q. (2019). Incorporação de okara na formulação de hambúrguer de frango: Influências nas características físicas e químicas. *Revista Brasileira de Tecnologia Agroindustrial*, *13*(1), 2752-2766. https://doi.org/10.3895/rbta.v13n1.6952

Downes, F. P., & Ito, K. (2001). *Compendium of methods for the microbiological examination of foods* (4ª ed.). American Public Health Association.

Guimarães, R. M., Ida, E. I., Falcão, H. G., Rezende, T. A. M., Silva, J. S., Alves, C. C. F., Silva, M. A. P., & Egea, M. B. (2020). Evaluating technological quality of okara flours obtained by different drying processes. *LWT - Food Science and Technology*, *123*, 1-8. https://doi.org/10.1016/j.lwt.2020.109062

Guimarães, R. M., Oliveira, D. E. C., Resende, O., Silva, J. S., Rezende, T. A. M., & Egea, M. B. (2018). Thermodynamic properties and drying kinetics of 'okara'. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *22*(6), 418-423. https://doi.org/10.1590/1807-1929/agriambi.v22n6p418-423

Hirakuri, M. H., & Lazzarotto, J. J. (2014). *O agronegócio da soja nos contextos mundial e brasileiro*. Embrapa Soja. Retrieved from https://www.embrapa.br/busca-de-publicacoes/-/publicacao/990000/o-agronegocio-da-soja-nos-contextos-mundial-e-brasileiro

Horwitz, W., & Latimer, G. W. (2006). *Official methods of analysis of AOAC International* (18ª ed.). AOAC International.

Izar, M. C. O., Lottenberg, A. M., Giraldez, V. Z. R., Santos Filho, R. D. S., Machado, R. M., Bertolami, A., Assad, M. H. V., Saraiva, J. F. K., Faludi, A. A., Moreira, A. S. B., Geloneze, B., Magnoni, C. D., Scherr, C., Amaral, C. K., Araújo, D. B., Cintra, D. E. C., Nakandakare, E. R., ... & Machado, V. A. (2021). Posicionamento sobre o consumo de gorduras e saúde cardiovascular. *Arquivos Brasileiros de Cardiologia*, *116*(1), 160-212. https://doi.org/10.36660/abc.20201340

Kamble, D. B., & Rani, S. (2020). Bioactive components, in vitro digestibility, microstructure and application of soybean residue (okara): a review. *Legume Science*, *2*(1), e32. https://doi.org/10.1002/leg3.32

Kamble, D. B., Singh, R., Rani, S., & Pratap, D. (2019). Physicochemical properties, in vitro digestibility and structural attributes of okara-enriched functional pasta. *Journal of Food Processing and Preservation*, *43*(12), 1-9. https://doi.org/10.1111/jfpp.14232

Leite Júnior, B. R. C. L., Oliveira, P. M., Castro, R. L. E., Lamas, J. M. N., & Martins, E. M. F. (2013). Desenvolvimento e caracterização de doce de goiaba cremoso adicionado de farinha de okara. *Revista Vértices*, *15*(2), 25-37. https://doi.org/10.5935/1809-2667.20130016

Lee, M. R. F., Tweed, J. K. S., Kim, E. J., & Scollan, N. D. (2012). Beef, chicken and lamb fatty acid analysis: a simplified direct bimethylation procedure using freeze-dried material. *Meat Science*, *92*(4), 863-866.

Li, B., Yang, W., Nie, Y., Kang, F. H. Goff, D., & Cui S. W. (2019). Effect of steam explosion on dietary fiber, polysaccharide, protein and physicochemical properties of okara. *Food Hydrocolloids*, *94*, 48-56. https://doi.org/10.1016/j.foodhyd.2019.02.042

Lin, N., Liu, B., Liu, Z., & Qi, T. (2020). Effects of different drying methods on the structures and functional properties of phosphorylated Antarctic krill protein. *Journal of Food Science*, *85*(11), 3690-3699. https:// doi.org/10.1111/1750-3841.15503

Loi, C. C., Eyres, G. T., & Birch, E. J. (2019). Effect of milk protein composition on physicochemical properties, creaming stability and volatile profile of a protein-stabilised oil-in-water emulsion. *Food Research International*, *120*, 83-91. https://doi.org/10.1016/j.foodres.2019.02.026

Mateos-Aparicio, I., Redondo-Cuenca, A., & Villanueva-Suárez, M. J. (2010). Isolation and characterisation of cell wall polysaccharides from legume by-products: Okara (soymilk residue), pea pod and broad bean pod. *Food Chemistry*, *122*(1), 339-345. https://doi.org/10.1016/j.foodchem.2010.02.042

Mozafarpour, R., Koocheki, A., Milani, E., & Varidi, M. (2019). Extruded soy protein as a novel emulsifier: Structure, interfacial activity and emulsifying property. *Food Hydrocolloids*, *93*, 361-373. https://doi.org/10.1016/j.foodhyd.2019.02.036

Muliterno, M. M., Rodrigues, D., Lima, F. S., Ida, E. I., & Kurozawa, L. E. (2017). Conversion/degradation of isoflavones and color alterations during the drying of okara. *LWT - Food Science and Technology*, *75*, 512-519. https://doi.org/10.1016/j.lwt.2016.09.031

Ostermann-Porcel, M. V., Rinaldoni, A. N., Rodriguez-Furlán, L. T., & Mercedes, E C. (2017). Quality assessment of dried okara as a source of production of gluten-free flour. *Journal of the Science of Food and Agriculture*, *97*(9), 2934-2941. https://doi.org/10.1002/jsfa.8131

Perussello, C. A., Mariani, V. C., & Amarante, Á. C. C. (2012). Numerical and experimental analysis of the heat and mass transfer during okara drying. *Applied Thermal Engineering*, *48*, 325-331. https://doi.org/10.1016/j.applthermaleng.2012.04.025

Pinto, D. D. J., & Castro, P. S. (2008). Estudo preliminar da secagem do okara (resíduo do extrato aquoso de soja) para inativação dos fatores antinutricionais e conservação. *Brazilian Journal Food Technology*, *12*, 125-131. Retrieved from http://bjft.ital.sp.gov.br/especiais/especial_2009_2/v12ne_t0246.pdf

Priulli, E. (2020). *Aproveitamento do resíduo do extrato hidrossolúvel de soja (okara) na elaboração de tapioca* (Dissertação de mestrado, Universidade Federal do Tocantins).

R Core Team (2022). *R: a language and environment for statistical computing* [Software]. R Foundation for Statistical Computing. Retrieved from https://www.R-project.org

Seibel, N. F. & Beléia, A. D. P. (2009). Características químicas e funcionalidade tecnológica de ingredientes de soja [Glycine Max (L.) Merrill]: carboidratos e proteínas. *Brazilian Journal of Food Technology*, *12*(2), 113-122. https://doi.org/10.4260/BJFT20093607

Taneja, A., Ye, A., & Singh, H. (2015). Influence of protein concentration on the stability of oil-in-water emulsions formed with aggregated milk proteins during spray drying. *Dairy Science and Technology*, *95*, 279-293. https://doi.org/10.1007/s13594-014-0208-z

Vong, W. C., & Liu, S. Q. (2016). Biovalorisation of okara (soybean residue) for food and nutrition. *Trends in Food Science & Technology*, *52*, 139-147. https://doi.org/10.1016/j.tifs.2016.04.011

Yoshida, B. Y., Pereira, D. G., Castilho, S. P. G., & Seibel, N. F. (2014). Produção e caracterização de cookies contendo farinha de okara. *Alimentos e Nutrição*, *25*(1), 49-54.