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Composition of fatty acids by gas chromatography, physicochemical, sensory quality, and index of quality tapioca lipids enriched with okara

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Abstract

Okara is a by-product of soybeans containing protein, fiber, and fatty acids. However, it is rarely used. This research proposed the use of okara flour in tapioca formulations. It aims to identify the physicochemical and technological aspects of the tapioca-added okara flour and quantify the fatty acid content of the formulations to determine their nutritional lipid quality and evaluate their acceptability. The study compared a standard cassava starch formulation (SF) with four tapioca formulations replaced partially by okara flour in 15% (F15), 30% (F30), 40% (F40), and 50% (F50). The analyses conducted included microbiological, physicochemical, technological composition, fatty acid, and intention to purchase. The addition of okara flour increased lipids, proteins, fibers, moisture, ash, luminosity, reddish and yellowish color, and water and oil absorption indexes. Additionally, okara flour improved the nutritional lipid quality as indicated by the atherogenicity index, thrombogenicity index, hypocholesterolemic/hypercholesterolemic ratio, and polyunsaturated/saturated ratio. These improvements in the nutritional and technological characteristics of the flour mixtures suggest promising potential for the traditional Brazilian tapioca partially replaced with okara flour, as evidenced by the similarity in purchase intention among SF, F15, F30, F40, and F50 formulations, with no statistical differences in purchase intention.

Keywords: okara; by-product; tapioca; lipid quality; tapioca.

Practical Application: Incorporating okara flour into tapioca can improve its nutritional profile, increasing protein, fiber, and beneficial fatty acids, aligning with healthy eating patterns. Technologically, it enhances water retention and texture, adding value to a soy by-product and reducing waste. In addition, it maintains sensory acceptability, ensuring market viability and promoting the development of sustainable and innovative products.

1 INTRODUCTION

Okara is a by-product derived from producing foods such as water-soluble soybean extract (WSE) and tofu. The okara contains many nutrients, such as protein, fiber, and fatty acids. However, this residue has a high moisture content of approximately 70–80%, making it susceptible to deterioration (Vong & Liu, 2016).

Using by-products represents an opportunity to obtain products with added nutritional value (Cavalcanti et al., 2019). However, a large amount of okara produced annually is rarely used globally (Li et al., 2019). One method to preserve the integrity of the okara is by drying, as it removes the moisture present in the wet mass after soy water-soluble extract (Guimarães et al., 2018). Using okara flour, studies have investigated the enrichment of the nutritional value of foods, such as cookies, guava jam, hamburgers, cheese bread, and French bread (Bowles & Demiate, 2006; Leite Junior et al., 2013; Ostermann-Porcel et al., 2017).

The use of flour in bakery products and their technological performance depends on their functional characteristics (Santana et al., 2017). In this context, the technological function of okara flour has previously been associated with characteristics that may be desirable for food products, such as the color of guava jam (Leite Junior et al., 2013) and a higher water absorption capacity in cookies (Ahmed et al., 2018).

In the nutritional aspect, using agri-food by-products can reduce food waste during production and add value to the production of new products. In this context, studies that used okara to replace other ingredients partially demonstrate an increase in ash in nuggets (Echeverria et al., 2022), fiber and fat in guava jam (Leite Junior et al., 2013), as well as protein and fibers in cookies (Ostermann-Porcel et al., 2017). Recently, studies have developed products using okara to increase the vegetal fat source of foods rather than animal fat sources, as okara is a source of unsaturated fat (Echeverria et al., 2022).

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The effects of lipids on human health depend on their fatty acid profile (Cruz & Faria, 2019). The characteristics of the fatty acid profile of the soybean by-product (okara) are poorly studied, especially regarding new products developed with okara flour (Matos et al., 2019). In this context, the assessment of the nutritional quality of lipids, using the calculated indices and proportions, allows a better understanding of the functional health effects of the different fatty acids present in the food. Highlighted are the techniques for fatty acid profile measurement, which allow the obtainment of indices that classify the nutritional quality of the fat in each food. Among the nutritional quality indexes of the diet, there are the atherogenicity index (AI), thrombogenicity index (TI) (Ulbricht & Southgate, 1991), hypocholesterolemic/hypercholesterolemic ratio (h/H) (Santos-Silva et al., 2002), polyunsaturated and saturated fatty acids ratio (P/S) (DHSS, 1984), and omega 6 and omega 3 ratios (ω6/ω3) (Simopoulos, 2006).

The study of consumers' preferences is required to investigate new products. Sensory analysis of foods is fundamental in measuring, analyzing, and interpreting reactions and characteristics of food and materials as consumers perceive them, such as the intention to purchase the product (Lemes et al., 2018).

In this context, this research was carried out to study the use of okara flour in tapioca formulations. It aims to identify the physicochemical and technological changes that okara flour provides to the food and quantify the fatty acid content of the formulations to determine their nutritional lipid quality and evaluate their acceptability. We hypothesize that an industrial soybean by-product can add nutritional value to traditional Brazilian tapioca with satisfactory acceptability.

2 MATERIALS AND METHODS

The raw material used to obtain the okara was composed of soybeans acquired in the trade of Palmas/TO, paying attention to the integrity of the packaging and the expiration date. For manufacturing the okara flour, the National Health Surveillance Agency implemented resolution RDC nº 275 of October 21, 2002, and followed good manufacturing practices (GMP) recommendations (Brasil, 2002).

Soybeans were soaked in water for 12 h to prepare okara flour and then taken for cooking. The grains were washed in running water and crushed in an industrial blender with 10:1 water. Once the WSE was extracted, the excess water was removed from the okara with a cloth strainer, and then the wet okara was homogenized, weighed, and placed in a drying oven at 70°C for 12 h to produce okara flour (Guimarães et al., 2018). The okara flour was crushed in a blender and sieved through an 18-mesh sieve.

Five tapioca formulations were prepared, with a standard sample made with 100% cassava starch (SF) and four tapioca with partial starch replacement with okara flour in 15% (F15), 30% (F30), 40% (F40), and 50% (F50).

To prepare the tapioca, the cassava starch/okara flour mixes were hydrated in 50 mL of water, added with 0.5 g of salt, homogenized by hand, sieved, and placed in a pre-heated 15-cm non-stick frying pan so that its entire surface was filled. With the aid of a polyethylene spoon, the tapioca was shaped so that it was flat and uniform until the tapioca acquired the necessary firmness. It was turned with the help of a spoon to carry out the cooking on both sides. The samples were prepared in the Food Technology Laboratory of the Universidade Federal de Tocantins (UFT) in triplicates, which were then crushed and stored in amber flasks coated with aluminum foil and kept at room temperature in a cool place in the absence of light until the analysis. Furthermore, the okara flour was also separated for subsequent physical–chemical and technological analyses.

2.1 Physicochemical and microbiological analysis

For the analysis of the proximate composition of the elaborated formulations (traditional sample and tapioca enriched with okara), the standards of the Association of Official Analytical Chemists (AOAC, 2000) were adopted.

The moisture analysis was carried out by drying in an oven at 105°C until constant weight, accordant method No. 967.08 (AOAC, 2000). The ashes were determined using the muffle incineration method at 550°C until continual weight, accordant method No. 942.05 (AOAC, 2000). The lipid content was determined by the Soxhlet method, using hexane as the solvent for extraction, accordant method No. 2003.06 (AOAC, 2000). Proteins were quantified using the Kjeldahl method and were estimated using a nitrogen conversion factor of 6.25, accordant method No. 988.05 (AOAC, 2000). The crude fiber content was obtained from the methodology of Van Kamer and Van Ginkel (1952), accordant method No. 958.06. The total carbohydrates or glycosidic fraction was calculated by difference, that is, 100 g of the food less the total sum of the values found for moisture, protein, lipid, fibers, and mineral residue fixed in the integral matter. The carbohydrate levels were calculated using the Equation 1:

Calculation of the carbohydrate by difference:

$$100\ (g) - \text{moisture}\ (g) + \text{lipid}\ (g) + \text{protein}\ (g) + \text{ash}\ (g) + \text{crude fiber}\ (g) \quad (1)$$

The colorimetric analysis was performed using a MINOLTA digital colorimeter, model CR 400, through the analysis of the luminosity (L*), red color and green (a*), and yellow color and blue (b*) coordinates, employing the CIELAB scale. The L* value ranges from 0 (black) to 100 (white). A high L* value indicates a light color, while a low value indicates a dark color. The a* value indicates the position of the color between red and green. Positive values of a* indicate redder tones, while negative values indicate greener tones. Finally, the b* value represents the color position between yellow and blue. Positive values of b* indicate more yellow tones, while negative values indicate bluer tones.

To characterize the technological and functional properties of SF, F15, F30, F40, and F50, in addition to the okara flour (FO), water absorption index (WAI) and oil absorption index (OAI) analyses were carried out according to the methodology developed by Anderson et al. (1969).

As tapioca would undergo sensory analyses, all tapioca formulations were evaluated following the microbiological standard for foods ready to be offered to consumers based on

Brazilian regulation No. 60 of December 23, 2019. This standard was considered the reference for microbial standards for soy- and starch-based products (Brasil, 2019).

2.2 Determination of the lipid profile

The lipids were extracted and determined using the method of Bligh and Dyer (1959). This technique has advantages such as the extraction of all classes of lipids without heating, and the obtained extract can be used in later analyses such as determining fatty acids (Bligh & Dyer, 1959).

The total fatty acid content of tapioca was determined by gas chromatography using a Thermo Fisher CG chromatograph (series 12550060) and a 120 m × 0.25 mm TR-FAME column. Regarding the chromatographic conditions, the injector temperature was 225°C, and the detector temperature was 285°C. The column temperature was initially adjusted to 100°C (isotherm) and maintained at that temperature for 4 min, which was later increased to 240°C at a speed of 3°C/min (AOCS, 2017).

2.3 Nutritional quality indexes

The indexes applied to calculate the nutritional quality of the samples are presented in Table 1.

Low values of IA and IT are desirable as reference values. A higher value is desirable in the ratio h/H. For the ratio P/S, values higher than 0.45 are desirable. In the ratio ω6/ω3, a ratio of 5:1 is desirable.

2.4 Sensory analysis

Acceptance tests were conducted at the Universidade Federal do Tocantins (UFT), with 87 untrained judges randomly selected. The inclusion criteria were individuals who reported liking the tapioca product. The samples were encoded with three-digit numbers containing 30 g of tapioca with the addition of okara and served on plastic plates to each judge in individual booths lit with fluorescent light and accompanied by a glass of mineral water for washing the palate.

The intention to purchase the product was assessed using a 5-point scale, with the extremes 1 = certainly would not buy and 5 = certainly would buy (Dutcosky, 2011).

For conducting sensory tests, this work was approved by the Research Ethics Committee (opinion number 3.147.012).

2.5 Statistical analysis

A completely randomized experimental design was adopted, arranged in a factorial scheme with five types of formulations: a sample of standard tapioca (SF) produced with 100% starch and four formulations of tapioca with okara flour replacing the starch in proportions of 15% (F15), 30% (F30), 40% (F40), and 50% (F50).

The physicochemical, technological, and sensory analysis results were subjected to analysis of variance (ANOVA). The Tukey test at 5% significance was adopted using the SISVAR 5.0 program (Ferreira, 2000).

3 RESULTS AND DISCUSSION

3.1 Proximate composition

Formulations F40 and F50 presented the highest concentrations of lipids (F40: 3.57 ± 0.26; F50: 3.72 ± 0.08) and ash (F40: 1.21 ± 0.02; F50: 1. 21 ± 0.03). The F50 formulation presented the highest concentration of protein (12.40 ± 0.54), crude fiber (3.17 ± 0.26), and kilocalories (241.02 ± 2.12). All formulations presented humidity higher than the standard formulation (29.62 ± 0.75). All values had a p-value lower than 0.05 (Table 2).

The higher moisture content in the okara addition samples may be associated with the increased percentage of fiber due to the increased water retention capacity of the food products (Candia et al., 2014). The higher concentrations of lipids and ash in the F40 and F50 formulations, as well as the higher concentrations of protein in the F50, are related to the composition of the okara, which is around 10–20% lipids (Vong & Liu, 2016), 4% of ash, and 35% of protein (Ostermann-Porcel et al., 2017). While the SF containing only cassava starch has less than 1% of proteins, lipids, fiber, and ash, mainly composed of carbohydrates (70.09%) and moisture (29.62%), as described in Table 2. Proximate composition (g/100g) of okara flour (OF), standard formulation with 100% cassava starchy (SF), and tapioca with partial replacement of okara flour in concentrations of 15, 30, 40, and 50%.

3.2 Colorimetric analysis

The SF presented the highest values of L* (brightness) (99.84 ± 0.54) and b* (blue to yellow) (11.80 ± 0.13), indicating that it is a lighter sample with less yellow pigmentation (Table 3).

Table 1. Indexes of lipid nutritional quality of foods.

Abbreviation	Indexes (Author)	Formula
AI	Atherogenicity indexes (Ulbricht & Southgate, 1991)	[C12:0+(4xC14:0)+C16:0] / (ΣAGMI+Σω6+Σω3)
TI	Thrombogenicity index (Ulbricht & Southgate, 1991)	(C14:0+C16:0+C18:0) / [(0.5xΣAGMI) + (0.5xΣω6 + (3xΣω3) + (Σω3/Σω6)]
h/H	Ratio between hypocholesterolemic fatty acid/hypercholesterolemic fatty acid (Santos-Silva et al., 2002)	[C18:1cis9 + C18:2ω6 + C20:4ω6 + C18:3ω3 + C20:5ω3 + C22:5ω3 + C22:6ω3 / (C14:0 + C16:0)]
P/S	Polyunsaturated fatty acids and saturated fatty acids ratio (DHSS, 1984)	Polyunsaturated fatty acids/ saturated fatty acids
ω6/ω3	Ratio between ω6/ω3 (Simopoulos, 2006)	ω6/ω3

Table 2. Proximate composition of the okara flour (OF), standard formulation with 100% cassava starchy (SF), and tapioca with partial replacement of okara flour in concentrations of 15, 30, 40, and 50%.

Components	Formulation					
	OF	SF	F15	F30	F40	F50
Moisture	5.87 ± 0.33^{e}	29.62 ± 0.75^{c}	37.60 ± 0.81^{b}	38.83 ± 0.27^{ab}	39.80 ± 0.32^{a}	39.66 ± 0.13^{a}
Lipid	9.32 ± 0.39^{e}	0.560 ± 0.03^{d}	1.25 ± 0.16^{c}	2.58 ± 0.36^{b}	3.57 ± 0.26^{a}	3.72 ± 0.08^{a}
Protein	50.07 ± 1.09^{e}	0.20 ± 0.01^{d}	3.77 ± 0.36^{c}	8.58 ± 1.18^{b}	9.99 ± 0.77^{b}	12.40 ± 0.54^{a}
Fiber	17.62 ± 1.62^{e}	0.1 ± 0.08^{d}	1.05 ± 0.10^{c}	2.09 ± 0.53^{b}	2.51 ± 0.27^{ab}	3.17 ± 0.26^{a}
Ash	2.42 ± 0.05^{e}	0.12 ± 0.04^{d}	0.64 ± 0.01^{c}	1.07 ± 0.02^{b}	1.21 ± 0.02^{a}	1.21 ± 0.03^{a}
Carbohydrate	14.7 ± 2.11^{f}	70.09 ± 0.51^{a}	55.69 ± 0.10^{b}	45.86 ± 0.46^{c}	42.85 ± 0.63^{d}	40.55 ± 0.62^{e}
Kilocalories	342.96^{a}	280.97 ± 1.98^{b}	249.13 ± 2.78^{c}	245.88 ± 2.73^{c}	243.51 ± 4.97^{c}	241.02 ± 2.12^{c}

SF: standard formulation with 100% cassava starchy; F15: 15% of okara flour; F30: 30% of okara flour; F40: 40% of okara flour; F50: 50% of okara flour; OF: okara flour only. Results are described as mean ± standard deviation. Means followed by the same letter in the lines do not differ, using the Tukey test, at 5% significance.

Table 3. Color parameters of the okara flour (OF), standard formulation with 100% cassava starchy (SF), and tapioca with partial replacement of okara flour in concentrations of 15, 30, 40, and 50%.

Parameters	Formulation					
	OF	SF	F15	F30	F40	F50
L*	51,9^{a} ± 0,78	99,84^{d} ± 0,54	91,52^{c} ± 3,06	74,51^{b} ± 0,54	68,88^{b} ± 2,34	69,03^{b} ± 1,46
a*	4,52^{a} ± 0,07	0,55^{e} ± 0,02	2,19^{d} ± 0,05	3,62^{c} ± 0,03	4,05^{b} ± 0,15	4,53^{a} ± 0,19
b*	23,21^{a} ± 0,14	11,80^{d} ± 0,13	19,50^{c} ± 0,62	22,02^{b} ± 0,08	23,49^{a,b} ± 0,66	24,80^{a,b} ± 0,9

SF: standard formulation with 100% cassava starchy; F15: 15% of okara flour; F30: 30% of okara flour; F40: 40% of okara flour; F50: 50% of okara flour; OF: okara flour only; L*: brightness; a*: green to red; b* blue to yellow. Results are described as mean ± standard deviation. Means followed by the same letter in the lines do not differ, using the Tukey test, at 5% significance.

The yellow color in products with okara can be considered desirable from a sensory point of view for some foods, such as bread (Taghdir et al., 2017).

The SF formulation also identified the lowest value of a* (green to red) (0.55 ± 0.02). The color of the variable a* establishes a variation from green to red, indicating, in higher values, the existence of red pigments. With the addition of okara flour, which went through the cooking process, there was a change to positive and increasing values.

3.3 Technological analysis of water absorption index and oil absorption index

The F50 had the highest WAI (2.3 ± 0.08) and OAI (6.25 ± 0.02) (Table 4).

The WAI and OAI are hydration properties that are essential in bakery products due to their influence on sensory characteristics, such as taste and improved palatability (Seena & Sridhar, 2005). To determine the effect of different proportions of red teff, wheat, and okara flour on cookie preparation, Ahmed et al. (2018) observed an increasing trend of the WAI with the increase in okara and red flour. According to the authors, WAI flours have more hydrophilic constituents, such as polysaccharides.

The WAI and OAI are directly related to the availability of hydrophilic (Lustosa et al., 2008) and lipophilic (Bavaresco et al., 2019) groups to bind to water and oil molecules, respectively. The findings of this study show that the formulations with higher okara concentrations, which exhibited the highest WAI and OAI, can be attributed to the increased presence of fibers and lipids in these formulations.

3.4 Microbiological analysis

All samples analyzed showed adequate microbiological standards for human consumption by legislation No. 60 of December 23, 2019 (Brasil, 2019) and Leitão (1988). All samples met the standard for reference soy- and starch-based products (Brasil, 2019). The microbiological analyses met the microbial standards for Salmonella, Coliforms 45°C, Staphylococcus coagulase + (Brasil, 2019), and mesophilic bacteria (Leitão, 1988).

3.5 Composition of fatty acids

Table 5 shows the proportions of the primary fatty acids as a percentage of the total fatty acid content: saturated (∑ SFA), unsaturated (∑UFA), monounsaturated (∑ MUFA), polyunsaturated (∑ PUFA), omega 6 fatty acid (∑ Omega 6), omega 3 (∑ Omega 3), and omega 9 fatty acids (∑ Omega 9).

The saturated fatty acids (SFA) ranged from 0.08% (F15) to 1.54% (F50), mainly composed of palmitic acid, which is present in 2.87% of okara flour (Table 5). In fresh soybeans, palmitic acid is also the most present (Carrão-Panizzi et al., 2019).

The monounsaturated fatty acid (MUFA) ranged from 0.06% (F15) to 2.65% (F50), mainly composed of oleic acid (C18:1n9c), present in 6.28% of the okara flour. Consuming vegetables containing oleic acid, also found in fish, can be related to increased HDL (high-density lipoprotein) and reduced blood pressure (Matos et al., 2019).

The polyunsaturated fatty acids ranged between 0.07% (F15) and 6.20% (F50), being mainly composed of ω6 linoleic acid LA (C18:2n6c) and ω3 alpha linolenic acid LNA (C18:3n3), present in 12.70% and 1.42%, respectively, in okara flour. The human body does not produce ω3 and ω6 fatty acids, requiring daily

Table 4. Water absorption index (WAI) and oil absorption index (OAI) of the okara flour (OF), standard formulation with 100% cassava starchy (SF), and tapioca with partial replacement of okara flour in concentrations of 15, 30, 40, and 50%.

Index	Formulation					
	OF	SF	F15	F30	F40	F50
WAI	$4.38^{d} \pm 0.33$	$1.52^{a} \pm 0.09$	$1.29^{a} \pm 0.11$	$1.73^{a,b} \pm 0.13$	$2.20^{b,c} \pm 0.04$	$2.3^{c} \pm 0.08$
OAI	$6.19^{c} \pm 0.11$	$5.78^{a} \pm 0.07$	$5.93^{a,b} \pm 0.05$	$6.05^{b,c} \pm 0.05$	$6.06^{b,c} \pm 0.07$	$6.25^{c} \pm 0.02$

SF: standard formulation with 100% cassava starchy; F15: 15% of okara flour; F30: 30% of okara flour; F40: 40% of okara flour; F50: 50% of okara flour; OF: okara flour only; WAI: water absorption index; OAI: oil absorption index. Results are described as mean ± standard deviation. Means followed by the same letter in the lines do not differ, using the Tukey test, at 5% significance.

Table 5. Fatty acid composition of the okara flour (OF), standard formulation with 100% cassava starchy (SF), and tapioca with partial replacement of okara flour in concentrations of 15, 30, 40, and 50%.

Fatty acids	OF	SF	F15	F30	F40	F50
	%					
Saturated fatty acids (SFA)						
Myristic acid (C14:0)	0.02	-	-	-	0.01	-
Palmitic acid (C16:0)	2.87	0.05	0.33	0.70	0.99	1.22
Stearic acid (C18:0)	0.72	0.03	0.10	0.20	0.25	0.29
Araquic acid (C20:0)	0.07	-	0.01	0.01	0.02	0.03
Tricosanoic acid (C23:0)	0.01	-	-	-	-	-
Lignoceric acid (C24:0)	0.04	-	0.00	0.01	0.01	-
Margic acid (C17:0)	0.02	-	-	-	-	-
Σ AGS	3.76	0.08	0.44	0.92	1.29	1.54
Monounsaturated fatty acids (MUFA)						
Oleic acid (C18:1n9c)	6.28	0.06	0.67	1.40	2.14	2.65
Cis-11-eicosenoic acid (C20:1n9)	0.05	-	0.00	0.01	0.02	-
Palmitoleic acid (C16:1n7)	0.03	-	-	0.01	0.01	-
Σ AGMI	6.36	0.06	0.67	1.43	2.17	2.65
Polyunsaturated fatty acids (PUFA)						-
Cis-8,11,14-eicosatrienoic acid	0.05	-	0.01	0.01	0.02	-
Acid 5,8,11,14,17-EPA (C20:5n3)	0.01	-	-	-	-	-
Linoleic acid LA (C18:2n6c)	12.70	0.07	1.34	2.58	4.22	5.53
Alpha linolenic acid LNA (C18:3n3)	1.42	-	0.14	0.27	0.47	0.65
Σ Ômega 3	1.42	-	0.14	0.27	0.47	0.65
Σ Ômega 6	12.75	0.07	1.35	2.59	4.24	5.55
Σ AGPI	14.17	0.07	1.49	2.86	4.71	6.20
Σ MUFA + PUFA	20.52	0.12	2.16	4.29	6.87	8.85

SF: standard formulation with 100% cassava starchy; F15: 15% of okara flour; F30: 30% of okara flour; F40: 40% of okara flour; F50: 50% of okara flour; OF: okara flour only; Σ: soma; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; (-): not detected.

intake (Neto et al., 2003). Soy is the food with the highest ω3 content (6%) when compared to corn (1.8%), beans (1.1%), oats (1.1%), lentils (0.4%), peas (0.3%), and rice (0.1%). The ω6 is predominant in corn (58.6%), soybeans (44.6%), oats (24.4%), lentils and peas (1.4%), beans (0.8%), and rice (0.6%) (Martin et al., 2006). Among foods of animal origin, fish of marine origin from continental waters, such as sardines and salmon, have the highest amounts of ω3 (sardines: 14.8%; salmon: 25.6%) and ω6 (sardines: 35.4%; salmon: 2.2%) (Masley, 2018).

3.6 Nutritional quality of tapioca

The nutritional quality of tapioca obtained by different indexes is described in Table 6. The AI ranged from 0.38 ± 0.01 (SF) to 0.14 ± 0.02 (F50), and the TI ranged from 1.23 ± 0.01 (SF) to 0.24 ± 0.01 (F50). All tapioca with okara presented a difference in AI and TI compared to the SF ($p < 0.05$).

Ulbricht and Southgate (1991) developed the AI and TI indices based on the profile of food fatty acids and their contribution to preventing or promoting coronary heart disease in humans. AI represents the ability to reduce the content of lipids in the blood, and TI represents the ability to inhibit platelet activity in humans, with low AI and TI values being desirable and indicating a cardioprotective effect (Ulbricht & Southgate, 1991). In comparison, salmon has an AI and TI of 0.56 and 0.25, respectively (Tonial et al., 2010).

The relationship between polyunsaturated and saturated fatty acids (P/S) ranged from 0.88 ± 0.02 (SF) to 4.03 ± 0.02 (F50). Foods with a ratio of polyunsaturated and saturated fatty acids (P/S) below 0.45 are considered undesirable in a diet due to their potential to increase blood cholesterol (DHSS, 1984). In comparison, salmon has a P/S of 1.24 (Tonial et al., 2010).

Table 6. Indices of nutritional quality of the lipid fraction of the okara flour (OF), standard formulation with 100% cassava starchy (SF), and tapioca with partial replacement of okara flour in concentrations of 15, 30, 40, and 50%.

Samples	AI	TI	P/S	h/H	ω6/ω3
OF	0.14 ± 0.02[b]	0.26 ± 0.01[b]	3.77 ± 0.01[a]	7.10 ± 0.01[a]	8.91 ± 0.01[a]
SF	0.38 ± 0.01[a]	1.23 ± 0.01[a]	0.88 ± 0.02[b]	2.40 ± 0.01[b]	ND
F15	0.15 ± 0.01[b]	0.28 ± 0.02[b]	3.39 ± 0.01[a]	6.55 ± 0.02[a]	9.64 ± 0.02[a]
F30	0.16 ± 0.02[b]	0.31 ± 0.01[b]	3.11 ± 0.02[a]	6.13 ± 0.01[a]	9.59 ± 0.02[a]
F40	0.15 ± 0.01[b]	0.27 ± 0.02[b]	3.65 ± 0.01[a]	6.87 ± 0.01[a]	10.06 ± 0.02[a]
F50	0.14 ± 0.02[b]	0.24 ± 0.01[b]	4.03 ± 0.02[a]	7.25 ± 0.01[a]	8.53 ± 0.02[a]

FO: okara flour; SF: standard tapioca containing 0% okara flour; F15: tapioca containing 15% okara flour; F30: tapioca containing 30% okara flour; F40: tapioca containing 40% okara flour; F50: tapioca containing 50% okara flour; AI: atherogenicity index; TI: thrombogenicity index; h/H: Σ hypocholesterolemic/Σ hypercholesterolemic; P/S: polyunsaturated/saturated; ω6/ω3: Σ of the Omega 6 series/Σ of the Omega 3 series; ND: Not detected. Reference values, IA and IT: lower value is desirable; P/S: higher than 0.45 is desirable; h/H: higher value is desirable; ω6/ω3: 5:1 is desirable.

The ratio ∑ hypocholesterolemic fatty acids/∑ hypercholesterolemic fatty acids (h/H) ranged from 0.88 ± 0.02 (SF) to 4.03 ± 0.02 (F50). Higher values in the h/H ratio are desirable as they indicate a high amount of hypocholesterolemic acids concerning hypercholesterolemic acids (Santos-Silva et al., 2002).

No differences were identified in the ω6/ω3 ratio between the formulations with added tapioca, ranging from 10.06 ± 0.02 (F40) to 8.53 ± 0.02 (F50). According to Simopoulos (2006), a 5:1 ω6/ω3 ratio is recommended. Martin et al. (2006) evaluated the ω6/ω3 ratio in some foods and obtained the highest index in fresh corn (32.50), followed by oats (22.00), soybeans (7.50), peas (4.90), rice (4.80), lentils (3.70), and with the lowest ω6/ω3 ratio on beans (0.70), salmon (0.08), and sardines (2.4). In the present study, it was observed that tapioca with the addition of okara flour did not meet the literature recommendation for the ω6/ω3 ratio, which is 5:1.

3.7 Sensory analysis by intention to purchase

In total, 87 individuals participated in the affective sensory analysis test, 41% ($n = 36$) of males and 59% ($n = 51$) of females. Of these, 11% ($n = 10$) were aged between 25 and 35 years and 89% ($n = 77$) between 18 and 25 years. It was observed that 55% ($n = 48$) of the participants in this study consume tapioca two to three times a week, 20% ($n = 17$) consume this food every 15 days, and 5% ($n = 4$) monthly. Among the participants, 71% ($n = 62$) said they liked tapioca very much, and 29% ($n = 25$) liked it moderately.

The intention to purchase tapioca was evaluated on a scale between "I have doubts whether I would buy it" (3) and "I would probably buy it" (4). No statistically significant difference was observed between SF and tapioca with okara flour ($p < 0.05$), with an average score of 3.44 ± 1.31 (SF), 3.53 ± 1.33 (F15), 3.66 ± 1.16 (F30), 3.77 ± 1.19 (F40), and 3.77 ± 1.20 (F50).

Approximately 56.32% of the tasters said they would probably and/or certainly buy traditional tapioca from starch. For samples F15, F30, F40, and F50, the values were 57.47, 55.18, 58.65, and 58.62%, respectively.

Bowles and Demiate (2006) evaluated the intention to purchase a bakery product containing 10% okara residue in substitution for wheat and obtained an average rating between 4 and 5 (4.2), that is, between the terms "certainly would buy" and "probably would buy."

4 CONCLUSION

The addition of okara flour at a concentration of 50% in tapioca preparation improved the final product's nutritional value, making it a source of fiber and rich in protein. The addition of okara flour increased the water retention capacity in tapioca formulations, representing a change in the technological characteristics of flour mixtures that can be considered desirable for the new product since the judges were more satisfied with the texture.

Tapioca added with okara flour showed higher protein, fiber, PUFA ω-6 and ω-3, and MUFA ω-9. The assessment of the nutritional quality of lipids by AI, TI, h/H, P/S, and ω-6/ω3 indicates that the okara added to the tapioca improved the nutritional quality of the lipids of the product.

The use of okara flour can be an alternative as a source of lipids and an essential perspective for developing new products with this by-product. Tapioca produced with the addition of okara flour can be considered an attraction for consumers, as it has high averages for sensory attributes without any difference in terms of acceptance concerning the standard formulation.

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