ISSN 0101-2061 Ciência e Tecnologia de Alimentos

Original

Physical, chemical, technological and sensory characteristics of Frankfurter type sausage containing okara flour

Características químicas, físicas, tecnológicas e sensoriais de salsicha tipo Frankfurter enriquecida com farinha de okara

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Abstract

The addition of okara flour to an emulsified meat product (Frankfurter type sausage) was evaluated based on the physical, chemical, technological, and sensory characteristics of the final product. Okara, residue from soymilk production, was provided by two soymilk producing companies whose production systems were based on the hot disintegration of the decorticated (company B) or undecorticated (company A) soybeans. The okara was dehydrated using a flash dryer and then ground into flour (≥420 μm). However, The okara flours A and B showed approximately the same amount of protein (35 and 40 g.100 g^{-1} dwb). However, the okara flour A presented higher values ($p \le 0.05$) for all technological functional properties studied (emulsification capacity, emulsion stability, protein solubility, and water hold capacity) than those of okara flour B. The A and B okara flours were used in a frankfurter sausage formulation as substitution of 1.5% and 4% of meat. The results showed that the sausages containing okara flours A and B, as well as the control sausage, were accepted by the sensory panel. Moreover, there were no significant differences ($p \le 0.05$) in the physical (color, objective texture, and emulsion stability) and chemical (pH and proximate composition) measurements of the sausages with and without the okara flour.
Keywords: *residue; drying; pneumatic dryer; technological functional properties; Frankfurter type sausage.*

Resumo

Avaliou-se a adição de farinha de okara em produto cárneo emulsionado (salsicha tipo Frankfurter) com base nas características físicas, químicas e sensoriais do produto obtido. O okara, resíduo do processamento de 'leite' de soja, foi fornecido por duas empresas cujos sistemas de produção baseiam-se na desintegração a quente da soja com casca (empresa A) e sem casca (empresa B). O okara foi desidratado em secador *flash dryer* e moído na forma de farinha (≥420 μm). As farinhas de okara A e B apresentaram níveis aproximados de proteína (35 e 40 g.100 g^{-1} b.s., respectivamente). Entretanto, a farinha de okara A apresentou maiores valores ($p \le 0{,}05$) para todas as propriedades funcionais tecnológicas estudadas (capacidade de emulsificação, estabilidade da emulsão, solubilidade da proteína e capacidade de retenção de água), em comparação com a farinha de okara B. As farinhas de okara A e B foram adicionadas à formulação de salsicha substituindo 1,5% e 4% do peso de carne, respectivamente. Os resultados mostraram que as salsichas contendo farinhas de okara A e B e a salsicha padrão foram igualmente aceitas pela equipe de provadores. Além disso, não houve diferenças signficativas ($p \le 0{,}05$) entre as determinações físicas (cor, textura objetiva e estabilidade da emulsão) e químicas (pH e composição centesimal) das salsichas com ou sem farinha de okara.
Palavras-chave: *resíduo; secagem; secador pneumático; propriedade funcional tecnológica; salsicha.*

1 Introduction

There is considerable urgency for the development of technologies for the use of residues produced during the processing of soy protein extract, commonly known as soymilk, because of the large volume of residue produced, about 2 to 3 tons for each ton of soybean processed, according to Grizotto et al. (2006). This residue, containing 85% moisture content, has a high protein content (40 g.100 g^{-1} dry weight basis) (GRIZOTTO et al., 2006) and deteriorates quickly if no conservation method is applied (AGUIRRE et al., 1981).

The most feasible conservation technique is that of drying since it also minimizes handling, storage, and transportation costs (AGUIRRE et al., 1981). Studies on the drying of okara in a pneumatic or flash dryer were carried out by Nasrala et al. (2007) and Buso et al. (2008) using a pilot scale dryer with a capacity to remove 70 kg water/hour. The results obtained in these studies demonstrated the technical feasibility of drying okara in a flash dryer, and the drying conditions of this type of dryer, operating at high temperatures of above 250 °C and short drying cycles of 3 to 5 minutes, preserved the protein quality of the material showing better results for the technological functional properties as compared to the same material dried in a tray dryer with forced air circulation.

The stabilization of okara in the form of flour opens a variety of possibilities for a more effective use of this material,

Received 13/8/2010
Accepted 11/4/2012 (004985)
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DOI: http://dx.doi.org/10.1590/S0101-20612012005000076

such as, for example, as technical aid to the production of foods. Currently, this residue from the production of soymilk has been destined for animal feeding or even, in the case of excess production, relegated to sanitary dumps.

Recent studies have focused on applying okara flour in the production of bakery goods (GRIZOTTO et al., 2010; LAROSA et al., 2006), breakfast cereals (SANTOS; BEDANI; ROSSI, 2004), tortillas (WALISZEWSKI; PARDIO; CARREON, 2002), and French bread (BOWLES; DEMIATE, 2006).

Considering the high content of technologically good quality protein (40 g.100 g^{-1}, dry weight basis) present in okara, as determined in previous studies (BUSO et al., 2008; GRIZOTTO et al., 2007; NASRALA et al., 2007), it should be possible to use its flour as a substitute for meat protein in sausages within the limit allowed by Brazilian legislation (BRASIL, 2000) with no negative effect on the quality of the sausages. The meat product processing industry has long been using textured soy protein (TSP) as a substitute for animal protein in emulsified meat products.

The objective of this study was to test formulations containing 1.5% and 4% okara flour in an emulsified meat product (frankfurter type sausage) and evaluate the physical, chemical, technological, and sensory characteristics of the products obtained.

2 Materials and methods

2.1 Raw material

Okara, residue from the industrial production of soymilk, was provided by two companies whose production systems were based on the hot disintegration of undecorticated (company A) and corticated (company B) soybeans and separation of the soymilk. These industrial units, located in the cities of Pouso Alegre (MG, Brazil) (company A) and São Paulo (SP, Brazil) (company B), were chosen from a total of nine processing units based on the criterion of location of the industrial unit. Considering that a soymilk processing unit will use the most appropriate soybean cultivar for the region where it is located, it was thus likely that the soybean cultivar used by these companies would be that of greater agricultural diffusion, adapted to the southeast and part of the center-west regions of Brazil.

About 80 kg of okara obtained from each of these companies were dehydrated in the flash dryer to 6 g.100 g^{-1} moisture content using a recirculation rate (RR) of the dried residue of 26%, drying air temperature of 280 °C, and drying cycle of 310 seconds. These conditions were established in a previous study by Grizotto et al. (2007). After drying, the okara was ground into flour in a knife and hammer mill (Treu & Cia Ltda, Rio de Janeiro, Brazil) using the following sequence of sieves: 1.50, 1.15, 0.76, and 0.51 mm, and the material was used in the sausage formulation.

A small quantity (30 kg) of the wet okara, provided by companies A and B, was partially dried in a forced-air tray dryer (65 °C/8 hours) until reaching moisture content of 17 to 20 g.100 g^{-1}, and this material was ground in a hammer mill with half-inch sieve.

This partially dried okara was mixed with the wet okara in the ratio of 26%, enough to reach a moisture content around 60 g.100 g^{-1}, which is necessary to start the flash dryer

These conditions were determined by Grizotto and Aguirre (2011) in a study on the drying of soymilk residue in a pneumatic flash dryer using Response Surface Methodology (RSM).

2.2 Okara flour analyses

The contents of crude protein (ASSOCIATION…, 2005); lipids, by the Bligh-Dyer method (CECHI, 1999); moisture (ASSOCIATION…, 2005); total solids, calculated by difference from the moisture content [100 – moisture content]; neutral detergent fiber (NDF) or total fiber, expressed as cellulose, hemicellulose and lignin (ASSOCIATION…, 2005); ash (ASSOCIATION…, 2005); and carbohydrate, calculated by difference [100 – (protein + lipid + ash + moisture + NDF)] were determined. The determinations were carried out in triplicate, and the results were expressed on a wet weight basis (wwb) or dry weight basis (dwb). Granulometry was determined in a sieve shaker (Produtex, Rio de Janeiro, Brazil) using a sieve sequence of 28, 35, 48, 65, and 80 mesh with openings of 600, 420, 300, 210 and 180 μm, respectively. One hundred grams of okara flour were placed in the shaker, and the percent mass retained on each sieve was calculated after 30 minutes of shaking at maximum velocity.

The technological functional properties: protein solubility (PS) (MORR et al., 1985), water holding capacity (WHC) (REGENSTEIN; GORIMAR; SHERLON, 1979), emulsifying capacity (EC) (DE KANTEREWICZ et al., 1987), and emulsion stability (ES) (ACTON; SAFLE, 1970) were determined in the okara flours dehydrated in the flash dryer, in the original flours dehydrated in a tray dryer (65 °C/8 hours), and in a commercial textured soy protein (TSP). The determinations were carried out in triplicate with the exception of EC, for which a single determination was made in each case.

2.3 Processing of the emulsified meat product

Two levels of addition of the okara flours obtained from companies A and B were tested: 1.5% and 4.0% giving a total of four frankfurter sausage formulations (F_1, F_2, F_3, and F_4,). The control formulation (F_0) corresponded to the formulation without the addition of okara flour but containing 4% textured soy protein (TSP). TSP was used for comparison, since it is the soy derived protein most used in meat products, by replacing part of the meat protein with the objective of improving the emulsion stability, especially when using mechanically deboned meat. The sausage was processed in the Meat Technology Center pilot plant at ITAL, Brazil using the following steps: grinding of the frozen meats, addition of seasonings and ingredients in a cutter, stuffing, heat treatment, cooling, peeling, and vacuum packaging, as described by Yamada (2002). The following ingredients were used: shoulder of beef and bacon acquired from the local market, mechanically deboned chicken meat (MDCM) provided by the *Pena Branca* poultry slaughterhouse, water (ice), manioc starch, malt dextrin (Corn Products®), refined salt, Kerry 01 curing salt (Kerry®), Kerry fix 03 antioxidant (Kerry®), Kerry fat emulsifier (Kerry®), B-17 elite frankfurter sausage seasoning (Dicarne®), Kerry liquid smoke 0402 (Kerry®), Artycolor Carmin BC-Kerry dye (Kerry®), Maxten E-100 textured soy protein (Solae®), and the okara flours from companies A and B.

Table 1 shows the frankfurter sausage formulations, which were produced in batches of 8 kg.

2.4 Sausage analyses

The proximate composition (crude protein, moisture, fat, and ash) was determined according to AOAC (ASSOCIATION..., 2005), carbohydrates according to Brasil (1981), and pH using a Digimed model DM2 pH-meter with a DME-CF1 combined electrode for measurement with penetration. The sausages weight loss during cooking was determined by weighing the product before heat treatment and after cooling. Emulsion stability was determined using 45 to 50 g of meat batter placed in an impermeable, heat-resistant plastic bag, which was sealed and immersed in a water bath at 70 °C for 1 hour and then cooled. The solid parts of the batter were weighed, and the emulsion stability results expressed as % loss in the form of juice The lower the % loss of juice, the greater the emulsion stability. The amount of juice exuded in the package was calculated by weighing the vacuum packed sausages without the exuded juice after 7 days of storage at 2 °C ± 1 °C. Shear force was determined using the TA-XT2i texturometer with the 3 mm thick Warner Bratzler device for the cross-section of the entire sample, operating with the STABLE MICRO SYSTEMS Texture Expert software (1997), using the shear force operational mode, return to start option, pre-test velocity of 1.0 mm/s, and post-test velocity of 5.0 mm/s carrying out at least 20 readings for each treatment. The objective color was determined in a Minolta CM 508d portable spectrophotometer (Osaka, Japan); the readings for lightness (L*), redness (a*) and yellowness (b*) were read using the CIE system.

The external color of the sausage was determined by making 5 readings of 20 sausages per treatment giving a total of 100 readings per treatment. The internal color was determined using the same sausages cut longitudinally with a total of 100 readings per treatment. The water activity of the sausages was measured experimentally using a model CX-12 digital electronic hydrometer (Aqualab, Decagon Devices Inc., USA) at 25 °C ± 0.3 °C attached to a water bath.

The present study was submitted to and approved by the Ethics Committee of the Medical Science Faculty of UNICAMP, process nº 701/2006. The entire procedure adopted in the sensory test was explained in detail to the panelists taking part in the analyses, who signed a free and informed consent form.

The sausage samples (F_0, F_1, F_2, F_3, and F_4) were evaluated by the consumers using an affective test.

The acceptance test was carried out by 50 consumers as specified by Stone and Sidel (1985) including only those who appreciated frankfurter sausages and were available to carry out the test. The test was carried out at the Sensory Evaluation Laboratory of the Meat Technology Center of ITAL using individual computerized booths illuminated with fluorescent light. The software used for the preparation, filling in, and evaluation of the questionnaire was the 4.2 version of the computerized sensory analysis (CSA) software, COMPUSENSE INC. – Canada.

The sausages were cooked in boiling water for 5 minutes, cut into 2 cm cylinders and maintained in an incubator at approximately 40 °C until served. The samples were served on white plates coded with 3-digit random numbers and were

Table 1. Formulations[(1)] of the frankfurter sausages with the addition of 1.5% and 4% okara flours A (F_1 and F_2) and B (F_3 and F_4) and control (F_0) without okara flour.

Ingredients	Control (F_0)	Okara flour A		Okara flour B	
		F_1 (1.5% substitution)	F_2 (4% substitution)	F_3 (1.5% substitution)	F_4 (4% substitution)
Shoulder of beef	28.0	28.0	28.0	28.0	28.0
Chicken MDM	40.0	40.0	40.0	40.0	40.0
Bacon	6.0	6.0	6.0	6.0	6.0
Water (ice)	15.5	15.5	15.5	15.5	15.5
Starch	2.0	2.0	2.0	2.0	2.0
Malt dextrin	1.8	1.8	1.8	1.8	1.8
Salt	1.3	1.3	1.3	1.3	1.3
Curing salt	0.30	0.30	0.30	0.30	0.30
Antioxidant	0.30	0.30	0.30	0.30	0.30
Fat emulsifier	0.25	0.25	0.25	0.25	0.25
Frankfurter sausage seasoning	0.50	0.50	0.50	0.50	0.50
Liquid smoke	0.03	0.03	0.03	0.03	0.03
Carmine red dye	0.0	0.013	0.013	0.013	0.013
Textured soy protein	4.0	2.5	0.0	2.5	0.0
Okara flour A	0.0	1.5	4.0	0.0	0.0
Okara flour B	0.0	0.0	0.0	1.5	4.0

[(1)]Amounts of ingredients expressed in $kg.100\ kg^{-1}$.

presented in a monadic way. Salt water cracker and water were provided. The sensory attributes evaluated were: color, odor, texture, and flavor using a 7 point verbal hedonic scale, where 1 = "disliked a lot", 2 = "disliked moderately", 3 = "disliked slightly", 4 = "indifferent", 5 = "liked slightly", 6 = "liked moderately", and 7 = "liked a lot". Buying intention was analyzed in the same test using a five point scale as follows: 1 = "definitely not buy", 2 = "probably not buy", 3 = "maybe buy, maybe not", 4 = "probably buy", and 5 = "definitely buy". A completely random block statistical design was used.

2.5 Data analysis

The results of the physical, physicochemical, and sensory evaluations of the frankfurter sausages with and without (control) okara flour were submitted to ANOVA, and the Tukey's means comparison test was used to identify differences among the samples at a 5% significance level.

3 Results and discussion

Table 2 shows the results obtained in the physicochemical analyses and in the evaluation of the technological functional properties for the okara flours A and B dried in the flash dryer and the okara flours A and B dried in a tray drier. The results for the textured soy protein are also showed in Table 2. The discussion of the results will be focused on the okara flours dried in flash dryer because they were the materials used on the sausage formulation.

The initial moisture contents of the wet okara flours obtained from companies A and B were 83 g.100 g^{-1} (wwb) and 81 g.100 g^{-1} (wwb), respectively, close to the values found in such residues by Grizotto et al. (2006). The initial moisture of the okara flours A and B used in flash dryer were around 60 g.100 g^{-1}, which confirms that the mixture of part (74%) of the wet okara and part (26%) of the partially dried okara is enough to obtain the moisture content required for the functioning of the flash dryer, as determined by Grizotto and Aguirre (2011). The final moisture of the okara flours A and B dried in flash dryer was close to 6 g.100 g^{-1}, which is considered ideal in this case.

The protein (35 g.100 g^{-1} dwb) content in okara flour A was significantly below ($p \leq 0.05$) that in okara flour B (40 g.100 g^{-1} dwb), but it was close to 33 g.100 g^{-1} dwb, value found in commercially available okara flour in the USA (KATAYAMA; WILSON, 2008) and in Spain (MATEOS-APARICIO et al., 2010). The higher protein content in okara B (40 g.100 g^{-1}) is in agreement with that found by Grizotto et al. (2006) in a study with okara from ten Brazilian soybean cultivars: IAC PL1, IAC 18, IAC PL1HA, IAC Foscarin 31, BRS 267, BRS 257, Embrapa 48, BRS 213, BRS 230, and BRS 232, obtained after disintegration of the dehulled soybean in hot water at 80-100 °C and separation of the okara by filtering, according the hot-grind method proposed by Wilkens and co-workers in 1967 cited by Wolf (1975). This technological procedure remains recognized, and it is the procedure commonly applied by the Brazilian soymilk companies with little and peculiar modifications.

The lipid content was around 17 g.100 g^{-1} dwb for okara flours obtained from companies A and B, but it was slightly lower than those found by Grizotto et al. (2006), from 18 to 25 g.100 g^{-1} lipids dwb. A likely explanation for the lower protein and lipid contents in the residue provided by companies A and B was the greater efficiency of the industrial process, considering that Grizotto et al. (2006) produced the soymilk residue on a laboratory scale. A variation in the chemical composition of okara flour is in according with O'Toole (1999). The author stated that the chemical composition of okara depends on the amount of water phase extracted from the ground soybean and whether further water was added to extract residual extractable components, and it also depends on the cultivar of soybean and the production methods.

The okara flour from company A showed high fiber content (21.23 g.100 g^{-1} dwb), 1.3 and 1.8 times greater than that found in the okara B flour and in the okara studied by Aguirre et al.

Table 2. Results[(1)] of the centesimal composition and technological functional properties for the okara flours A and B dehydrated in a flash dryer[(2)] and in a tray dryer[(3)] and the commercial Textured Soy Protein (TSP).

Determination	Okara flour (flash dryer)		Okara flour (tray dryer)		TSP
	A	B	A	B	
Moisture $_{initial}$ (g.100 g^{-1} wwb)	61.21 ± 0.16^b	59.46 ± 0.24^c	82.58 ± 0.15^a	80.75 ± 0.08^a	n.d.
Moisture $_{final}$ (g.100 g^{-1} wwb)	6.29 ± 0.21^b	6.89 ± 0.11^b	17.43 ± 0,15^a	19.69 ± 0.08^a	n.d.
Protein (g.100 g^{-1} dwb)	34.78 ± 0.21^e	40.50 ± 0.36^c	36.91 ± 0.04^d	43.68 ± 0.19^b	56.64±0.03^a
Lipids (g.100 g^{-1} dwb)	16.61 ± 0.06^a	15.84 ± 0.09^b	16.43 ± 0.15^a	16.23 ± 0.46^{a,b}	n.d.
Fiber (g.100 g^{-1} dwb)	21.04 ± 0.35^a	15.46 ± 0.04^c	21.52 ± 0.42^a	19.17 ± 0.42^b	n.d.
Ash (g.100 g^{-1} dwb)	4.02 ± 0.12^a	3.76 ± 0.05^a	4.00 ± 0.00^a	3.98 ± 0.16^a	n.d.
Carbohydrates (g.100 g^{-1} dwb)	38.29 ± 0.61^a	33.01 ± 0.31^b	39.01 ± 0.20^a	33.11 ± 0.32^b	n.d.
Granulometry (% retention on Mesh 35)	86.74 ± 1.45^a	93.33 ± 2.44^a	70.73 ± 0.28^b	77.48 ± 1.97^b	91.49 ± 0.69^a
WHC[(4)] pH 5	26.08 ± 10.18^a	15.21 ± 10.7^b	17.35 ± 6.86^b	17.10 ± 5.26^b	8.65 ± 0.48^c
PS[(5)] pH 5	28.18 ± 1.22^a	12.25 ± 0.52^c	20.60 ± 0.00^b	21.28 ± 1.45^b	18.89 ± 0.75^b
EC[(6)]	414	75.9	244.0	58.4	83
ES[(7)]	89.24 ± 1.77^a	62.11 ± 3.73^b	4.05 ± 2.08^d	21.60 ± 7.09^c	85.23 ± 9.56^a

[(1)]Mean of three repetitions ± standard deviation, with the exception of EC, which was a single determination. n.d. = not determined. [(2)]Recirculation rate = 26%; Tdrying air = 280 °C and drying cycle of 310 seconds. [(3)]Tdrying air = 65 °C for 8 hours. [(4)]WHC = Water holding capacity (g.water.g–1 protein); [(5)]PS = Protein solubility (g soluble protein.100 g–1 material) [(6)]EC = Emulsification capacity (mL oil.g–1 protein); [(7)]ES = Emulsion stability (%). Different upper case letters in the same line differ significantly at the 95% of probability.

(1981), respectively, but two times lower than the values 42.5 g.100 g^{-1} and 54.3 g.100 g^{-1} found by Bowles and Demiate (2006) and Mateos-Aparicio et al. (2010), respectively, in similar materials. The probable explanation for the large difference in the fiber content between similar materials is the analysis procedure. Mateos-Aparicio et al. (2010) and Bowles and Demiate (2006) used the enzymatic-gravimetric method, whereas in the present study the procedure used was the Van Soest method with neutral detergent without the use of enzymes. Moreover, the greater fiber content found in the industrial residue A, when compared to that found by Aguirre et al. (1981) and that in residue B, could be explained by the production system used to prepare the soymilk. Company A produces soymilk by disintegrating non-decorticated soybeans, while company B and Aguirre et al. (1981) dehulled the soybeans before hot water extraction. In fact, the ash content (4.08 g.100 g^{-1} dwb) found in the okara flour A was greater than the values found in the okara flour B (3.74 g.100g^{-1}) and those found in the literature: 3.1 g.100 g^{-1} (AGUIRRE et al., 1981) and 3.4 g.100 g^{-1} (CAVALHEIRO, 2001), and it is associated with the presence of the soybean skin since company A produced the soymilk as from whole soybeans.

The A and B okara flours dried in the flash dryer and in a tray dryer and the commercial textured soy protein (TSP) showed percentages of particles retained by the 35 mesh sieve (opening of 420 μm) of between 70% and 93% . Therefore, they can be classified as medium sized granule flours.

The okara flour A had the significantly ($p \leq 0.05$) lowest level of protein (34.78 g. 100 g^{-1} dwb), but it showed higher values for emulsification capacity (414 mL oil.g^{-1} protein), water holding capacity (26.08 g.100 g^{-1}) ($p \leq 0.05$), protein solubility (28.18 g. 100 g^{-1}) ($p \leq 0.05$) than those of the okara flour B and the commercial textured soy protein, which had higher protein contents, 40.50 g. 100 g^{-1} dwb and 56.64 g. 100 g^{-1} dwb, respectively. The okara flour B showed good emulsification capacity (75.9 mL oil.g^{-1} protein), close to the commercial TSP, but the emulsion formed had significantly ($p \leq 0.05$) lower stability (62%,) compared to that of the same material. The commercial TSP used in the frankfurter sausage formulations ($F_{0,}$ F_1, and F_3) showed stable emulsion (85.23%), but it showed results significantly ($p \leq 0.05$) lower for protein solubility (18.89 g.100 g^{-1}) and water hold capacity at pH 5 (8.65 g.100 g^{-1}), as compared to the okara flour A.

Okara flour A had the highest ($p \leq 0.05$) protein solubility, and the okara flour B had lower protein solubility than that of commercial TSP. The explanation to the better performance of okara flour A is the good quality protein in the hypocotyls. According to Ma et al. (1997), the native soybean protein has higher solubility than denatured protein; thus, it can be concluded that the heat treatment in the flash dryer did not lead to marked denaturation of the major soy proteins. Wagner and Anon (1990) demonstrated that commercial soy protein isolates with low enthalpy protein solubility and high surface hydrophobicity indicate extensive protein denaturation

Based on the above results, one can conclude that the technological functional properties depend on the quality of the protein present in the material and not on the amount of protein. This statement is supported by Wolf and Cowan (1975), who claims that the primary structure of the protein in okara was unfolded by heat during drying to a more soluble form, which resulted in improved quality of this protein.

Comparing the two different drying systems, flash dryer versus tray dryer, it can be observed significantly ($p \leq 0.05$) lower levels of protein in the okara flours A and B dried in flash dryer than in those found in the same materials dried in tray dryer. Despite of these lower levels of protein, the technological functional properties of the okara flours (A and B) dried in flash dryer showed better results, significantly different ($p \leq 0.05$), comparing the same materials dried in tray dryer. On the other hand, comparing the two materials (okara flours A and B) in the same drying systems (flash dryer), it was observed better performance of the okara obtained from company A. The explanation for the good results in the technological functional properties of the okara flour A in comparison with the okara flour B, both dried in flash dryer, may be associated with the presence of the hypocotyls since company A processed whole soybeans. The hypocotyl, also known as the hypocotyledon or germ, corresponds to only 2% of the total weight of the soybean and is found close to the skin (BOURNE, 1970); it shows an elevated protein content (40 g.100 g^{-1}) of excellent quality and approximately 90% of the total isoflavones present in the soybean (GRIZOTTO et al., 2010).

Table 3 shows the results for the proximate composition and the physical and chemical evaluations of the frankfurter sausages produced with okara flours A and B and without okara flour (control).

The sausages produced according to the five formulations (F_0, F_1, F_2, F_3, F_4) presented moisture values close to 62 g.100 g^{-1} and water activity varying from 0.981 to 0.987 indicating the need for cold storage. The protein content of the samples containing okara flour A and B varied from 13.43 to 13.98 g.100 g^{-1}, which is close to 14.26 g.100 g^{-1}, value found in the control sample. These results can be explained because all the formulations, including the control, had a total of 4% non-meat protein. For example, the formulation with 1.5% okara flour (A or B) had the addition of 2.5% of commercial textured soy protein; on the other hand, in the formulations with 4% de okara flour (A or B) there was no commercial TSP

The fat content of samples F_0 (control), F_1, F_3, and F_4 are the same (approx. 16 g.100 g^{-1}), except for sample F_2, which showed the highest fat content (17 g.100 g^{-1}), significantly different from the control sample. No significant changes were observed with respect to the carbohydrate contents. Therefore, from the point of view of the proximate composition, the sausage containing 1.5% okara flour A showed values closest to those of the control sausage, which contained 4% of textured soy protein in its formulation.

The pH value remained around 6.3 for all formulations of sausages studied.

The loss of weight during cooking varied from 4.2% to 5.7% although the means did not vary significantly at 95% of probability. The data of loss of weight during cooking agreed with the values found for the percent loss of juice exuded in

Table 3. Results[(1)] of the proximate composition, physical, and physicochemical evaluations for the frankfurter sausages produced with the addition of 1.5% and 4% okara flours A (F_1 and F_2) and B (F_3 and F_4) and control (F_0) without okara flour.

Evaluation	Control F_0	Frankfurter sausages with added okara flour			
		F_1 (1.5% okara flour A)	F_2 (4% okara flour A)	F_3 (1.5% okara flour B)	F_4 (4% okara flour B)
Moisture (g.100 g^{-1})	62.34 ± 0.03^{a}	$62.45 \pm 0{,}04^{a}$	61.87 ± 0.15^{b}	61.92 ± 0.12^{b}	62.42 ± 0.26^{a}
Water activity	0.981 ± 0.002^{b}	$0.982 \pm 0{,}002^{b}$	0.981 ± 0.001^{b}	0.987 ± 0.001^{a}	$0.983 \pm 0.001^{a,b}$
Fat (g.100 g^{-1})	16.14 ± 0.02^{b}	$16.39 \pm 0.32^{a,b}$	17.04 ± 0.04^{a}	$16.22 \pm 0.58^{a,b}$	$16.23 \pm 0.20^{a,b}$
Protein (g.100 g^{-1})	14.26 ± 0.07^{a}	$13.98 \pm 0.32^{a,b}$	13.43 ± 0.34^{b}	13.51 ± 0.13^{b}	13.42 ± 0.16^{b}
Ash (g.100 g^{-1})	2.93 ± 0.03^{a}	2.83 ± 0.04^{b}	2.84 ± 0.15^{b}	$2.88 \pm 0.26^{a,b}$	2.83 ± 0.05^{b}
Carbohydrates (g.100 g^{-1})	4.52 ± 0.12^{a}	4.44 ± 0.16^{a}	4.58 ± 0.20^{a}	4.84 ± 0.09^{a}	4.54 ± 0.21^{a}
pH	6.30 ± 0.02^{a}	6.28 ± 0.02^{a}	6.23 ± 0.04^{a}	6.27 ± 0.02^{a}	6.21 ± 0.02^{a}
Loss of weight on cooking (%)	4.30 ± 1.10^{a}	4.20 ± 0.89^{a}	5.02 ± 1.47^{a}	5.70 ± 0.61^{a}	5.31 ± 0.95^{a}
Emulsion stability (% loss of juice)	3.91 ± 0.86^{b}	5.61 ± 0.89^{a}	4.60 ± 0.53^{b}	4.57 ± 0.53^{b}	5.78 ± 0.43^{a}
Juice exuded into package (%)	1.24 ± 0.18^{a}	1.23 ± 0.06^{a}	1.42 ± 0.12^{a}	1.31 ± 0.14^{a}	1.39 ± 0.11^{a}
Shear force (kgf)	$2.45 \pm 0.17^{c,d}$	2.34 ± 0.10^{d}	$2.52 \pm 0.18^{b,c}$	2.63 ± 0.17^{b}	3.16 ± 0.22^{a}
External color: L*	49.88 ± 0.79^{a}	49.98 ± 0.65^{a}	50.01 ± 0.46^{ab}	48.64 ± 0.65^{b}	50.29 ± 0.61^{a}
a*	19.84 ± 0.54^{b}	19.65 ± 0.55^{b}	19.16 ± 0.47^{b}	21.11 ± 0.58^{a}	19.41 ± 0.64^{b}
b*	13.89 ± 0.54^{b}	12.97 ± 0.55^{c}	$14.14 \pm 0.47^{a,b}$	14.36 ± 0.59^{a}	14.36 ± 0.63^{a}
Internal color: L*	55.85 ± 0.41^{a}	56.16 ± 0.33^{a}	56.90 ± 0.37^{a}	55.64 ± 0.49^{a}	57.17 ± 0.39^{a}
a*	14.53 ± 0.37^{b}	14.50 ± 0.15^{ab}	13.16 ± 0.24^{c}	14.77 ± 0.28^{a}	13.50 ± 0.18^{d}
b*	10.14 ± 0.57^{a}	9.70 ± 0.22^{b}	9.72 ± 0.22^{b}	10.22 ± 0.24^{a}	10.12 ± 0.16^{a}

[(1)]Means with three repetitions ± standard deviation. Different upper case letters in the same line differ significantly at the 95% of probability.

the package that was 1.24% to 1.42%, for which there was no significant difference between the means either.

The sausages containing 4% okara flour A (F_2) and 1.5% okara flour B (F_3) presented small values for juice loss percentage, 4.60% and 4.57%, respectively, which did not differ ($p \leq 0.05$) from that of the control sample (3.91%). These sausages formulations could be considered as stable emulsions. It is expected that the formulations with okara flour A presented higher values for emulsion capacity and emulsion stability than those of the textured soy protein and okara flour B. Surprisingly, the F_3 sausages containing 1.5% okara flour B also presented emulsion stability close to that of the control sausage although the technological functional properties of the okara flour B were not comparable to that of the okara flour A. In fact, the okara flour B used to produce the sausages presented low value of emulsifying capacity (75.9 mL oil.g^{-1} protein) (Table 2) and emulsion stability of 62% only (Table 2), significantly different ($p \leq 0.05$) from those of okara flour A. The good emulsion stability results could be partially explained based on the synergistic effect with the textured soy protein (TSP) since the formulations containing 1.5% of okara flour B were complemented with TSP to a total of 4% substitution of the meat protein. Although no reports corroborating this statement could be found in the literature.

The addition of 1.5% and 4% okara flour A did not significantly change the product firmness as compared to the control sausage. However, the sausage containing the highest level of okara flour B (F_4) was significantly firmer ($p \leq 0.05$) than all other samples, including the control sample. The high firmness (3.16 kgf) of sausage F_4 should not be associated with the high juice loss % of (5.78%) exuded in the package significantly different ($p \leq 0.05$) from the other samples because, despite the high percent loss of juice , moisture and water activity levels remained close to those of the other formulations.

The external and internal objective colors of the control frankfurter sausage (F_0) and those of the sausages containing okara flours A (F_1 and F_2) and B (F_3 and F_4) were very similar due to the addition of 0.013% red carmine dye in the formulations containing okara flour. The addition of dye was necessary to standardize the color since the commercial TSP contains a red dye in its formulation. This also explains why carmine was not added to the formulation with commercial TSP. All formulations presented similar colors, except for sample F_3, whose external ($a^* = 21.11$) and internal ($a^* = 14.77$) colors were significantly redder than the other samples. The samples containing higher amounts of okara flours A (F_2) and B (F_4) were less red internally. In the formulations F_2 and F_4, without commercial TSP, the quantity of carmine dye should be higher than 0.013 g.100 g^{-1} in order to compensate the lack of dye in commercial TSP.

Figures 1a, b show the external and internal aspects of the control sausages and of those with added okara flours A and B, respectively.

In the sensory evaluation of the five samples of frankfurter sausage, 80% of the panelists were women and 20% men. The majority (48%) of the panelists were in the age range between 21 and 30, and 34% were below 21 years old. The consumption frequency of frankfurter sausages among the panelists was considered high, 42% of the panelists consumed the product every week and a further 42% every fortnight. On the other hand, the panelists that consumed frankfurter sausages every month or every other month represented 16% of the total number of panelists.

Table 4 shows the scores attributed to the five sausage formulations by the 50 panelists in the acceptance test.

The panelists failed to perceive any differences in color, odor, taste, or texture between the control sausages and those containing okara flour ($p > 0.05$), which is a very good result. The slight differences in lightness (L*) and red color (a*) considered significant at the 95% level of probability (Table 3) were not perceived by the panelists in the sensory evaluation (Table 4). The products were attributed mean scores between 5 (liked slightly) and 6 (liked moderately). It can be seen in Table 4 that the mean score given for the attributes of taste and odor of the sausages with the smaller addition of okara flours A (F_1) and B (F_3) were the highest, close to 6 (liked moderately).

Table 5 shows the distribution of the consumer responses into 3 scale ranges: rejection (scores between 1 "disliked a lot" and 3 "disliked slightly"), indifferent (score equal to 4 "neither

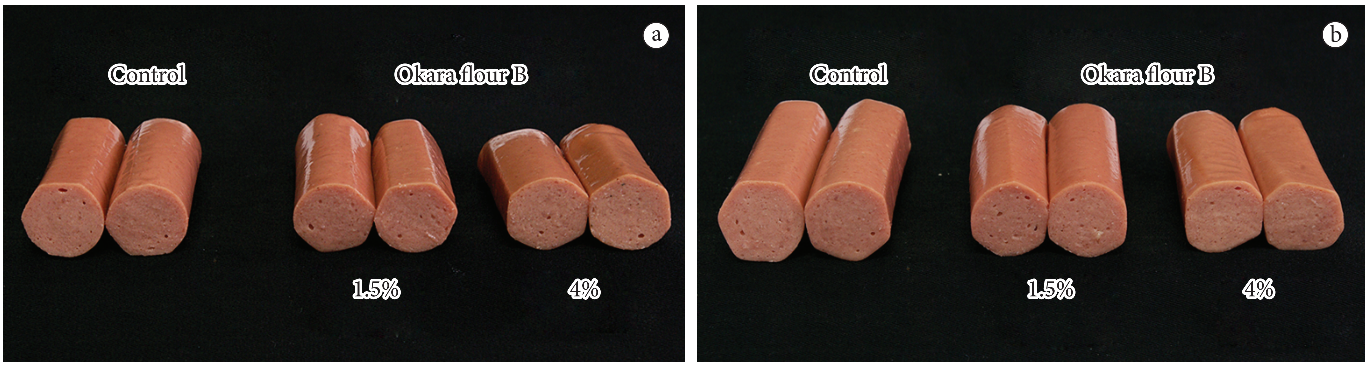

Figure 1. Internal and external appearance of the control frankfurter sausage and of those containing 1.5% and 4% okara flour from companies A (a) and B (b).

Table 4. Sensory parameters for the frankfurter sausages prepared with the addition of 1.5% and 4% okara flours A (F_1 and F_2) and B (F_3 and F_4) and control (F_0) without the addition of okara flour.

Sensory parameters*	F_0 (Control)	Frankfurter sausages with added okara flour			
		F_1 (1.5% okara flour A)	F_2 (4% okara flour A)	F_3 (1.5% okara flour B)	F_4 (4% okara flour B)
Color	5.34[a]	5.56[a]	5.38[a]	5.56[a]	5.18[a]
Odor	5.40[a]	5.52[a]	5.56[a]	5.74[a]	5.52[a]
Taste	5.44[a]	5.72[a]	5.22[a]	5.58[a]	5.46[a]
Texture	5.46[a]	5.30[a]	5.22[a]	5.56[a]	5.48[a]

The same upper case letters in the same line do not differ significantly at the 95% of probability. *Acceptance scores: 1 = disliked a lot; 2 = disliked moderately; 3 = disliked slightly; 4 = indifferent; 5 = liked slightly; 6 = liked moderately; 7 = liked a lot.

Table 5. Percentages of consumer responses according to the acceptance/rejection ranges.

Attributes	Scale ranges*	F_0 (control)	Frankfurter sausages with added okara flour			
			F_1 (1.5% okara flour A)	F_2 (4% okara flour A)	F_3 (1.5% okara flour B	F_4 (4% okara flour B)
Color						
	Acceptance	72	82	82	80	78
	Indifference	12	6	2	10	10
	Rejection	16	12	16	10	12
Odor						
	Acceptance	72	82	84	84	78
	Indifference	20	10	8	10	14
	Rejection	8	8	8	6	8
Taste						
	Acceptance	78	92	72	80	80
	Indifference	6	2	6	4	10
	Rejection	16	6	22	16	10
Texture						
	Acceptance	80	78	72	84	82
	Indifference	10	6	8	4	6
	Rejection	10	16	20	12	12

*Ranges on the hedonic scale: Acceptance: scores 7 to 5; Indifference: score 4; Rejection: scores 3 to 1.

liked nor disliked"), and acceptance (scores from 5 "liked slightly" to 7 "liked a lot").

Analyzing the distribution of acceptance by the panelists, that is, the frequency of scores between 5 ("liked slightly") and 7 ("liked a lot"), it can be seen that the formulations containing okara flour A (F_1 and F_2) showed higher percentages of acceptance for the attribute of color (82% for both). For the attribute of odor, it can be seen that the formulations containing okara flour A (F_2) and B (F_3) showed the highest percentages of acceptance (84% for both), followed by 82% acceptance for the formulation containing 1.5% okara flour A (F_1). The formulation containing 1.5% okara flour A (F_1) showed the highest frequency (92%) of acceptance for the attribute of flavor, and the textures of the sausages containing okara flour B (F_3 and F_4) were more accepted by the panelists, with values of 84% and 82%, respectively. Thus, it can be said that the sausage formulations containing 1.5% and 4% of okara flours A and B were equally accepted by the panelists, with emphasis on the formulation containing 1.5% okara flour A, which received the highest frequencies of scores in the acceptance range for the parameters of color, odor, and taste.

The buying intention of the five products reflected the results of the acceptance test. The majority of the consumers (62.5 and 70%) would probably or certainly buy the products with the smaller additions of okara flour (F_1 and F_3, respectively). The buying intention showed that the addition of okara flour did not affect negatively the sensory quality of the frankfurter sausages.

With basis on the physical, chemical, and sensory results, it can be concluded that it is possible to substitute part of meat protein for vegetable protein in the formulations of Frankurt type sausage within the limit allowed by the Brazilian legislation (Normative Instruction nº 4 of March 31st 2000) published in Brasil (1999), which is 4% non-meat protein in emulsified meat products.

4 Conclusions

The technological functional properties depend on the quality of the protein present in the material and not on the amount of protein.

The okara flours A and B were used in the sausage production (frankfurter sausage) based on the emulsifying capacity of 414 mL oil.g^{-1} protein (company A) and 75.9 mL oil.g^{-1} protein (company B) and emulsion stability of 89% (company A) and 62% (company B). This criterion was adopted since these are the most important technological functional properties for this class of product.

The frankfurter sausage formulations containing 1.5% and 4% of okara flours A and B and the control formulation were equally accepted by the panelists.

The sausages containing okara flour A (1.5% and 4%) showed highest percentages of acceptance for color (82% for both) and odor (82% and 84%). However, the panelists detected small difference in the texture and therefore gave them lower scores, 78% for the sausage with 1,5% okara flour A and 72% for the sausage with 4% okara A.

The taste of the sausages containing 1.5% okara flour A showed the highest acceptance (92%) amongst the panelists.

The panelists declared the same buying intention ("probably buy" and "certainly buy") for the control sausage and for those containing 1.5% and 4% okara flour indicating that the addition of okara flour did not affect negatively the quality of the sausages.

Acknowledgements

RKG is grateful for the financial support provided by FAPESP – Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil.

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