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Avaliação físico-química e tecnológica de farinhas elaboradas a partir de coprodutos de frutas para uso em alimentos

Physicochemical and technological evaluation of flours made from fruit co-products for use in food products

Evaluación fisicoquímica y tecnológica de harinas elaboradas a partir de subproductos frutales para su uso en alimentos

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Resumo

Frutas e vegetais são amplamente processados e, durante o processamento, os coprodutos são, muitas vezes, descartados. Alguns coprodutos, como as cascas, possuem uma composição rica, e poderiam ser aproveitados. Entretanto, a alta perecibilidade, decorrente do alto teor de umidade, limita este aproveitamento. A redução da umidade, conseguida por meio da secagem, representa uma alternativa para a utilização destes coprodutos. Farinhas elaboradas a partir de coprodutos de abacaxi (*Ananas comosus*), banana (*Musa* sp.), lichia (*Litchi chinensis*) e mamão (*Carica papaya*), por meio do processo de secagem, foram avaliadas em relação à granulometria, atividade de água, potencial hidrogeniônico (pH), acidez titulável, sólidos solúveis totais, solubilidade em água e em leite e absorção de água, leite e óleo, com o objetivo de caracterizá-las e sugerir possíveis aplicações em produtos alimentícios. Os valores de atividade de água (0,21 a 0,38) e pH (3,58 a 5,84) apresentaram-se favoráveis à conservação das farinhas, que demonstraram, ainda, melhor solubilidade em água (17,57 a 53,52%) que em leite (4,46 a 11,22%), além de maior absorção de água (2,16 a 6,35 g g^{-1}) e leite (3,19 a 6,61 g g^{-1}), em comparação à absorção de óleo (1,09 a 1,74 g g^{-1}). Os resultados indicaram bom potencial de utilização na elaboração de alimentos, principalmente em produtos instantâneos, cárneos e de panificação, seja para desenvolvimento de novos produtos ou para substituição de ingredientes já utilizados, representando alternativa para o aproveitamento de coprodutos.

Palavras-chave: Frutas; Coprodutos; Casca de frutas; Farinha; Propriedades tecnológicas.

Abstract

Fruits and vegetables are widely processed, and during its processing, co-products are often discarded. Some co-products, such as peels, have a rich composition and could be used. However, the high perishability, due to high moisture content, limits this use. The reduction of moisture, achieved by drying, is an alternative to use these co-products. Flours, made from pineapple (*Ananas comosus*), banana (*Musa* sp.), lychee (*Litchi chinensis*) and papaya (*Carica papaya*) peels, through drying process, were evaluated for particle size distribution, water activity, hydrogenionic potential, titratable acidity, total soluble solids, solubility in water and in milk and water, milk and oil absorption, in order to characterize them and suggest potential applications in food products. Water activity (0.21 to 0.38) and pH (3.58 to 5.84) values were favorable for the preservation of flours, which also showed better solubility in water (17.57 to 53.52%) than in milk (4.46 to 11.22%), as well as a higher water uptake (2.16 to 6.35 g g^{-1}) and milk (3.19 to 6.61 g g^{-1}) compared to oil absorption (1.09 to 1.74 g g^{-1}). These results indicated good potential for use in food processing, especially in instant products, meat and bakery, to develop new products or replace ingredients, representing an alternative to the use of co-products.

Keywords: Fruit; Co-products; Fruit peel; Flour; Technological properties.

Resumen

Las frutas y verduras se procesan ampliamente y, durante el procesamiento, los subproductos a menudo se descartan. Algunos coproductos, como la corteza, tienen una composición rica y podrían usarse. Sin embargo, la alta perecebilidad, debido al alto contenido de humedad, limita este uso. La reducción de la humedad, lograda mediante el secado, representa una alternativa para el uso de estos coproductos. Las harinas hechas de coproductos de piña (*Ananas comosus*), plátano (*Musa* sp.), Lychee (*Litchi chinensis*) y papaya (*Carica papaya*), a través del proceso de secado, se evaluaron en términos de granulometría, actividad del agua, potencial de hidrógeno (pH), acidez titulable, sólidos solubles totales, solubilidad en agua y leche y absorción de agua, leche y aceite, para caracterizarlos y sugerir posibles aplicaciones en productos alimenticios. Los valores de actividad del agua (0.21 a 0.38) y pH (3.58 a 5.84) fueron favorables para la conservación de las harinas, que también demostraron una mejor solubilidad en agua (17.57 a 53.52%) que en la leche (4.46 a 11.22%), además de una mayor absorción de agua (2.16 a 6.35 g g^{-1}) y leche (3.19 a 6.61 g g^{-1}), en comparación con la absorción de aceite (1.09 a 1.74 g g^{-1}). Los resultados indicaron un buen potencial para su uso en la preparación de alimentos, principalmente en productos instantáneos de carne y panadería, ya sea para el desarrollo de nuevos productos o para la sustitución de ingredientes ya utilizados, lo que representa una alternativa para el uso de coproductos.

Palabras clave: Frutas; Coproductos; Cáscara de fruta; Harina; Propiedades tecnológicas.

1. Introdução

The food industry is responsible for generating large quantities of waste or co-products. Studies have shown that about 1.3 billion tons of foods are wasted worldwide per year, representing one-third of the total production of the food industry. Of this, about 0.5 billion tons are fruits and vegetables. In addition to losses in the field, great losses are observed during industrial processing (Gustavsson, et al., 2011).

In this context, there is a need to improve the full utilization of fruits and vegetables, thus minimizing the disposal and generation of co-products, and enabling their use in human nutrition rather than animal feed or organic fertilization only (Ayala-Zavala et al., 2010; Ayala-Zavala et al., 2011; Sun-Waterhouse, 2011). The use of fruit and vegetable processing co-products as raw material for the development of new food products has commercial importance, considering the interest in sustainable development of the food industry, and the consumer awareness of the benefits of natural foods (Canett-Romero et al., 2004; Yagci & Gogus, 2009; Ajila, et al., 2010; Betoret et al., 2011; Rosales Soto, Brown, & Ross, 2012).
However, these products are susceptible to microbiological degradation, mainly due to their high water content and chemical composition, impairing their utilization (Schieber, Stintzing,

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& Carle, 2001; Carle & Schieber, 2006). Thus, the reduction of moisture content after drying and subsequent transformation into flour can be a viable alternative for use of these co-products (Ferreira et al., 2015).

Oven-drying is a simple technology to dry food products using moderate temperatures, below 65 °C, with no changes in the functional properties and nutritional content of fruits and vegetables and their co-products (Martínez et al., 2012). However, the use of dried products or flours as food ingredients requires the knowledge about their functionality, i.e., the properties that affect the behavior of the biomolecules, thus interfering with their use (Mizubuti et al., 2000).

Functional properties reflect the complex interaction between the composition, structure, molecular conformation and physicochemical properties of food components together with the nature of the environment in which these are associated and measured (Kinsella, 1976).

There is a vast literature referring to studies on the characterization of flours obtained from fruit co-products, such as Oliveira et al. (2019) when evaluating flours obtained from orange co-products, Resende et al. (2019) evaluating the flour obtained from co-products of buriti and Santos et al. (2017) when studying flours obtained from pineapple co-products. However, studies that evaluate the technological properties of flours from fruit by-products are still limited.

Given the above, this study aimed to evaluate the chemical and technological characteristics of flours made from pineapple, banana, lychee, and papaya co-products and suggest possible applications in food products.

2. Material and methods

Ripe pineapple (*Ananas comosus*), banana (*Musa* sp.), and papaya (*Carica papaya*) fruits were provided by CEASA - GO (State of Goiás Supply Center), and lychee (*Litchi chinensis*) peels were provided by the ice cream company Frutos do Brasil.

2.1 Sampling

Ripe pineapple (*Ananas comosus*), banana (*Musa* sp.), and papaya (*Carica papaya*) fruits were transported in PVC (polyvinyl chloride) trays to the Laboratory of Food Chemistry and Biochemistry, Faculty of Pharmacy, Federal University of Goiás. The fruits were selected for the absence of defects, washed with mild soap and running water, sanitized with sodium

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hypochlorite solution 100 $mL.L^{-1}$ for 15 minutes, and drained. Then, they were peeled manually with a knife. Pineapple and papaya co-products (peels + residual pulp), and banana peels were packed in low-density polyethylene bags and subjected to drying and physicochemical characterization.

Previously sanitized lychee (*Litchi chinensis*) peels from pulp processing were packed in low-density polyethylene bags, and transported to the Laboratory of Food Chemistry and Biochemistry, Faculty of Pharmacy, Federal University of Goias, for drying and physicochemical characterization.

Fruit peels and co-products were dried in forced air drying oven at 55 °C to constant weight. After drying, peels were ground in micro knife mill Willye type (Tecnal, TE-648), resulting in pineapple co-product flour (FCA), banana peel flour (FCB), lychee peel flour (FCL), and papaya co-product flour (FCM).

2.2 Particle Size

The particle size of flours was determined according to the methodology described by Zanotto and Bellaver (1996), with modifications. For that, 50 g sample was sieved in a set of sieves with 1000, 710, 500, 250, 150, and 106 µm in diameter (corresponding to 16, 24, 32, 60, 100 and 150 mesh, respectively) for 10 minutes, using an electromagnetic agitator (Bertel) under constant stirring and speed. The fraction retained in each sieve was calculated using Equation 1:

$$\%R = \frac{Pr\,x\,100}{P} \qquad \text{(Equation 1)}$$

Where Pr = weight of the sample retained on each sieve, and W = weight of the initial sample.

Fineness modulus (FM), which is the sum of the fractions retained on each sieve divided by 100, was calculated using Equation 2:

$$FM = \frac{\Sigma\,(\%R\,x\,index)}{100} \qquad \text{(Equation 2)}$$

Where R% = fraction retained on each sieve, and index = fixed value decreasing from 6 to 0, following the decreasing order of aperture size.

2.3 Water activity (Aw)

The water activity of flours was determined at 25 °C using a portable analyzer (Novasina, Labswift-Aw).

2.4 Hydrogenionic potential (pH)

The hydrogen ionic potential (pH) was measured using a digital potentiometer (pHTEK, PHS-3B) calibrated with pH 4.0 and 7.0 buffer solutions, by direct immersion of the electrode into the beaker containing the sample macerated with distilled water, according to the methodology proposed by the AOAC (2012).

2.5 Titratable acidity

The titratable acidity was determined by titration with 0.1N sodium hydroxide (NaOH) using phenolphthalein as an indicator (AOAC, 2012), and the values were expressed as grams of citric acid per 100 grams of sample.

2.6 Total soluble solids

The total soluble solids content was determined at 20 °C by readings of degree Brix in digital refractometer (Reichert, AR200), according to the method proposed by AOAC (2012).

2.7 Water solubility index and milk solubility index

The solubility of flours in water and in milk was determined according to adaptations by Okezie & Bello (1988). For water solubility index, a suspension with 25 mL water and 0.5 g flour was stirred by vortexing for 1 minute and then centrifuged at 5300 rpm for 20 minutes in a centrifuge (Eppendorf 5403). To determine the milk solubility index, a suspension with 25 mL water and 0.5 g flour was stirred and centrifuged at 3000 rpm for 10 minutes at 4 °C. The supernatant was drained into a pre-weighed Petri dish and dried in an oven. The solubility index was calculated by the weight of dry solids in the supernatant expressed as a percentage of the original weight of the sample, according to Equation 3:

$$\text{Solubility} = \frac{dry\ solids\ in\ the\ supernatant\ (g)}{sample\ (g)}\ x\ 100 \qquad \text{(Equation 3)}$$

2.8 Water absorption index (WAI)

The water absorption index (WAI) of flours was determined according to adaptations by Okezie & Bello (1988). A suspension with 25 mL of water and 0.5 g flour was stirred by vortexing for 1 minute and then centrifuged at 5300 rpm for 20 minutes in a centrifuge (Eppendorf 5403). The supernatant was drained, and the remaining material was weighed. The difference between the sample weight before and after water absorption represented the amount of absorbed water. The water absorption index was calculated according to Equation 4:

$$\text{Water absorption index (WAI)} = \frac{absorbed\ water\ (g)}{sample\ (g)} \qquad \text{(Equation 4)}$$

2.9 Milk absorption index (MAI)

The milk absorption index (MAI) of flours was determined according to the methodology described in section WAI centrifuging the suspension containing 25 mL of milk and 0.5 g of sample at 3000 rpm for 20 minutes, 4 ºC. The milk absorption index was calculated according to Equation 5:

$$\text{Milk absorption index (MAI)} = \frac{absorbed\ milk\ (g)}{sample\ (g)} \qquad \text{(Equation 5)}$$

2.10 Oil absorption index (OAI)

The oil absorption index (OAI) was determined according to the methodology described in section WAI, using 25 mL of soybean oil. The oil absorption index was calculated according to Equation 6:

$$\text{Oil absorption index (OAI)} = \frac{absorbed\ oil\ (g)}{sample\ (g)} \qquad \text{(Equation 6)}$$

2.11 Statistical Analysis

The experiment was carried out in a completely randomized design. The analyses were performed in triplicate, with four replications. The results were subjected to analysis of variance (ANOVA) and Tukey`s test to compare means, with the aid of SISVAR software, using a significance level of 5%. The values were expressed as mean ± standard deviation.

3. Results and Discussion

The results of the particle size of flours and fineness modulus are presented in Table 1.

According to the fineness modulus, flours can be classified as coarse (≥ 4.10 FM), medium (FM = 3.20), fine (FM = 2.30), and very fine (FM ≤ 1.50) (Ortolan, 2006). Thus, the samples FCA, FCB, and FCL (FM = 2.67, 2.91, and 2.74, respectively) were classified as fine to medium flours, while the sample FCM (FM = 3.32) was classified as medium to coarse flour.

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Table 1. Particle size and fineness modulus of pineapple, banana, lychee and papaya peels flours.

Particle size (µm)	FCA	FCB	FCL	FCM
> 1000	2.46 ± 1.19	2.85 ± 0.47	3.76 ± 0.85	16.73 ± 1.61
710 – 1000	6.24 ± 1.27	10.09 ± 1.38	10.95 ± 0.44	15.07 ± 0.68
500 – 710	13.29 ± 0.83	18.72 ± 0.52	17.64 ± 1.30	15.25 ± 0.67
250 – 500	33.59 ± 8.37	29.86 ± 0.65	27.12 ± 0.51	21.11 ± 0.47
150 – 250	28.39 ± 8.37	22.93 ± 1.40	18.08 ± 0.78	12.61 ± 0.19
106 – 150	9.81 ± 2.23	13.13 ± 0.69	8.87 ± 0.29	6.37 ± 0.70
< 106	6.21 ± 6.63	2.42 ± 0.45	13.57 ± 1.14	12.87 ± 0.39
Fineness modulus	2.67 ± 0.14	2.91 ± 0.05	2.74 ± 0.06	3.32 ± 0.04

Values expressed as mean ± standard deviation. FCA = pineapple peel flour. FCB = banana peel flour. FCL = lychee peel flour. FCM = papaya peel flour.

Flour particle size can vary depending on the milling process, and the heterogeneity can compromise the final quality of the manufactured products (Linden and Lorient, 1994). The particle size homogeneity promotes proper and uniform cooking, and prevents hardness and partial cooking, which affect the quality of the product, both in appearance and palatability (Ramirez & Wanderlei, 1997). Although the particle size is influenced by the milling process, it can be easily standardized in the sieving step. However, Martínez et al. (2012) have emphasized that large particle sizes are more advantageous in maintaining the hydration and texture characteristics of the product.

All flours had low water activity (Aw), with values ranging from 0.21 to 0.38, as shown in Table 2. The free water, represented by the water activity, is directly related to the physicochemical and microbiological changes in foods during storage, which interferes with their conservation (Rockland & Nishi, 1980), once water molecules weakly associated with other food constituents can effectively participate in degradation reactions when compared to the strongly associated water molecules (Damodaran et al., 2010).

According to Alzamora et al. (2003), Aw values lower than 0.60 prevent microbial spoilage, once they prevent the growth of microorganisms. Thus, the samples of the present study are below the limit for microbial growth.

Table 2. Chemical characteristics of pineapple, banana, lychee and papaya peels flours.

	FCA	FCB	FCL	FCM
A_w	$0.21^d \pm 0.00$	$0.37^b \pm 0.00$	$0.38^a \pm 0.00$	$0.35^c \pm 0.00$
pH	$3.85^c \pm 0.02$	$5.84^a \pm 0.03$	$3.58^d \pm 0.03$	$4.36^b \pm 0.04$
TA (g citric acid. . 100 g^{-1})	$2.56^a \pm 0.36$	$1.36^c \pm 0.21$	$2.00^b \pm 0.11$	$2.62^a \pm 0.45$
TSS (ºBrix)	$7.24^b \pm 0.19$	$6.75^c \pm 0.60$	$3.57^d \pm 0.16$	$7.81^a \pm 0.07$

Values expressed as mean ± standard deviation. Same letters in the same line, do not differ by Tukey test ($p < 0.05$). FCA = pineapple peel flour. FCB = banana peel flour. FCL = lychee peel flour. FCM = papaya peel flour. Aw = water activity. pH = hydrogenionic potential. TA = titratable acidity. TSS = total soluble solids.

The pH of the samples are shown in Table 2 and ranged from 3.58 to 5.84, which classify the samples as acidic or slightly acidic flours. The titratable acidity values are also presented in Table 2, and ranged from 1.36 to 2.62 g citric acid 100 g^{-1}.

The acidity of the flours analyzed in this work showed a result compatible with Brazilian legislation, which establishes a maximum limit of 5% for flour acidity (Brasil, 2005). Acidity is an important quality parameter, especially because it prevents microbial growth and enzymatic reactions, which affects the stability and quality of food products, as well as influencing food flavor (Cecchi, 2003; Souza et al, 2008). During storage, the assessment of acidity enables observation of product's conservation, since the decomposition process by hydrolysis or oxidation often changes the sensory and nutritional characteristics of the product (Ferreira et al., 2015). In addition, it is an essential measurement for use of a given ingredient in pH sensitive formulations, including milk and dairy products (Sogi et al., 2013). The low acidity and water activity of flours of the present study contribute to safety and stability during storage.

With respect to the total soluble solids content (Table 2), flours presented values ranging from 3.57 to 7.81 ° Brix. In the food industry, the soluble solids content is used, mainly, in the correction of sugar levels of products, such as sweets, juices, nectar, pulps, ice cream, liquors, among others.

The results of the technological functional characteristics (Table 3) indicated that the solubility in water ranged from 17.57% to 53.52%.

Solubility index is related to the amount of soluble solids in the sample (Ferreira et al., 2015), which can be determined by comparing the solubility values in water and soluble solids content, which depends on several factors, including the chemical composition, amount of hydrophilic and hydrophobic groups on the surface, compounds to be solubilized, and

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interactions between biomolecules, and between biomolecules and water. Flours were more soluble in water than in milk, since the milk solubility indices varied from 4.46 to 11.22%. Solubility is a physical-chemical property influenced by the greater, or better, affinity of protein molecules for the solvent (Sgarbieri, 1996), which in the case of flour, was water, therefore, it is recommended to use it in products that need this characteristic, for example, liquid foods, instant soups, drinks, among others.

Table 3. Technological characteristics of pineapple, banana, lychee and papaya peels flours.

	FCA	FCB	FCL	FCM
Water solubility (%)	$41.82^{b} \pm 3.48$	$17.57^{c} \pm 0.79$	$20.28^{c} \pm 0.24$	$53.52^{a} \pm 4.16$
Milk solubility (%)	$6.55^{b} \pm 1.32$	$4.46^{b} \pm 1.31$	$5.09^{b} \pm 1.02$	$11.23^{a} \pm 2.66$
WAI ($g\ g^{-1}$)	$3.58^{b} \pm 0.30$	$6.35^{a} \pm 0.05$	$2.78^{c} \pm 0.10$	$2.16^{d} \pm 0.34$
MAI ($g\ g^{-1}$)	$5.68^{a} \pm 0.24$	$6.61^{a} \pm 0.09$	$3.19^{b} \pm 0.67$	$5.72^{a} \pm 0.84$
OAI ($g\ g^{-1}$)	$1.49^{b} \pm 0.02$	$1.51^{b} \pm 0.04$	$1.74^{a} \pm 0.10$	$1.09^{c} \pm 0.02$

Values expressed as mean ± standard deviation. Same letters in the same line, do not differ by Tukey test ($p < 0.05$). FCA = pineapple peel flour. FCB = banana peel flour. FCL = lychee peel flour. FCM = papaya peel flour. WAI = water absorption index. MAI = milk absorption index. OAI = oil absorption index.

The water absorption index (WAI) of flours ranged from 2.16 to 6.35 g. g^{-1}. Becker et al. (2014) found water absorption index of 2.76 g g^{-1} for rice flours. The WAI, which is the weight of water absorbed per weight of flour (Sogi et al., 2013) is related to the availability of hydrophilic groups to bind water molecules, gel forming ability of starch molecules (Filli & Nkama, 2007), and the hygroscopic property of fibers, which also allows water absorption (Fonseca Filho et al., 1997). High water absorption capacity of flour is desirable for use in products that require good viscosity, such as soups, sauces, and instant products (Torres et al., 1999), and those requiring hydration and moisture retention, including meat and bakery products, besides improving the product`s texture (Wang et al., 2006).

The milk absorption index (MAI) of flours ranged from 3.19 to 6.61 g.g^{-1}, higher than that found in rice flour (3.26 g.g^{-1}) by Becker et al. (2014). The MAI is important in the manufacture of dairy products, like children's instant foods or dairy desserts, once it allows rapid homogenization of the product and prevents syneresis. In the case of breakfast cereals, however, high milk absorption rates are not interesting, since one of the characteristics of these products is their crunchy texture, even when soaked in milk (Becker et al., 2014).

The oil absorption index (IAO) ranged from 1.09 to 1.74 g g^{-1}, and was similar to that found by Becker et al. (2014) in rice flours (1.75 $g.g^{-1}$). The oil absorption is related to the hydrophobic groups of the products, and the ability to trap oil in their structure (Ravi & Suselamma, 2005; Leoro, 2007). Fruit peels are rich in monosaccharides, polysaccharides, and their derivatives, such as pectin, which has many hydrophilic groups in its structure, available to bind water molecule by hydrogen bonds (Ferreira et al., 2015), which explains the greater absorption of water than of oil.

Therefore, the results indicate that flours of this study can be used satisfactorily in meat products and baking, instantaneous water-based products that require high viscosity, like soups and sauces, and also in instant milk-based foods, such as infant foods and dairy desserts since the acidity does not negatively interfere with their use.

Conclusion

The evaluation of the prepared flours showed water activity and pH favorable to the conservation of microbiological quality during storage. Flours showed higher water solubility than milk solubility, in addition to greater water and milk absorption compared to oil absorption. The results indicated potential for use in food processing. Therefore, it is suggested that future works use the flours analyzed in this study, in products such as snapshots, meat and baked goods, aiming at improving their sensory characteristics and taking advantage of agro-industrial by-products.

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References

Ajila, C. M., Aalami, M., Leelavathi, K., & Rao U. (2010). Mango peel powder: A potential source of antioxidant and dietary fiber in macaroni preparations. *Innovative Food Science and Emerging Technologies*, 11, 219–224.

Alzamora, S. M., Tapia, M. S., López-Malo, A., & Welti-Chanes, J. (2003). The control of water activity. In: Zeuthen, P., & Bogh-Sorensen, L. (Eds), *Food Preservation Techniques*. Cambridge: Woodhead Publishing.

Association of Official Analytical Chemistry. (2012). *Official methods of analysis*. (19th ed.). Gaithersburg.

Ayala-Zavala, J. F., Rosas-Domínguez, C., Vega-Vega, V., & González-Aguilar, G. A. (2010). Antioxidant enrichment and antimicrobial protection of fresh-cut fruits using their own by-products: Looking for integral exploitation. *Journal of Food Science*, 75, 175–181.

Ayala-Zavala, J. F., Vega-Vega, V., Rosas-Dominguez, C., Palafox-Carlos, H., Villa-Rodriguez, J. A., Siddiqui, M. W., Davila-Avina, J.E., & Gonzalez-Aguilar, G. A. (2011). Agro-industrial potential of exotic fruit byproducts as a source of food additives. *Food Research International*, 44, 1866–1874.

Becker, F. S., Damiani, C., Melo, A. A. M., Borges, P. R. S., & Vilas Boas E. V. B. (2014). Incorporation of buriti endocarp flour in gluten-free whole cookies as potential source of dietary fiber. *Plants Foods for Human Nutrition*, 69, 344–350.

Betoret, E., Betoret, N., Vidal, D., & Fito, P. (2011). Functional foods development: trends and technologies. *Trends in Food Science and Technology*, 22, 498–508.

Brasil. (2005). Agência Nacional de Vigilância Sanitária (ANVISA). Resolução n. 263, de 22 de setembro de 2005. Aprova regulamento técnico para produtos de cereais, amidos, farinhas e farelos. Diário Oficial da República Federativa do Brasil, Poder Executivo, Brasília – DF.

Canett-Romero, R., Ledesma-Osuna, A. I., Robles-Sánchez, R. M., Morales-Castro, R., León-Martínez, L., & León-Gálvez, R. (2004). Characterization of cookies made with deseeded grape pomace. *Archivos Latinoamericanos de Nutrición*, 54, 93–99.

Carle, R. & Schieber, A. (2006). Functional food components obtained from waste of carrot and apple juice production. *Gewinn Funct Lebensm Restst Karottensaft*, 53, 348–352.

Cecchi, H. M. (2003). *Fundamentos teóricos e práticos em análises de alimentos*, (2nd ed.). Campinas: Editora da Unicamp.

Damodaran, S., Parkin, K. L., & Fennema, O. R. (2010). *Química de alimentos* de Fennema, (4th ed.). Artmed.

Ferreira, M. S. L., Santos, M. C. P., Moro, T. M. A., Basto, G. J., Andrade, R. M. S., & Gonçalves, E. C. B. A. (2015). Formulation and characterization of functional foods based on fruit and vegetable residue flour, *Journal Food Science and Technology*, 52(2), 822–830.

Filli, K. B., & Nkama, I. (2007). Hydratation properties of extruded fura from millet and legumes. *British Food Journal*, 109, 68-80.

Fonseca Filho, A., Araújo, W., Falcirolli, D., Pilla, N., & Marques, A. (1997). Avaliação da qualidade tecnológica de pães enriquecidos com farelo de trigo. *Alimentos e Nutrição*, 8(3), 17-25.

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R., & Mcybeck, A. (2011). *Global food losses and food waste*: extent, causes and prevention. Food and Agriculture Organization of the United Nations, Rome.

Kinsella, J. E. (1976). Functional properties of protein in foods: a survey. *Journal of Food Science and Nutrition*, 7, 219-280.

Leoro, M. G. V. (2007). Desenvolvimento de cereal matinal extrusado orgânico à base de farinha de milho e farelo de maracujá (Dissertação de mestrado). Universidade Estadual de Campinas.

Linden, G., & Lorient, D. (1994). *Bioquímica agroindustrial*. Zaragoza: Acribia.

Martínez, R., Torres, P., Meneses, M. A., Figueroa, J. G., Pérez-Álvarez, J. A., & Viuda-Martos, M. (2012). Chemical, technological and in vitro antioxidant properties of mango, guava, pineapple and passion fruit dietary fibre concentrate. *Food Chemistry*, 135, 1520–1526.

Mizubuti, I. Y., Biondo Jr, O., Souza, W. O., Silva, R. S. S., & Ida, E. I. (2000). Propriedades funcionais da farinha e concentrado protéico de feijão guandu (Cajanus cajan (I.) Mill sp). *Archivos Latinoamericanos de Nutrición*, 50, 274 -280.

Okezie, B. O., & Bello, A. B. (1988). Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. *Journal of Food Science*, 53, 450-454.

Oliveira, N. A. S., Winkelmann, D. O. V. & Tobal, T. M. (2019). Farinhas e subprodutos da laranja sanguínea-de-mombuca: caracterização química e aplicação em sorvete. *Brazilian Journal of Food Technology*, 22, 1-8.

Ortolan, F. (2006). Genótipos de trigo do Paraná – Safra 2004: caracterização e fatores relacionados à alteração de cor de farinha (Dissertação de mestrado). Universidade Federal de Santa Maria.

Ramirez, J. L. A., & Wanderley, C. P. (1997). Effect de los parametros de extrusion, caracteristicas de pasta y textura de pellets (snacks de terceira generacion) producidos a partir de trigo y maiz. *Alimentaria*, 279, 93-98.

Ravi, R., & Suselamma, N. S. (2005). Simultaneous optimization of a multi-response system by desirability function analysis of boondi making: a case study. *Journal of Food Science*, 70(8), 539-547.

Resende, L. M., Franca, A. S., Oliveira, L. S. (2019). Buriti (Mauritia flexuosa L. f.) fruit by-products flours: Evaluation as source of dietary fibers and natural antioxidants. *Food Chemistry*, 270, 53-60.

Rockland, L. B., & Nishi, K. S. (1980). Influence of water activity on food product quality and stability. *Food Technology*, 4, 42-52.

Rosales Soto, M. U., Brown, K., & Ross, C.F. (2012). Antioxidant activity and consumer acceptance of grape seed flour-containing food products. *International Journal of Food Science & Technology*, 47, 592–602.

Santos, C. C. S., Guimarães, P. B., Ramos, S. A., & Capobiango M. (2017). Determination of centesimal composition of flour obtained from the bark of pineapple. *Sinapse Múltipla*, 6(2), 341-344.

Schieber, A., Stintzing, F. C., & Carle, R. (2001). By-products of plant food processing as a source of functional compounds - recent developments. *Trends in Food Science and Technology*, 12, 401–413.

Sgarbieri, V. C. (1996). *Proteínas em alimentos protéicos propriedades, degradações e modificações*. São Paulo: Varela.

Sogi, D. S., Siddiq, M., Greiby, I., & Dolan, K. D. (2013). Total phenolics, antioxidant activity, and functional properties of 'Tommy Atkins' mango peel and kernel as affected by drying methods. *Food Chemistry*, 141, 2649–2655.

Souza, P. A., Finger, F. L., Alves, R. E., Puiatti, M., Cecon, P. R., & Menezes, J. B. (2008). Conservação pós-colheita de melão Charentais tratado com 1-MCP e armazenamento sob refrigeração e atmosfera modificada. *Horticultura Brasileira*, 26, 464-470.

Sun-Waterhouse, D. (2011). The development of fruit-based functional foods targeting the health and wellness market: A review. *International Journal of Food Science & Technology*, 46, 899–920.

Torres, R. L., González, R. J., Sánchez, H. D., Osella, C. A., & Torre, M. A. G. (1999). Comportamiento de variedades de arroz en la elaboración de pan sin gluten. *Archivos Latinoamericanos de Nutrición*, 9(2), 162-165.

Yagci, S., & Gogus, F. (2009). Development of extruded snack from food byproducts: A response surface analysis, *Journal of Food Process Engineering*, 32, 565–586.

Zanotto, D. L., & Bellaver C. (1996). *Método de determinação da granulometria de ingredientes para uso em rações de suínos e aves*. Brasil: Embrapa/CNPSA.

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