

# Viability of peach palm by-product, *Spirulina platensis*, and spinach for the enrichment of dehydrated soup

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**Abstract** – The objective of this work was to develop dehydrated soup formulations using flour from peach palm by-product (PPB), *Spirulina platensis* or spinach, as well as to evaluate their composition by physical, chemical, instrumental, and sensory methods. Four formulations were developed: standard, PPB flour, PPB flour and *S. platensis*, and PPB flour and spinach. The samples were analyzed for proximate composition, chlorophyll content, total phenolic compounds, antioxidant activity, color, viscosity, water absorption, and microbiological parameters. The sensory characterization was performed by the check-all-that-apply method. The soups containing spinach or *S. platensis* presented the highest protein contents of 3.3 and 4.6 g 100 g<sup>-1</sup>, respectively. The soups formulated with the microalgae *S. platensis* showed higher contents of fibers, lipids, and antioxidants. Changes were observed in the color and viscosity of the soups. The standard dehydrated soup was characterized as shiny, creamy, with seasoning flavor and fragments, and a pale-yellow color; the formulation with spinach, as grainy, with an herb odor and flavor, seasoning fragments, and a dark-green color; and with *S. platensis*, with herb flavor, seasoning fragments, and a dark-green color. The developed formulations are within the microbiological standards for food established by the Brazilian legislation. The sensory analysis revealed a new market niche, and the soups containing PPB and *S. platensis* showed good acceptability. Peach palm flour, *Spirulina platensis*, and spinach are alternatives for the nutritional enrichment of dehydrated soups with high protein, ash, fiber, and antioxidant contents.

**Index terms:** *Bactris gasipaes*, *Spinacia oleracea*, antioxidant activity, check-all-that-apply, fibers, functional foods.

## Viabilidade de subproduto de pupunha, *Spirulina platensis* e espinafre para enriquecimento de sopa desidratada

**Resumo** – O objetivo deste trabalho foi preparar formulações de sopa desidratada com farinha de subproduto de pupunha (SPP), *Spirulina platensis* ou espinafre, bem como avaliar sua composição por meio de métodos físicos, químicos, instrumentais e sensoriais. Foram preparadas quatro formulações: padrão, farinha de SPP, farinha de SPP e *S. platensis*, e farinha de SPP e espinafre. As amostras foram avaliadas quanto a composição aproximada, conteúdo de clorofila, compostos fenólicos totais, atividade antioxidante, cor, viscosidade, absorção de água e parâmetros microbiológicos. As características sensoriais foram analisadas pelo método “check-all-that-apply”. As sopas contendo espinafre ou *S. platensis* apresentaram os maiores teores de proteína de 3,3 e 4,6 g 100 g<sup>-1</sup>, respectivamente. As sopas preparadas com a microalga *S. platensis* tiveram os maiores teores de fibras, lipídios e antioxidantes. Foram observadas diferenças na cor e na viscosidade das sopas. A sopa desidratada padrão foi caracterizada como brilhante, cremosa, com sabor e fragmentos de tempero e cor amarelo-clara; a formulação com espinafre, como granulosa, com odor e sabor de ervas, fragmentos de tempero e cor verde-escura; e a com *S. platensis*, com sabor de ervas, fragmentos de tempero e cor verde-escura. As formulações preparadas estão de acordo com os padrões microbiológicos para alimentos estabelecidos pela legislação brasileira. A análise sensorial indicou novo nicho de mercado, e as sopas com SPP e *S. platensis* mostraram boa aceitabilidade. Farinha de pupunha, *Spirulina platensis* e espinafre são alternativas para o enriquecimento nutricional de sopas desidratadas com alto teor de proteínas, cinzas, fibras e antioxidantes.

**Termos para indexação:** *Bactris gasipaes*, *Spinacia oleracea*, atividade antioxidante, check-all-that-apply, fibras, alimentos funcionais.



## Introduction

The food industry has been increasingly investigating natural compounds to enrich foods due to the trend of many consumers seeking a healthier diet. At the same time, the demand for ready-to-eat products, such as instant dehydrated soups, has grown. One of the challenges of developing functional foods is improving their quality regarding technological, nutritional, safety, and economic aspects, as well as satisfying consumer expectations in terms of sensory acceptance (Deladino et al., 2013).

Corn (*Zea mays* L.) starch is one of the main ingredients of soup formulations, being used to provide viscosity after preparation. Therefore, the partial replacement of starch by other ingredients may affect the viscosity and sensory parameters of the developed product (Patana-Anaque & Barringer, 2015).

Agro-industrial by-products are alternative ingredients in food formulations, leading to a more comprehensive use of raw materials. This is the case of the by-product of peach palm, known in Brazil as “pupunha” (*Bactris gasipaes* Kunth). Many parts of this species, representing around 84% of its weight, cannot be used for canning or minimally processed products, but can be processed into flours in order to be incorporated into food products. The flours produced have a high fiber content of 62–72% (Bolanho et al., 2014). This is important since the consumption of foods rich in fiber decreases blood lipid levels and the speed of nutrient absorption due to increasing stool and intestinal transit time, and the consumption of dietary fiber can reduce the risk of cardiovascular diseases, diabetes mellitus, colon cancer, constipation, and diverticulitis (Tharanathan & Mahadevamma, 2003).

Another species that stands out is *Spirulina platensis*, a microalga considered a source of protein, with high digestibility and an amino acid profile similar to that recommended by Food and Agriculture Organization (Gutiérrez-Salmeán et al., 2015). It presents considerable proportions of carotenoids, phycocyanins, chlorophyll, vitamins, and polyunsaturated fatty acids, including gamma-linolenic and linoleic acids (Gutiérrez-Salmeán et al., 2015). It is also a potential source of bioactive compounds, which have diverse therapeutic properties, a low nucleic acid content, and a low requirement for growth, besides being easy to separate due to their cellular dimensions (Vaz et al., 2016). The species is already consumed in many countries and is

classified by Food and Drug Administration (FDA, 2008) as generally recognized as safe.

Spinach (*Spinacia oleracea* L.) is one of the vegetables with high chlorophyll, vitamin, and mineral contents, commonly used in dehydrated soups. Due to these characteristics and its green coloration, the species was chosen for comparison with the formulations using *S. platensis* (Galla et al., 2017).

Therefore, peach palm by-product, spinach, and *S. platensis* can be used as ingredients in the formulation of soups, particularly due to their high levels of antioxidant compounds (Colla et al., 2007; Bolanho et al., 2014). These substances are capable of preventing the effects of oxidation, inhibiting lipoperoxidation, and interacting with free radicals and/or chelating metallic ions, being used to preserve the shelf life of processed foods (Franco & Martínez-Pinilla, 2017).

One of the most commonly used methods for the sensory evaluation of new products is the quantitative descriptive analysis. However, this method requires the training of assessors, which has implications in terms of costs and implementation time. Consequently, new methodologies are aiming to include consumers in the processes of development of new products, which can reduce the time and cost of the analysis (Ares et al., 2014a; Jorge et al., 2015). One of the methods that has been gaining increasing attention is check-all-that-apply (CATA), which includes the concepts of acceptability, “just about right”, and market analysis. This is an effective method in which the participants are asked to choose from a list of descriptive and subjective attributes those they consider related to the use or concept of the product, which allows a deeper analysis of its characteristics (Ares et al., 2013, 2014b; Jorge et al., 2015).

The objective of this work was to develop dehydrated soup formulations using flour from peach palm by-product, *Spirulina platensis* or spinach, as well as to evaluate their composition by physical, chemical, instrumental, and sensory methods.

## Materials and Methods

The studied soup formulations were developed and analyzed regarding their characteristics at Centro de Tecnologia Agroalimentar of Universidade Estadual de Ponta Grossa (25°5'23"S, 50°6'23"W), from March to December, 2015. Four soup formulations were

evaluated: SF, standard formulation only with corn starch; PPB, formulation with the addition of flour from peach-palm by-product; PPBSp, formulation with peach palm flour and *S. platensis*; and PPBS, formulation with peach palm flour and spinach (Table 1).

The by-product of peach palm (stem portion) and spinach were dehydrated in the MA035/5 forced-air circulation oven (Marconi Equipamentos Para Laboratórios Ltda, Piracicaba, SP, Brazil), at 60°C, for 36 hours, and then milled in the SL-31 Wiley-type mill (Solab Equipamentos para Laboratórios, Piracicaba, SP, Brazil). The ingredients used in the formulations – corn starch, maltodextrin, powdered skimmed milk, powdered egg, salt, seasoning, and dehydrated spices – were bought at a local market in the municipality of Ponta Grossa, in the state of Paraná, Brazil.

The soups were stored in 500-g polypropylene containers, wrapped in aluminum foil, and kept at room temperature until the moment of analysis. All tests were carried out in triplicate, using chemical reagents of proven purity grade.

Moisture, ash, total protein, lipid, and fiber contents were determined according to Association of Official Analytical Chemists (AOAC, 2016). Carbohydrates were calculated by difference, and the caloric value was obtained by the Atwater conversion factors (Merril & Watt, 1973). The phenolic and antioxidant compounds were extracted using the method of Van Hung (2009). Total phenolic compounds were obtained by the Folin-Ciocalteu method, as described by Swain (1959). The antioxidant potential was determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method, as in Brand-Williams (1995).

Chlorophyll pigments were extracted from 0.25-g samples, which were macerated in the presence of N,N-dimethylformamide (Cabral-Malheiros et al., 2010). The suspension was filtered in paper, and the volume was completed to 50 mL. The reading was made using the UV-Vis UVmini-1240 spectrophotometer (Shimadzu do Brasil, Barueri, SP, Brazil) at 647 and 664 nm. Total pigment concentration was calculated by applying the results from the equation: [total chlorophyll] = 7.04 A<sub>664</sub> + 20.27 A<sub>647</sub>, where A<sub>664</sub> is the absorption at 664 nm and A<sub>647</sub>, at 647 nm.

Color analysis was carried out with the MiniScan EZ colorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA) using the CIELab parameters: L\*, luminosity; a\*, red to green color; and b\*, yellow to blue color. Water activity was obtained at 25°C by direct measurement using the Aqualab Series 3 water activity meter (Aqualab, Rio de Janeiro, RJ, Brazil).

The water absorption index (WAI) and water solubility index (WSI) were determined as described by Santos et al. (2010). To assess viscosity, 17.5 g soup were added to 350 mL water following the consumption instructions for similar products, covered by a lid, and stirred at boiling temperature for 5 min; the samples were prepared for analysis in the DV-III Ultra rheometer using the Rheocalc, version 3.2, software (Ametek Brookfield, Middleboro, MA, USA). The rheological properties were measured four times in a concentric cylinder system with the SC4-31 spindle (Ametek Brookfield, Middleboro, MA, USA), at 40°C; this temperature was controlled by water circulation in the T-184 equipment (Tecnal Equipamentos Científicos, Piracicaba, SP, Brazil).

**Table 1.** Ingredients of the developed dehydrated soup formulations<sup>(1)</sup>.

Component (%)	SF	PPB	PPBSp	PPBS
Corn starch\maltodextrin	60\10	20\10	20\10	20\10
Flour of peach palm ( <i>Bactris gasipaes</i> ) by-product	-	40	40	40
Powdered skimmed milk	10	10	12	12
Powdered egg	6	6	8	8
Salt	7	7	4	4
Powdered seasoning	5	5	4	4
Dehydrated spices	2	2	2	2
Spinach ( <i>Spinacia oleracea</i> ) or <i>Spirulina platensis</i>	-	-	15	15

<sup>(1)</sup>SF, standard soup formulation with corn (*Zea mays*) starch; PPB, soup formulation with flour from peach palm (*Bactris gasipaes*) by-product; PPBSp, soup formulation with flour from peach palm by-product and *Spirulina platensis*; and PPBS, soup formulation with flour from peach palm by-product and spinach (*Spinacia oleracea*).

The soup formulations were analyzed regarding their microbiological quality according to the protocol proposed by Silva et al. (2010). The presence of total coliforms, coliforms at 45°C, *Bacillus cereus*, and *Salmonella* sp. was identified following the current legislation for this type of product (Anvisa, 2001).

For data analysis, the results expressed by mean values and standard deviation were subjected to the one-factor analysis of variance (Anova), in order to verify statistical differences, at 5% probability. Means were compared by Tukey's test to check differences between samples. The obtained data were processed using the trial version of the XLStat 2015 software (Addinsoft, 2015).

Besides the microbiological analysis of the products, the sensory analysis was performed in a controlled environment following the ISO 8589 standard (ISO, 2007), after approval by the ethics committee on research of Universidade Estadual de Ponta Grossa, under protocol number 673.493. The CATA method was applied with the aid of 65 consumers (assessors), who answered a market research questionnaire. The assessors were directed to sensory booths with white light where they received one 32-mL soup sample at a time, prepared with 10 g of each formulation and 100 mL boiling water, presented in plastic cups (Eggert & Zook, 1986) at a consumption temperature of 68°C (Kähkönen et al., 1995). The assessors were asked to evaluate the samples regarding acceptability, according to a nine-point hedonic scale: 1, extremely dislike; and 9, extremely like (Meilgaard et al., 1991). Regarding purchase intent, the samples were assessed using a five-point scale: 1, certainly would not buy; and 5, certainly would buy. The assessors were also asked to check from the following list of 24 attributes, defined by a focus group, those they considered to apply to each sample: pale-yellow color, dark-green color, shiny, opaque, grainy, creamy, fibrous, viscous, herb odor, mild odor, peach palm odor, seasoning fragments, seasoning flavor, artificial flavor, herb flavor, bitter taste, bitter aftertaste, spicy aftertaste, salty taste, peach palm taste, low quality, high quality, and healthy product (Varela & Ares, 2012; Jorge et al., 2015).

Acceptability data were evaluated by the agglomerative hierarchical analysis (AHA) to identify consumer classes according to the scores given to the assessed samples (Schilling & Coggins, 2007). The consumers were separated into groups, which were

analyzed using the one-way Anova and Fisher's least significant difference test to indicate the difference between the samples within each class, showing a market segmentation. The CATA data were subjected to Cochran's Q test and to the correspondence analysis, in order to classify the samples according to the frequency (>20%) that the attributes were selected (Meyners et al., 2013). The sensory data were analyzed using the trial version of the XLStat 2015 software (Addinsoft, 2015).

## Results and Discussion

The flour produced from the peach palm by-product, *S. platensis*, and spinach increased the nutritional value of the developed soups (Table 2), especially in the case of the formulation containing *S. platensis* (PPBSp), which had the highest protein and ash contents, followed by the one with spinach (PPBS).

The protein contents in the formulations PPB, PPBS, and PPBSp, respectively, increased 2.6, 3.3, and 4.6 times more compared with the standard. These results are in alignment with the literature, in which *S. platensis* showed a high protein content of 50–70% and spinach of 35%, both on a dry basis (Vaz et al., 2016).

Total fiber content also increased considerably in the tested formulations, in comparison with the standard. Considering the intake of a 20-g of dehydrated soup, PPBSp is a source of 3.87 g per portion of fibers and it had 10.66% of the recommended daily intake (RDI) of protein. PPBS had a high fiber content of 5.35 g per portion and supplied 8.46% of the RDI of protein.

The highest soluble fiber contents were found for PPBSp and PPBS, especially for the formulation with spinach. These fibers have functional properties, both as a thickener and gelling agent, and can be applied to dietetic supplies or functional foods (Tharanathan & Mahadevamma, 2003).

PPBSp also showed the highest lipid contents of 6.55 g 100 g<sup>-1</sup>; it is important to emphasize that the microalgae added to this formulation presented a great quantity of polyunsaturated fatty acids, including gamma linolenic and linoleic acids, which can promote benefits to cardiovascular health (Mori, 2017).

The replacement of starch by peach palm flour in PPB, PPBSp, and PPBS resulted in a decrease in moisture, which is a positive factor regarding the storage and stability of instant soups. The developed

formulations also showed a lower caloric value and total carbohydrate content than the standard soup.

Although spinach is one of the most commonly used vegetables in dehydrated soup formulations, *S. platensis* showed a similar quantity of chlorophyll content and a higher nutritional value (Vaz et al., 2016). In the present study, a higher chlorophyll content was found in PPBSp, compared with PPBS. This pigment is important for the metabolism of microalgae and it shows beneficial biological activity, with antioxidant, anti-carcinogenic, anti-inflammatory, anti-obesity, and neuroprotective properties (Vaz et al., 2016).

The content of total phenolic compounds increased with the addition of the flour from the peach palm by-product, *S. platensis*, and spinach to the soups, compared with the standard (Table 3). Deladino et al. (2013) also observed an increase in the phenolic compounds of instant soups when encapsulated yerba mate (*Ilex paraguariensis* A.St.-Hil.) was added.

The antioxidant potential determined by the DPPH method was also greater in the PPB, PPBSp, and PPBS formulations, showing that it is possible to increase the antioxidant potential of dehydrated soups by

**Table 2.** Proximate composition, calorific value, chlorophyll content, total phenolic compounds, and antioxidant activity of the developed dehydrated soup formulations<sup>(1)</sup>.

Composition	Dehydrated soup formulations <sup>(2)</sup>			
	SF	PPB	PPBSp	PPBS
Moisture (g 100 g <sup>-1</sup> )	8.11±0.06a	6.97±0.09b	6.84±0.08b	6.89±0.03b
Protein (g 100 g <sup>-1</sup> )	6.02±0.28d	15.84±0.32c	27.64±0.32a	20.14±0.08b
Lipids (g 100 g <sup>-1</sup> )	5.69±2.30b	5.11±0.62c	6.55±2.44a	5.52±0.22b
Ash (g 100 g <sup>-1</sup> )	7.67±0.04d	12.64±0.07c	14.83±0.02b	16.19±0.18a
Insoluble dietary fiber (g 100 g <sup>-1</sup> )	0.46±0.01d	8.37±0.01c	12.98±0.01b	20.95±0.01a
Soluble dietary fiber (g 100 g <sup>-1</sup> )	1.16±0.01b	1.32±0.01b	6.39±0.01a	5.80±0.01a
Total dietary fiber (g 100 g <sup>-1</sup> )	1.62	9.69	19.37	26.75
Carbohydrates different from fibers (g 100 g <sup>-1</sup> )	70.89	49.75	24.77	24.51
Caloric value (kcal 100 g <sup>-1</sup> )	358.85	308.35	242.99	237.24
Chlorophyll (mg g <sup>-1</sup> )	-	-	7.82±1.18a	4.22±2.15b
Total phenolic compounds (mg gallic acid 100 g <sup>-1</sup> )	45.31±1.26d	124.51±10.39c	172.20±3.48b	214.21±14.60a
DPPH (μmol Trolox g <sup>-1</sup> ) <sup>(3)</sup>	0.27±0.05c	0.42±0.04b	0.54±0.06ab	0.59±0.04a

<sup>(1)</sup>Means followed by equal letters, in the lines, do not differ by Tukey's test, at 5% probability. <sup>(2)</sup>SF, standard soup formulation with corn (*Zea mays*) starch; PPB, soup formulation with flour from peach palm (*Bactris gasipaes*) by-product; PPBSp, soup formulation with flour from peach palm by-product and *Spirulina platensis*; and PPBS, soup formulation with flour from peach palm by-product and spinach (*Spinacia oleracea*). <sup>(3)</sup>Antioxidant activity by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method.

**Table 3.** Water absorption index (WAI), water solubility index (WSI), water activity, viscosity, and color parameters of the developed dehydrated soup formulations<sup>(1)</sup>.

Parameter	Dehydrated soup formulations <sup>(2)</sup>			
	SF	PPB	PPBSp	PPBS
WAI (g 100 g <sup>-1</sup> )	1.86±0.01c	4.49±0.18b	4.76±0.08a	4.34±0.12b
WSI (g 100 g <sup>-1</sup> )	40.99±0.82a	35.24±2.57c	40.46±0.74a	38.58±0.26b
Water activity	0.400±0.002c	0.465±0.003ab	0.442±0.003b	0.472±0.005a
Viscosity (mPA s <sup>-1</sup> )	71.43±11.27a	47.50±4.38b	17.26±2.96c	11.57±2.33c
L*	65.08±0.49a	66.60±1.06a	54.58±0.19b	45.95±0.53c
a*	0.37±0.04a	0.26±0.02b	-0.91±0.03d	-1.64±0.10c
b*	14.45±0.38a	9.40±0.13b	15.37±0.18a	10.24±0.35b

<sup>(1)</sup>Means followed by equal letters, in the lines, do not differ by Tukey's test, at 5% probability. SF, standard soup formulation with corn (*Zea mays*) starch; PPB, soup formulation with flour from peach palm (*Bactris gasipaes*) by-product; PPBSp, soup formulation with flour from peach palm by-product and *Spirulina platensis*; and PPBS, soup formulation with flour from peach palm by-product and spinach (*Spinacia oleracea*). L\*, luminosity; a\*, red to green color; and b\*, yellow to blue color.

incorporating different ingredients into them. This fact is important, because antioxidants are compounds that can interact with free radicals, which are unstable molecules whose increase is associated with several diseases, raising the product's potential to prevent, for example, neurodegenerative diseases, some kinds of cancer, arteriosclerosis, and aging effects (Franco & Martínez-Pinilla, 2017). The most commonly known antioxidant compounds include: ascorbic acid, tocopherols, carotenoids, chlorophyll, and a variety of phenolic compounds that can be found in vegetables and microalgae (Lanfer-Marquez et al., 2005). These results, together with a high fiber content (Table 2), are indicative that these products, particularly PPBSp and PPBS, have the potential to be considered as functional foods.

The microbiological analyses did not show the growth of the investigated microorganisms, as observed by the obtained results: absence of total coliforms, most probable number per gram of coliforms at 45°C  $\leq 3$ , absence of *B. cereus* in colony-forming unit per gram, and absence of *Salmonella* sp. in 25 g. These results are in alignment with resolution RDC No. 12 adopted in January 2001 regarding soups, broths, and stews (Anvisa, 2001); therefore, the developed soups are considered suitable for consumption.

Regarding the technological properties of the soups (Table 3), there was an increase in the WAI of PPB, PPBSp, and PPBS compared with the standard. This was due to the high fiber and protein contents in these formulations, as these molecules have polar or charged groups that are capable of water association (Malucelli et al., 2015). It should be noted that the WAI influences the functionality and sensory properties of processed products (Sreerama et al., 2012). The WSI is related to

sugar and soluble protein contents (Kühn et al., 2006), which were similar in SF and PPBSp, but lower in the other formulations.

The water activity values in the formulations varied from 0.400 to 0.472, which are considered inadequate for the development of most microorganisms, as also verified in the microbiological analysis. This aids in the maintenance of the shelf-life stability of the developed products (Leistner & Gorris, 1995).

The highest apparent viscosity was found for SF, which also had the highest starch amount (60%) and the lowest fiber content (1.62%), compared with the formulations in which starch was partially replaced by peach palm flour. Low viscosity values were observed for PPBSp and PPBS, which had higher fiber contents than the other formulations. Previous studies showed that the use of fibers containing cellulose can decrease apparent viscosity (Malucelli et al., 2015).

The color of the soups was affected by the addition of spinach or *S. platensis* (Table 4), which are dark-green ingredients due to the presence of chlorophyll. This caused a decrease in luminosity ( $L^*$ ) in the PPBSp and PPBS samples. In the case of *S. platensis*, which only has chlorophyll a with a greater heat stability, its dark-green color was maintained after the addition of hot water. It should be pointed out that chlorophyll is considered a bioactive compound, decreasing the risk of several diseases (Lanfer-Marquez et al., 2005; Tańska et al., 2017).

A Brazilian study showed that consumers expect soup to be creamy and homogeneous (Santos et al., 2010). The correlation of these physical parameters, measured by instrumental equipment, and consumer acceptability can be determined through the sensory analysis of the products. The hedonic means indicated

**Table 4.** Hedonic scores for acceptability by and purchase intent of the different classes of consumers for the developed dehydrated soup formulations<sup>(1)</sup>.

Sample <sup>(2)</sup>	Acceptability without consumer segmentation	Acceptability of two segmentation classes		Purchase intent	
		Class 1	Class 2	Class 1	Class 2
SF	6.83a	6.75a	7.00a	3.86a	4.13a
PPB	4.54b	3.72b	6.18a	2.16b	3.32b
PPBSp	4.17b	3.16b	6.23a	2.02b	3.32b
PPBS	4.18b	3.77b	4.95b	2.00b	2.60c
p-value	<0.01	<0.01	<0.01	<0.01	<0.01

<sup>(1)</sup>Means followed by equal letters, in the columns, do not differ by Tukey's test, at 1% probability. <sup>(2)</sup>SF, standard soup formulation with corn (*Zea mays*) starch; PPB, soup formulation with flour from peach palm (*Bactris gasipaes*) by-product; PPBSp, soup formulation with flour from peach palm by-product and *Spirulina platensis*; and PPBS, soup formulation with flour from peach palm by-product and spinach (*Spinacia oleracea*).

that SF had the highest acceptability (SF = 6.83) compared with the other formulations (PPB = 4.54, PPBS = 4.17, and PPBSp = 4.18), which did not differ significantly ( $p > 0.01$ ) from each other (Table 4). For a deeper analysis, hedonic tendencies were used to determine the different behavior of consumers by the AHA, indicating market segmentation. It was observed that the two formed groups (consumer classes) gave similar scores to the standard samples, but different ones to the other three formulations. The first class showed a lower acceptability of the PPB and PPBSp soups, and the second of PPBS.

According to the hedonic scores for the samples, the first class, which contained 66% of the consumers, showed good acceptability of and purchase intent for SF (Table 4), which were both low for the other formulations. The second class, which comprised 33% of the consumers, had good acceptability of the products, except of PPBS; therefore, this class can be considered a new market niche for *S. platensis* and peach palm flour soups. Since the purchase intent score was also higher for this class, it can also be a good market niche for the other developed products.

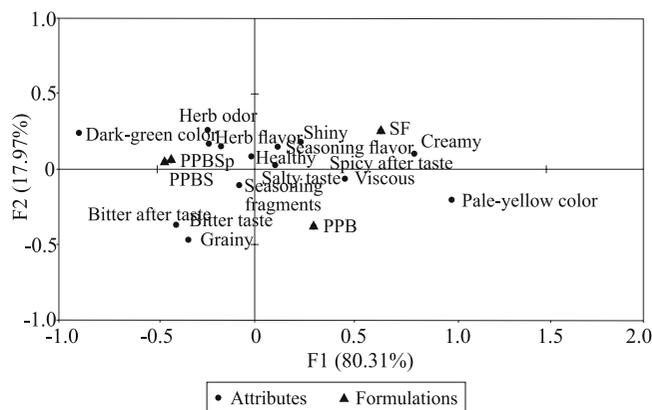
Out of 24 attributes, only 15 were selected at a frequency higher than 20% and were considered for Cochran's Q test (Figure 1). The attributes salty taste and healthy product were not significant ( $p = 0.7219$  and  $p = 0.5839$ , respectively) and did not differ between formulations. The samples were characterized by the graph generated by the correspondence analysis (Figure 1), which explained 98.28% of data variability. This means that the attributes have a good correspondence to the samples, which may be characterized without the use of a trained panel (Ares et al., 2013).

The pale-yellow color attribute was not included in the list for the samples with *S. platensis* and spinach, due to their dark-green color. The attribute seasoning fragments was ticked by 75% of the testers to characterize the samples SF, PPBSp, and PPBS, which differed significantly from the standard. SF contained a higher amount of starch (Table 1), which masked the perception of seasoning and gave it a shiny appearance. PPB showed a high frequency of the grainy attribute, which was due to an excess of fiber (Table 2). It was concluded that the presence of dehydrated vegetables increases the dark-green color and bitter taste of the soup, and also decreases viscosity and seasoning perception (Park & Lee, 2007).

The spinach soup was considered to have an herb flavor and odor, differing significantly from the other formulations (Figure 1). The PPB, PPBSp, and PPBS samples showed a bitter taste and aftertaste, being similar to each other but differing from the standard. Therefore, the choice of herbs should be monitored, since the use of ingredients with a pronounced flavor can alter consumer acceptability (Ghawi et al., 2014). These authors also found that, although every individual has a different perception of products, when used in the correct amount, herbs have been shown to increase the acceptability of low-salt soups.

The attribute creamy was frequently checked for the standard sample (SF) and the control (PPB) (Figure 1). According to the assessors, the addition of spinach and *S. platensis* decreased creaminess, compared with the other formulations. The textural differences between the control and *S. platensis* soups can be correlated with the perception of the added spices, which was not the case for the standard soup that contained more starch. Therefore, those ingredients can cause a bias in sensory perception (Patana-Anake & Barringer, 2015).

The attributes used by the testers to characterize the soups were: shiny, seasoning flavor, spicy aftertaste, viscous, creamy, and pale-yellow color for SF; pale-yellow color, viscous, grainy, bitter taste, and seasoning



**Figure 1.** Correspondence analysis for significant attributes of the developed dehydrated soups formulations. SF, standard soup formulation with corn (*Zea mays*) starch; PPB, soup formulation with flour from peach palm (*Bactris gasipaes*) by-product; PPBSp, soup formulation with flour from peach palm by-product and *Spirulina platensis*; and PPBS, soup formulation with flour from peach palm by-product and spinach (*Spinacia oleracea*).

fragments for PPB; bitter taste and aftertaste, dark-green color, and seasoning fragments for PPBSp; and herb odor and flavor, dark-green color, seasoning fragments, and bitter taste for PPBS.

By using specific marketing strategies, the enriched soups developed in the present study can reach the market niche that values functional foods due to their health benefits, as shown by the results obtained for the second class of consumers (Table 4). Due to the low acceptability of the soups with spinach, *S. platensis*, and peach palm flour, additional studies are necessary to monitor the types and quantities of seasoning to be used in order to improve the acceptability of these formulations.

### Conclusions

1. Peach palm (*Bactris gasipaes*) by-product flour, *Spirulina platensis*, and spinach (*Spinacia oleracea*) are alternatives for the nutritional enrichment of dehydrated soups with high protein, ash, and fiber contents.

2. The soups developed with *S. platensis* and spinach can be considered a source of bioactive compounds due their high chlorophyll content and antioxidant activity.

3. The partial replacement of starch by flour of peach palm by-product, rich in fibers, modifies the color, viscosity, water absorption, and solubility of the developed soup formulations.

4. The conditions in which the soup formulations were developed allow obtaining safe products regarding microbiological aspects according to the current Brazilian legislation.

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