Protein-enriched umbu (Spondias tuberosa) jam prepared by supplementation with Spirulina sp. LEB-18

Geleia de umbu (S. tuberosa) enriquecido com proteínas pela adição de Spirulina sp. LEB-18

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ABSTRACT
We developed a protein-enriched umbu (S. tuberosa) jam by adding Spirulina sp. LEB-18 to it to improve its nutritional value. Three formulations were developed: UJ1 (jam without Spirulina), UJ2spirulina (jam with 1.0% Spirulina), and UJ3spirulina (jam with 1.4% Spirulina). Physicochemical properties, chemical composition, and sensory acceptance were determined. Jam products were deemed to be stable and safe for consumption because their water activity (Aw; 0.58–0.61), pH (2.60–3.42), and total titratable acidity (14.59–22.27%) values were considered to prevent the growth of microorganisms. There were statistically significant differences in these parameters, except for the Aw, among the umbu jams with Spirulina. The moisture content was lower in the jams produced (10.66–16.79%) than in commercial formulations, but the energy value (332.91–358.87 kcal/100 g) was higher when compared to other studies. In this study, the most significant result was that the supplementation of umbu jam with 1.0% and 1.4% of Spirulina statistically significantly increased the amount of protein (136–232%) and total ash (96–235%). Furthermore, the acceptability indices for UJ1, UJ2spirulina, and UJ3spirulina were 81.3, 78.0, and 75.3%, respectively, and therefore, they were considered as acceptable products (over 70%). Thus, the results indicate that supplementation with Spirulina sp. LEB-18 may improve the nutritional value of food and provide health benefits when incorporated into different food industry products, especially as a protein-enriched functional food ingredient.

Keywords: Umbu product. Physicochemical properties. Enrichment nutritional. Sensory acceptance.
RESUMO
Desenvolvemos um atolamento de umbu enriquecido com proteínas (S. tuberosa) adicionando Spirulina sp. LEB-18 para melhorar seu valor nutricional. Foram desenvolvidas três formulações: UJ1 (geléia sem espirulina), UJ2spirulina (geléia com 1,0% de espirulina) e UJ3spirulina (geléia com 1,4% de espirulina). Propriedades físico-químicas, composição química e aceitação sensorial foram determinadas. Os produtos de geleia foram considerados estáveis e seguros para o consumo, porque seus valores de atividade da água (Aw; 0,58-0,61), pH (2,60-3,42) e acidez titulável total (14,59-22,27%) foram considerados para impedir o crescimento de microorganismos. Houve diferenças estatisticamente significantes nesses parâmetros, com exceção do Aw, entre as geleias de umbu com Spirulina. O teor de umidade foi menor nas geleias produzidas (10,66 a 16,79%) do que nas formulações comerciais, mas o valor energético (332,91 a 358,87 kcal / 100 g) foi maior quando comparado a outros estudos. Neste estudo, o resultado mais significativo foi que a suplementação de geleia de umbu com 1,0% e 1,4% de Spirulina aumentou estatisticamente significativamente a quantidade de proteína (136-232%) e cinzas totais (96-235%). Além disso, os índices de acetabilidade para UJ1, UJ2spirulina e UJ3spirulina foram 81,3, 78,0 e 75,3%, respectivamente, e, portanto, foram considerados produtos aceitáveis (acima de 70%). Assim, os resultados indicam que a suplementação com Spirulina sp. O LEB-18 pode melhorar o valor nutricional dos alimentos e proporcionar benefícios à saúde quando incorporado a diferentes produtos da indústria de alimentos, especialmente como ingrediente funcional funcional enriquecido em proteínas.

Palavras-chave: Umbu product. Propriedades físico-químicas. Enriquecimento nutricional. Aceitação sensorial.

1 INTRODUCTION
Brazil is one of the main fresh fruit producers worldwide because of its favorable climatic conditions. Some recent studies have shown that the biomes of the Brazilian territory include a variety of native and exotic species that could be used in food (Souza et al., 2018; Teixeira et al., 2019) to improve its nutritional value and provide health benefits owing to the presence of a great diversity of bioactive chemical compounds (Paz et al., 2015). However, information on this potential of some species is not only limited, but completely absent. In addition, Brazil has a natural abundance of tropical fruits, but only a few species are available to consumers (Teixeira et al., 2019).

Some researchers have indicated that one of the reasons is the lack of knowledge about the properties of native species and the poor scientific evidence on their biological effects. Thus, studies characterizing the composition of under-explored species, defining their nutritional value as a source of nutrients, and demonstrating their possible health benefits are required (Biazotto et al., 2019). In support, the intake of fruits and vegetables has been shown to reduce the incidence and mortality risk caused by various chronic diseases, especially
cardiovascular diseases and cancers. This effect has been attributed to the antioxidant activity exerted by bioactive compounds (Aune et al., 2017).

One recent study has shown that the biodiversity in Brazilian fruit provides numerous secondary metabolites and has immense nutritional and nutraceutical potential, mainly in the food and pharmaceutical industries. In a previous study, the researchers identified fifty-one phenolic compounds, eight iridoids, twenty-three carotenoids, and two anthocyanins in nine fruits (Cambuci, pitanga, cagaita, jabuticaba, araçá, jatobá, mangaba, pequi, and jenipapo), but they showed that there are still few studies that detail the composition of these fruits (Biazotto et al., 2019).

In this sense, the umbu (Spondias tuberosa Arruda Camara) fruit is under-explored, and knowledge about its properties is still unsatisfactory.

The species popularly known as “umbuzeiro” or “umbu” belongs to the Anacardiaceae family and is a native and endemic species distributed throughout northeast and southeast Brazil. The umbu fruits are consumed as fresh fruits or used to make pulp, juices, sweets, jellies, and ice cream. Currently, the production of the fruit is totally extractivist, with the state of Bahia being considered the largest national producer (76%), and its commercialization is incipient (Oliveira et al., 2018).

The umbu fruit is 2-3.5 cm long and weighs 10-20 g; it is round, ovoid, or oblong in shape and greenish yellow in color when ripe, with a thin skin and a large seed. The pulp is soft, juicy, and has a bitter-sweet taste. Regarding its physicochemical properties, it has a pH of 2.90–3.30, total titratable acidity (TTA) between 0.95–1.13%, and total soluble solids (TSS) content of 8.9–10.2% Brix. Concerning the proximal composition, the moisture content is 85.38–88.57% and contents of lipids, proteins, crude fiber, reducing sugars, and carbohydrates are 0.81–0.89%, 0.24–0.38%, 0.97–1.09%, 3.37–6.63%, and 3.37–6.63%, respectively (Narain et al., 1992).

Microalgae have been used in human nutrition for thousands of years (Tang et al., 2020). Therefore, in this study, Spirulina LEB-18 was used to improve the nutritional quality of the jam-product made from the umbu fruit. Recently, many studies have used microalgae in formulations for the same purpose because of their nutritional attributes that are considered important (Adiba et al., 2011; Çelekli et al., 2019; Grahl et al., 2020; Lucas et al., 2018). In particular, the production of high concentrations of protein during microalgae development has been highlighted (Ravindran et al., 2016).
Given the above, native and/or exotic Brazilian fruits, including the umbu fruit, have great nutritional and economic potential, but it is necessary to obtain information about this species to promote its beneficial use and to generate income for local producers. Therefore, the aim of this study was to develop a protein-enriched umbu (*Spondias tuberosa*) jam in combination with *Spirulina* sp. LEB-18 to improve its nutritional value.

2 MATERIAL AND METHODS

2.1 RAW MATERIALS

The umbu fruits (*S. tuberosa* Arr. Cam.) were obtained from the São Joaquim market, located in the city of Salvador (12°57′ 07″ S 38°30′ 06″ W, BA, Brazil). The *Spirulina* sp. LEB-18 used in this study was cultivated on one pilot plant in northeast Brazil (12°58′16″ S, S/38°30′30″W, Salvador, BA, Brazil). Outdoor cultivation was carried out in a raceway tank, and all the experimental conditions were as described by Jesus *et al.* (2018). Sucrose, pectin, and citric acid reagents were purchased from Rica Nata® (Indústria e Comércio Ltda, Piracema, MG, Brazil).

2.2 JAM FORMULATION AND EXPERIMENTAL DESIGN

Fully ripened fruits were selected and imbibed in distilled water at 95 °C for 10 min, and subsequently, the seeds were manually removed. The umbu extract consisted of the fruit peel and pulp. The umbu jam formulation consisted of the extract 60 g/100 g, sucrose 34.5 g/100 g, pectin 0.5 g/100 g, and citric acid 5 g/100 g. The extract and sugar were first mixed with water and heated to 95°C, followed by addition of the other minor ingredients. Then, the material was maintained at this temperature and manually stirred until the final product was generated with 65-68 °Brix value, using a digital refractometer at 25 °C (HI 96801, Hanna Instruments®, Rhode Island, USA). Afterwards, 1.0% and 1.4% (w/w) Spirulina was added to produce the final UJ2spirulina and UJ3spirulina products, respectively. The jams were stored in glass jars under refrigeration (8 °C) (Amorim *et al.*, 2019). Some samples were directly analyzed to determine and quantify the proximate composition, and others were used for consumer testing (**Figure 1**).
Figure 1 – Steps for the preparation of umbu jams with or without *Spirulina* sp. LEB-18 supplementation

2.3 PHYSICOCHEMICAL PROPERTIES

Water activity (Aw) was determined using an Acqualab Lite instrument (3TE, Decagon® Devices, São José dos Campos, Brazil). The pH was determined by potentiometry using a pHmeter (PHS-3D, Bridgesi Instruments, Hefei, China) at 25 °C, TTA was determined by titration analysis, and the TSS content (Brix) was measured using a Brix refractometer (ITREF95, Instrutemp, São Paulo, SP, Brazil) at 25 °C.

2.4 ANALYSIS OF CHEMICAL COMPOSITION

The moisture content was determined by drying at 105 °C to a constant weight. The total protein content was calculated by multiplying the total nitrogen content obtained by the Kjeldahl method by the coefficient 6.25. The ash content was obtained by calcination of the sample in an oven at 550 °C, during 6 h. The total lipid content was estimated according to the proportion of the fruit used in the Umbu jam preparation, and the carbohydrate content was estimated by calculating the percent remaining after all the other components had been measured (% carbohydrates = 100 − [moisture + protein + lipid + ash]) (AOAC, 2000).
2.5 OVERALL ACCEPTANCE TEST

The protocol of the acceptance test was approved by the Ethics Committee of the Federal University of Rio Grande under the protocol (CAAE n° 1.525.184). All the subjects were properly informed of the objectives of the research and gave signed consent for their participation. A total of 40 Brazilian consumers (aged between 18 and 50 years old, from both genders) evaluated the three samples in the Sensory Analysis Laboratory at the School of Pharmacy of the Federal University of Bahia (Salvador, Brazil).

Umbu jams were served in 5 g samples in dishes coded with three-digit random numbers, using the sequence without and with Spirulina. In addition, water and unsalted crackers were available to clean the palate. Acceptability was assessed using a 9-point structured scale anchored at the extremes by “disliked very much” and “liked very much” (Teixeira, 2009).

2.6 STATISTICAL ANALYSES

The means of the results were evaluated using one-way analysis of variance (ANOVA). For multiple comparisons, the Tukey's test was used (SigmaStat®, v. 3.5, Systat software, California, USA). The significance level was set at p ≤ 0.05. All results are expressed as the mean ± standard deviation of the results obtained from least three independent analyses.

3 RESULTS AND DISCUSSION

In this study, we determined the physicochemical properties, chemical composition, and sensory acceptance of the umbu jams prepared with or without supplementation (0.0, 1.0, and 1.4%) of Spirulina sp. LEB-18, with the aim of producing a value-added product—protein-enriched jam.

Umbu jam was prepared using the edible parts of the fruit, the peel, and pulp (Figure 1). Besides, Spirulina was added with the objective of improving the nutritional and functional properties of the jam-product (Adiba et al., 2011; Çelekli et al., 2019; Grahl et al., 2020). Generally, the industrialized products, such as jellies, are composed of high amounts of sucrose, they are considered nutritionally poor (Naeem et al., 2017).

Studies have shown that frequent consumption of these products that are considered to be ultra-processed, such as soft drinks, processed juices, cookies, candies, ready-made spices, and jams, increase the risk of diseases (Lawrence and Baker, 2019; Srour et al., 2019; Vandevijvere et al., 2019). Furthermore, they are associated with one or more behavioral risk factors including high consumption of unhealthy diet rich in saturated fat, salt, and sugar and
low consumption of fruits, vegetables, and grains; less physical inactivity; smoking; and excessive alcohol use (Aune et al., 2017).

Previous studies have explored the use of microalgae in food in order to improve the nutritional attributes of products (Grahl et al., 2020; Lucas et al., 2018). This is because more recent studies have shown the presence of a great variety of bioactive chemical compounds (Seghiri et al., 2019; Tang et al., 2020). In addition, microalgae have the characteristic of accumulating high amounts of protein during their development (Ravindran et al., 2016). In the present study, 1 or 1.4% dry Spirulina was added at the end of the preparation of umbu jam.

It is well established in the literature that some physical-chemical parameters of foods/products are essential for preserving the sensory and nutritional properties of the food and for preventing the growth of microorganisms (Amit et al., 2017; Veld, 1996). Therefore, Aw, pH, TTA, and TSS of jams were determined (Table 1).

Table 1 – Water activity, pH, total titratable acidity, and total soluble solids of the umbu jams prepared with or without Spirulina sp. LEB-18 supplementation†

| Parameters* | UJ1  | UJ2_spirulina | UJ3_spirulina |
|-------------|------|---------------|---------------|
| Water activity | 0.61 ± 0.03 | 0.59 ± 0.02 | 0.58 ± 0.04 |
| pH           | 2.60 ± 0.05<sup>c</sup> | 2.98 ± 0.06<sup>b</sup> | 3.42 ± 0.10<sup>a</sup> |
| Titratable total acidity (%) | 22.27 ± 0.23<sup>c</sup> | 18.41 ± 0.43<sup>b</sup> | 14.59 ± 0.30<sup>c</sup> |
| Total soluble solids (ºBrix) | 62.30 ± 0.29<sup>c</sup> | 64.80 ± 0.25<sup>b</sup> | 68.10 ± 0.10<sup>a</sup> |

*The values (mean ±SE) correspond to averages from three replicates. †Different letters in the same line indicate significant differences between the values (p < 0.05) by Tukey’s test. UJ1, umbu jam without Spirulina, UJ2_spirulina, umbu jam with 1% of Spirulina, UJ3_spirulina, umbu jam with 1.4% of Spirulina.

Jam products are considered safe as far as the development of most bacteria is concerned when their water activity is lower than 0.86 (Amit et al., 2017). In this study, the Aw values of the umbu jams were between 0.58–0.61, which do not allow the growth of microorganisms. However, other studies have reported Aw ranging between 0.92 and 0.96 in low-calorie jams produced from tomato pomace (Belović et al., 2017) and grape peel extract jam (Amorim et al., 2019), which is especially high for products in which sucrose is substituted with other sweeteners. The pH (2.60–3.42) and TTA (14.59–22.27%) values are considered safe, since the high acidity prevents the growth of microorganisms (Touati et al., 2014), but they may allow chemical and enzymatic reactions. Studies on jam produced with different fruits have found variable pH values, as has been observed in grape peel extract jam (3.25–3.91) (Amorim...
et al., 2019), acerola pulp and juice jam (3.42–3.48) (Caetano et al., 2012), tomato pomace low calorie jam (3.50–3.57) (Belović et al., 2017), and in reduced sugar sapodilla jam (5.40) (Shinwari and Rao, 2020). TSS values ranging between 62.3 and 68.10° Brix, are in accordance with the technical recommendations for this type of product.

There were statistically significant differences \((p < 0.05)\) between the umbu jams in terms of pH, TTA, and TSS values, except for the Aw parameter. These differences are attributed to the addition of Spirulina. Although the pH of the umbu fruit is within the acidic range (2.50–2.82), the optimum pH for microalgae growth is between 9.1 and 10.2 (Jesus et al., 2018). Therefore, the supplementation of Spirulina in the formulation led to a reduction in the values of the acidity parameters (pH and TTA). Evidently, the addition of biomass led to an increase in TSS values \((p < 0.05)\), as shown in Table 1. Moreover, the results for the jams used in this study were similar to those for commercial apricot jam (64.42%) (Touati et al., 2014) and acerola pulp and juice jam (66.92–67.97%) (Caetano et al., 2012), but higher than those for reduced-sugar sapodilla jam (23.17%) (Shinwari and Rao, 2020), tomato pomace low calorie jam (24.26–48.33%) (Belović et al., 2017), and grape peel extract jam (39–43.02%) (Amorim et al., 2019).

The moisture, protein, total ash, total lipids, carbohydrates, and energy values of the umbu jams prepared with or without Spirulina are presented in Table 2. The umbu jam had the lowest moisture content (10.66–16.79%) when compared (29.79–69.46%) with that in other formulations (Amorim et al., 2019; Caetano et al., 2012; Shinwari and Rao, 2020). In general, low levels of moisture in foods indicates a higher shelf life. In this study, the total carbohydrate content (78.28–87.56%) and energy value (332.91–358.87 kcal/100 g) were considered high when compared with those in tomato pomace low calorie jam (17.23–43.81%; and 87.10–193.7 kcal) (Belović et al., 2017), grape peel extract jam (45.19%; and 177.80 kcal) (Amorim et al., 2019), acerola pulp and juice jam (54.38–60.88%) (Caetano et al., 2012), and commercial fruit (Grape, apricot, blueberry and strawberry) jams (65.99–67.65%; and 266.16–273.89 kcal) (Naeem et al., 2017), respectively. In contrast, it was observed that supplementation of umbu jam with Spirulina led to a decrease in the amount of total carbohydrates and calories; this result was statistically significant \((p < 0.05)\) only in the UJ3Spirulina jam.

The total lipid (0.51%), ash (0.26%), and protein (1.01%) content found in the umbu control jam (UJ1) was the same as those reported in other studies (Amorim et al., 2019; Belović et al., 2017; Naeem et al., 2017). All the common ingredients used in the formulation
The amounts of protein (136% – 232%) and total ash (96% – 235%) were significantly higher ($p < 0.05$) in umbu jam supplemented with 1.0 and 1.4% of *Spirulina*, respectively, than in umbu jam without *Spirulina* (Table 2).

In the present study, the amounts of protein (2.38% and 3.35%) and total ash (0.51% and 0.87%) in the UJ2Spirulina and UJ3Spirulina, respectively, were considered higher than the amounts of protein and total ash in commercial jams of grape (0.27% and 0.18%), apricot (0.43% and 0.25%), blueberry (0.31% and 0.12%), strawberry (0.41% and 0.23%) (Naeem *et al.*, 2017), tomato pomace low-calorie jam (protein 1.32–2.03%) (Belović *et al.*, 2017), and grape peel extract jam (1.21% and 0.29%) (Amorim *et al.*, 2019).

Table 2 – Proximate composition of the umbu jams prepared with or without *Spirulina* sp. LEB-18 supplementation†

| Parameters (g/100g)* | UJ1       | UJ2Spirulina | UJ3Spirulina |
|----------------------|-----------|-------------|-------------|
| Moisture             | 10.66 ± 0.01b | 11.39 ± 0.01b | 16.79 ± 0.01a |
| Protein              | 1.01 ± 0.02c | 2.38 ± 0.11b | 3.35 ± 1.27a  |
| Total ash            | 0.26 ± 0.01a | 0.51 ± 0.00b | 0.87 ± 0.02c  |
| Total lipids         | 0.51 ± 0.03c | 0.59 ± 0.03b | 0.71 ± 0.04a  |
| Carbohydrates        | 87.56 ± 0.53b | 85.13 ± 0.46b | 78.28 ± 0.28a |
| Energy (Kcal)        | 358.87 ± 1.90a | 355.35 ± 1.63a | 332.91 ± 0.91b |

*The values (mean ±SE) correspond to averages from three replicates. †Different letters in the same line indicate significant differences between the values ($p < 0.05$) by Tukey’s test. UJ1, umbu jam without *Spirulina*. UJ2Spirulina, umbu jam supplemented with 1% of *Spirulina*. UJ3Spirulina, umbu jam supplemented with 1.4% of *Spirulina*.

Previous studies have shown that the dry matter of *Spirulina* sp. LEB-18, which was also used in this study, stands out for its content of protein (53% –76%), total ash (10.21–19.35%), and other bioactive compounds (Jesus *et al.*, 2018; Seghiri *et al.*, 2019). In addition, many studies have described the supplementation of several products with microalgae to improve the nutritional value of the products (Adiba *et al.*, 2011; Çelekli *et al.*, 2019; Grahl *et al.*, 2020; Lucas *et al.*, 2018), and in some cases, the results suggest good commercial viability (Çelekli *et al.*, 2019; Lucas *et al.*, 2018). However, the intense and unpleasant sensory characteristics of *Spirulina*, such as the musty and earthy notes of the algae, are challenges...
that need to be overcome for the widespread use of microalgae as a supplement for enrichment of the nutritional value of foods (Grahl et al., 2020).

Recently, two formulations of snacks have been developed: one enriched with 2.6% of *Spirulina* sp. LEB 18 and one without such enrichment. The results showed that the addition of *Spirulina* provided a nutritional increase in protein (22.6%) and minerals (46.4%), without affecting physical parameters such as expansion index and hardness. In addition, a sensory acceptance index of 82% was observed. The authors concluded that the *Spirulina*, at a concentration of 2.6%, could be used to produce snacks with high nutritional content (Lucas et al., 2018). Another study evaluated the growth and activity of probiotic bacteria in the presence of 0, 0.25, 0.5, and 1% of *Spirulina platensis* in ayran, a refreshing yogurt drink that is very popular in Turkey, Bulgaria, Armenia, Balkans, and the Middle East. The researchers reported that *S. platensis* had a significant effect on the growth of bacteria (*S. thermophilus*, *L. delbrueckii* spp. bulgaricus, *L. acidophilus*, and *B. lactis*) and biochemical variables. Moreover, the samples containing *S. platensis* had significantly higher total solid and protein levels compared to the control samples, and thus the use of microalga has great potential for enhancing the growth of probiotic bacteria and nutritional content of ayran (Çelekli et al., 2019).

In another study, filled pasta variants with three levels of *Spirulina*-soy-extrudate in the filling (10, 30, or 50%) were developed and investigated for their sensory characteristics and consumer preference. Consumer tests were conducted in Germany (n=139), the Netherlands (n=137), and France (n=144), and a conventional sensory profiling was accomplished with trained panelists (n=12). The authors observed that, for all the flavors tested in the study, products supplemented with *Spirulina* were liked more before the other spices were added to the products than after the addition of spices. It was shown that the low general food neophobia and familiarity with *Spirulina* promoted consumer liking. Sensory profiling revealed that the *Spirulina*-soy-extrudate content affected all sensory attributes identified across all flavors. The study confirmed that it is important to consider differences in consumer motivation as well as the product’s conceptual and intrinsic sensory characteristics for new product development (Grahl et al., 2020).

In our study, the mean scores of overall acceptance of the UJ1, UJ2spirulina, and UJ3spirulina jams were 7.32±0.30, 7.02±0.22, and 6.78±0.25, respectively. Furthermore, the acceptability index (AI) for the samples was 81.3, 78.0, and 75.3%, respectively, as shown in Figure 2.
Some researchers have considered that for a product to be accepted with respect to its sensorial characteristics, an AI index higher than 70% is required (Lucas et al., 2018; Queiroz and Treptow, 2006), which was observed for all the formulations of umbu jams prepared with or without *Spirulina* sp. LEB-18 supplementation. However, the supplementation of *Spirulina* sp. LEB-18 led to a decrease in the sensory acceptance by 4.10% and 7.38% of the umbu jam with 1.0% *Spirulina* (UJ2spiralina) and 1.4% *Spirulina* (UJ3spiralina), respectively, but this decrease was not significantly different (*p* > 0.05).

The frequency of the 9-point structured scale was used individually for each umbu compote prepared with or without *Spirulina* sp. LEB-18 supplementation (Figure 3). Although, there was a decrease in the sensory acceptance of umbu jams supplemented with 1.0 and 1.4% of *Spirulina* sp. LEB-18, the values were close in the structured scale, from 5 to 8 points, compared to the values in the control umbu jam that lacked *Spirulina*. Thus, based on the physicochemical properties, chemical composition, and overall acceptance, supplementation of umbu fruit jam and other sweets with *Spirulina* is recommended, as it is for other common fruits (Caetano *et al.*, 2012; Teixeira *et al.*, 2009).
4 CONCLUSION

In this study, the physicochemical properties, chemical composition, and overall acceptance of umbu jams prepared with or without *Spirulina* sp. LEB-18 supplementation were evaluated. The umbu fruit presents favorable properties because of which it can be commercialized in the form of jams or other similar products. In addition, supplementation with *Spirulina* sp. LEB-18 may improve the nutritional properties and provide health benefits when incorporated into different food industry products, especially as a protein-enriched functional food ingredient.

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**CONFLICT OF INTEREST STATEMENT**

All the authors declare no conflict of interest with regard to the described research, the publication of the results, and financial issues.

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