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Analysis of fruit bars elaborated with flour from the residue of acerola processing

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ABSTRACT: The generation of agro-industrial residues has increased considerably in recent times, including those from acerola processing. These residues can provide several nutrients necessary for health, such as vitamins, minerals, fibers, carbohydrates, proteins and can be used as raw material to obtain new products of high added value, promoting numerous possibilities for sustainable production. Fruit bars are versatile products, made from a variety of ingredients and, in this context, the use of flour from the by-product of acerola juice processing (ARF) is a viable option for adding value and improving product quality. Therefore, the present study aimed to elaborate and characterize fruit bars added with ARF. Four formulations were elaborated, being a control formulation (F1), without addition of ARF and three formulations with different concentrations of ARF in relation to the final mass: F2 (10%), F3 (15%) and F4 (20%). It is concluded that the proportion of 10% of ARF presented a good alternative for the elaboration of fruit bars, due to the greater global impression and purchase intention. However, it is suggested that further studies be carried out with ARF, not only in fruit bars, but also in other potential products.

Key words: agro-industrial residue; by-product; nutrients

Avaliação de barras de frutas elaboradas com farinha do subproduto do processamento do suco de acerola

RESUMO: A geração de resíduos agroindustriais tem aumentado consideravelmente nos últimos tempos, inclusive aqueles provenientes do processamento de acerola. Esses resíduos podem fornecer diversos nutrientes necessários à saúde, como vitaminas, minerais, fibras, carboidratos, proteínas e podem ser utilizados como matéria-prima para a obtenção de novos produtos de alto valor agregado, promovendo inúmeras possibilidades para uma produção sustentável. As barras de frutas são produtos versáteis, elaboradas a partir de uma variedade de ingredientes e, neste contexto a utilização da farinha do subproduto do processamento do suco de acerola (FRA) é uma opção viável para agregação de valor e melhoria da qualidade do produto. Portanto, o presente estudo objetivou elaborar e caracterizar física, química e sensorialmente as barras de frutas adicionadas de FRA. A FRA foi obtida da extração de polpa para a fabricação de sucos. Foram elaboradas quatro formulações, sendo uma formulação controle (F1), sem adição de FRA e três formulações com diferentes concentrações de FRA em relação à massa final: F2 (10 %), F3 (15 %) e F4 (20 %). Foram analisadas a acidez titulável, o teor de fibra alimentar total e proteínas, umidade, textura, além de análise microbiológica e sensorial das barras de frutas. Conclui-se que, a proporção de 10% de FRA apresentou uma boa alternativa para elaboração de barras de frutas, em função da maior aceitação global e intenção de compra. No entanto, sugere-se que novos trabalhos sejam realizados com FRA, em outros potenciais produtos.

Palavras-chave: resíduos agroindustriais; subproduto; nutrientes

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Introduction

Fruits are an important source of nutrients because they contain bioactive compounds such as phenolic compounds, vitamins, carotenoids and minerals, as well as sources of soluble and insoluble dietary fiber, which play an important role in the diet (Schiassi et al., 2018).

The increase in fruit consumption has an impact on the agricultural and food sectors, generating a substantial amount of residues. According to a report by the Food and Agriculture Organization of the United Nations, the world wastes around 1.3 billion tons of food every year (FAO, 2013), making up around a third of all the food produced in the world, or around 1.6 billion tons a year. In this scenario, the valorization of this residue, then known as by-products, has emerged as a fundamental strategy for sustainable production, since it can be used as a raw material to obtain high value-added products.

Residues include those from the processing of fruit pulp, such as acerola, for the production of juices, syrups, jellies, among others. And given that acerola production residues can vary from 15 to 41% (Nogueira et al., 2023), depending on the type of processing used, it is necessary to think of alternatives for their utilization. This residue can be processed into flour, providing various nutrients that are commonly present in greater quantities than in other parts of the fruit. In addition to flour, another option would be to use it to develop new products, such as fruit bars. Thus, Ressutte et al. (2019) state that acerola pomace flour can be used as a food ingredient in the preparation of cakes, cookies, breads and cereal bars.

Fruit bars are versatile products made from a variety of ingredients, the selection of which depends on the target audience. Due to their high protein and calorie content, attractive color and pleasant flavor, fruit bars are interesting for consumers as a good alternative to conventional snacks. It is believed that acerola processing residue flour has the potential to be used in the formulation of fruit bars.

In the food industry, the concept of resource recovery has been explored, both in terms of separating valuable material from agro-industrial residues to create a food ingredient, and in using these residues as inputs to develop new products (Udugama et al., 2019).

In view of the above, the objective was to study the use of acerola juice processing residue flour to see if it could be a viable source for the formulation of fruit bars, checking its physical and chemical characteristics, as well as its microbiological safety and sensory acceptability.

Materials and Methods

The analyses were carried out in three replicates for the four bar formulations made with different percentages of acerola processing residue flour (0, 10, 15 and 20%). The process was divided into three stages: I) obtaining flour from the residue of acerola processing (ARF); II) making fruit bars with added flour; and, III) physical-chemical, microbiological and sensory characterization of the product.

Obtaining acerola bagasse flour

The acerola agro-industrial residues used in this study came from the extraction of pulp for the manufacture of juices and were donated by the company Bela Ischia Alimentos Ltda, a fruit processing industry located in the municipality of Astolfo Dutra, Minas Gerais state, Brazil.

The by-product was stored in a freezer at -18 °C until it was used. Prior to use, they were thawed at room temperature (15 ± 1 °C), on the laboratory bench, overnight. This stage lasted around 12 hours. The samples were then dried in a forced-air circulation oven at 60 °C for 24 hours until they reached a constant mass (Monteiro et al., 2020; Magalhães et al., 2021). The dehydrated residue was then ground in a Moedor de Café Di Grano (Cadence MDR302) “portable type”, with a power of 150 W, for 20 seconds, until an average particle size of 1.70 ± 0.05 mm was obtained, resulting in acerola residue flour (ARF). The flour obtained was stored in transparent low-density polypropylene plastic bags for 60 days at room temperature (25 ± 2 °C) until it was used (Figure 1). It was decided to use room temperature so that the environmental conditions were as close as possible to the temperature at which the residues remain in the industry, in order to check the feasibility of using the flour without adding costs to the process.

A. B. C.

Figure 1. Acerola bagasse residue (A) before drying, (B) after drying and (C) after drying and grinding - FRA.

Preparation of fruit bars with acerola residue flour

The formulation of the fruit bars was adapted from Ressutte et al. (2019), adding acerola flour in order to reach an adequate percentage for this study. It has been observed in other studies that the addition of fruit residue flour generally ranged from 5 to 30%. Taking into account that acerola is an acidic fruit, a medium percentage was worked out, for which four different formulations were made, varying the amount of flour, as shown in Table 1.

The process of obtaining the fruit bar occurred through the compression of a mass with a mixture of around 20 to 60% of dry ingredients such as whole grains, processed cereals, seeds, nuts, flour, fruits and vegetables (Friedrichsen et al., 2022). In the preparation of the bars for this study, around 50% of the dry ingredients were used in the compression stage.

The mixture obtained was spread on a stainless steel baking sheet measuring 46.5 × 33 × 4.5 cm (length, width and depth),

Table 1. Composition of fruit bars with different percentages of acerola residue flour (ARF).

Ingredients	Formulation			
	F1 (0%)	F2 (10%)	F3 (15%)	F4 (20%)
Pitted dried plum (g)	300	300	300	300
Black raisin (g)	100	100	100	100
Chopped Brazil nuts (g)	100	100	100	100
Coarsely grated coconut (g)	50	50	50	50
Residue flour (g)	0	62	93	124
Coconut oil (g)	13	13	13	13
Unsalted sunflower seeds (g)	12	12	12	12
Pumpkin seeds, peeled and salted (g)	10	10	10	10
Chia (g)	13	13	13	13
Sesame (g)	12	12	12	12
Golden linseed (g)	10	10	10	10

which was kept in a forced-air circulation oven at 100 °C for approximately 20 minutes. After this period, the samples were taken out of the oven to be cut into fruit bars measuring 7.5 × 3.5 × 1.0 cm (length, width and height). The bars were wrapped in PVC plastic film and kept in the fridge until the analysis was carried out, so that the properties of the bar were not altered until later. This maintenance lasted one day. Figure 2 shows the preparation of the fruit bar with added ARF.

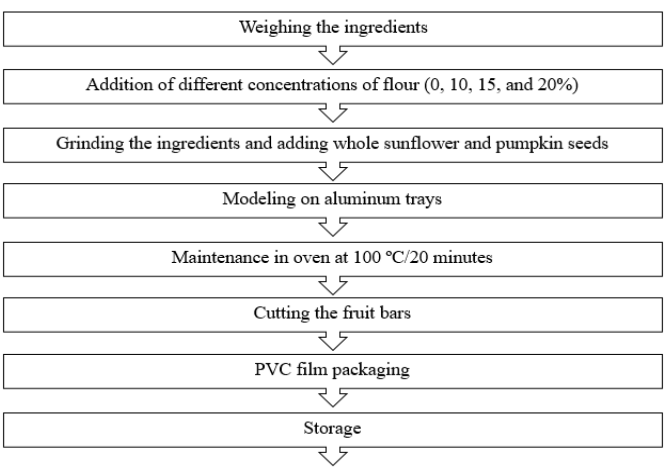

Figure 2. Stages in the preparation of the fruit bar with added ARF.

Physico-chemical analysis

The titratable acidity analysis was carried out according to the methodology of AOAC (1992). Ten grams of the sample were weighed and 100 mL of distilled water was added. The indicator used was phenolphthalein and the titration solution was 0.1 N sodium hydroxide (NaOH).

The total dietary fiber content (g $100g^{-1}$) was determined using the enzymatic-gravimetric method. The methodologies used were those recommended by AOAC 991.43 (AOAC, 2005), carried out by a third-party laboratory. The methodology for analyzing the percentage of Vitamin C present in the fruit bars, with the addition of the acerola residue, was determined by potentiometric titration (Limit of Quantification of 0.3 g $100g^{-1}$). This analysis was also carried out by a third-party laboratory.

The Kjeldahl method (AOAC, 2012) was used to quantify proteins, using a correction factor of 6.25 to determine the total nitrogenous matter of a sample.

Instrumental texture analysis or shear force was determined using a Brookfield texturometer, model CT3-Texture Analyzer. The samples were sheared with a TA 10 blade at a pre-test speed of 2 mm s^{-1}, test speed of 2 mm s^{-1}, post-test speed of 2 mm s^{-1} and a distance of 10 mm, ensuring a complete cut.

Moisture analyses were also carried out using the gravimetric method, according to Brasil (2022). Objective color determination was carried out by directly reading the reflectance of the L*, a* and b* coordinates using the CIELAB scale using a calorimeter (Konica Minolta CR-10, Osaka, Japan).

Microbiological analysis

The characterization of the fruit bars was carried out on all the samples based on Normative Instruction No. 60, of December 23, 2019 (Brasil, 2019), which establishes the lists of microbiological standards for foods and ANVISA RDC No. 712, of July 1, 2022 (Brasil, 2022), for cereal products, starches, flours and meals.

The method recommended by Andrews et al. (2001) was used to determine *Salmonella* spp. in 25 g of sample. To check for the presence/absence of fecal coliforms, the temperature of 30°/45°C, Most Probable Number (MPN) of coliforms at 35 °C and *Escherichia coli* were used. The APHA 20; 2001 plating method (Beuchat & Cousin, 2001) was used to analyze the mold and yeast count in the fruit bar.

Sensory analysis

The sensory analysis was carried out after approval by the Human Research Ethics Committee (Comitê de Ética em Pesquisa com Seres Humanos - CAAE 58682622.4.0000.5588), in the Sensory Analysis Laboratory of the Food Science and Technology Department of the IF Sudeste - MG, Rio Pomba Campus. The samples of fruit bars formulated with acerola residue flour were evaluated by 102 untrained tasters, including men and women, potential consumers over the age of 18. Participants signed the Free and Informed Consent Form (Termo de Consentimento Livre e Esclarecido - TCLE) before participating in the analyses. The evaluator was informed about the composition of the samples and if he had any dietary restrictions, he would not take part in the analysis.

Each evaluator initially received a product evaluation card and then a single sample for each treatment in disposable dishes, coded with three-digit numbers, along with a glass of water. The sensory acceptance of the products was evaluated using a 9-point hedonic scale ranging from “extremely dislike” to “extremely like”, in individual booths under white light, to assess the following attributes (overall acceptance, appearance, color, aroma, flavor and texture). The intention to buy the different compositions was also assessed using a 5-point scale, ranging from “1 - I would definitely not buy” to “5 - I would definitely buy”.

Statistical analysis

The data obtained for the physicochemical analyses were subjected to analysis of variance (ANOVA) and the Tukey test at 5% probability using Sigmaplot 14 software.

The results of sensory acceptance and purchase intention were treated with statistical data, using analysis of variance (ANOVA), randomized block design, whose sources of variation correspond to the sample and the evaluator, and the means were compared using the Tukey test at a 5% significance level, using the Sisvar program version 5.3 and principal component analysis (PCA), using the Senso Maker program, MatLab® version 1.9.

Results and Discussion

Physico-chemical results

The results for acidity, protein and texture showed a significant difference, while the results for color and moisture showed no significant difference between the treatments ($p < 0.05$) (Table 2).

The addition of 20% ARF significantly altered the titratable acidity of the fruit bars, with a higher value than the control and 10 and 15% ARF. According to Magalhães et al. (2021), acerola pulp flour has an average acidity of 3.30 g 100g^{-1}. Therefore, by increasing the amount of ARF in the formulations from 0 to 124 g (Table 1), it is expected that there will be an increase in acidity, as shown in Table 2. More acidic products have a longer shelf life. However, according to Vieira et al. (2019), titratable acidity values provide information on product quality, where higher values of this parameter imply greater conversion of long-chain fatty acids into short-chain organic fatty acids, which give products an unpleasant flavor and odor. Sensory analysis is therefore extremely important to ascertain the impact of this increase in titratable acidity.

The values found for total titratable acidity increased from 0.51 to 1.03 g 100g^{-1} of sample. These values depend on the acidity content of the ARF used and the final product, and varying values can be obtained. Aquino et al. (2010) indicated a titratable acidity of 8.13 g 100g^{-1} for ARF and 0.03 to 0.50 g 100g^{-1} for cookies made with ARF. Storck et al. (2015) reported acidity between 0.56 and 0.69 g 100g^{-1} for the acerola residue for different grain sizes. Reis et al. (2017) found a titratable acidity value of 1.12 g 100g^{-1} for ARF and values between 4.12 and 10.75 g 100g^{-1} for dried flours with and without seeds during storage. Magalhães et al. (2021) indicated a titratable acidity of 3.30 g 100g^{-1} of ARF. These variations indicate the importance of evaluating both the ARF and the products produced.

The incorporation of fruit residue flour can enrich food preparations in order to increase their functional properties and encourage the population to make full use of them (Barros et al., 2019). Aquino et al. (2010) state that given the high production of residues from the processing of acerola pulp and their nutritional quality and high ascorbic acid content, flour from these residues is an excellent low-cost alternative for enriching food products, as seen in this study.

Other studies have used different raw materials, such as: pineapple peel for the production of cookies (Barros et al., 2019); pineapple peel flour with okara flour, in the incorporation of cereal bars (Vieira et al., 2019), which was well accepted by the judges and presented itself as slightly acidic with a titratable acidity of 0.54 to 0.56 g 100g^{-1}; passion fruit flour for the production of cookies (Lima et al., 2022), which presented an acidity of 9.3 g 100g^{-1} associated with a low pH (3.38). This demonstrates the importance of carrying out studies with different agro-industrial residues for the development of new products.

Proteins can aid in the production of enzymes, hormones, antibodies and in the repair and growth of cells (Silva et al., 2020). Although there are no specific regulations for cereal bars in Brazilian legislation, a minimum of 6 g of protein in 100 g of the fruit is required to be considered a protein source (Brasil, 2012). Therefore, this analysis was necessary to find out the potential of fruit bars with added ARF in relation to the presence of this nutrient, noting that all the formulations made are considered to be protein sources (Table 2). In addition, it can be seen that the protein content values are close to the range found in different studies. Aquino et al. (2010) found 6.78 g 100g^{-1} in the preparation of cookies with 10% acerola residue flour. Papaya peel can also be used, while still green, to make flour, as described by Carvalho et al. (2020), which showed satisfactory characteristics from a nutritional point of view, especially in relation to the high protein content (25.10 g 100g^{-1}). This difference in protein value is related to the raw material, i.e. the region where it was grown, the ripeness of the fruit, the species grown, among other attributes.

Table 2. Values found for acidity, protein, texture, moisture and color (L*, a* b*) available (mean ± standard deviation) in the different formulations with acerola residue flour (ARF).

Parameters	F1 (0%)	F2 (10%)	F3 (15%)	F4 (20%)
Titratable acidity (g 100g^{-1})	0.51 a ± 0.14	0.56 a ± 0.02	0.70 ab ± 0.02	1.03 b ± 0.02
Protein (g 100g^{-1})	7.21 c ± 0.09	6.47 ab ± 0.25	6.04 a ± 0.08	6.77 bc ± 0.38
Texture (N)	17.26 a ± 4.21	35.00 b ± 3.60	20.80 a ± 7.73	14.41 a ± 2.25
Moisture (g 100 g^{-1})	22.02 a ± 1.25	21.07 a ± 0.61	19.33 a ± 0.74	20.56 a ± 2.88
L*	34.00 a ± 1.33	31.50 a ± 9.12	31.70 a ± 1.08	31.50 a ± 0.55
a*	12.60 a ± 3.51	14.60 a ± 4.61	13.43 a ± 2.50	10.30 a ± 1.57
b*	5.00 a ± 1.18	9.50 a ± 14.02	9.00 a ± 2.29	11.50 a ± 1.04

* Averages followed by the same lowercase letter in the row for each parameter evaluated do not differ statistically by the Tukey test at 5% probability.

With regard to the texture results, there was no significant difference ($p > 0.05$) in shear force between the F1, F3 and F4 experimental formulations. The addition of ARF to the F2 formulation significantly increased the shear force when compared to the other formulations. It is possible that the increase in the amount of ARF in the F3 and F4 formulations did not allow a close interaction with the other ingredients in the fruit bars, making them more crumbly. Santos et al. (2022) report that the shear strength is affected by the fiber content, in this case provided by the ARF. Ten percent ARF is the ideal amount for this interaction to be adequate in terms of shear force. This study did not use binding agents, which aim to facilitate the interaction between the different ingredients. Oliveira et al. (2020) showed that the addition of pomace flour, together with xanthan gum and guar gum, contributed to the stability and firmness of cereal bars. While Cano-Chauca et al. (2021) detail that there were significant differences in the texture values obtained between the three dehydrated fruit bar formulations.

The moisture content of the samples in this study ranged from 19.33 to 22.02 g $100g^{-1}$. Due to the lack of specific legislation for fruit bars, we used Resolution-RDC No. 263 of September 22, 2005 (Brasil, 2005), which deals with the technical regulations for cereal products, starches, flours and meals, indicating that the moisture content should be less than 14 g $100g^{-1}$. Although the moisture content is higher than recommended by the aforementioned regulation, it cannot be concluded that the product is out of compliance, as the regulation is not specific to fruit bars. Studies using flour from the residue of other fruits in the application of other products have shown similar results and percentages of flour used. Barros et al. (2019) used pineapple peel flour as an ingredient for the production of cookies, the moisture content of which was 17.52 g $100g^{-1}$. Sousa et al. (2020) showed that the addition of 10% pineapple peel flour in the formulation of cookies had a moisture content of 2.48 g $100g^{-1}$. It is suggested that future studies assess whether the resulting moisture content of the fruit bars is suitable for storage at room temperature or whether they need to be refrigerated.

The L*, a* and b* coordinates showed no significant differences ($p > 0.05$) between the samples, indicating that the addition of ARF did not interfere with these color parameters. Since it is a fruit bar, which has a darker color towards brown, and the acerola pomace flour has a lighter color, it was noticed that its addition to the fruit bar did not cause significant differences in the color parameter. This is different from what was observed by researchers who evaluated the effect of adding acerola residue flour to cookies (Aquino et al., 2010).

The values found in the fruit bar samples for total dietary fiber varied between 20.93 and 30.28 g $100g^{-1}$, showing no trend as the amount of ARF increased (Table 3).

According to the value required by RDC No. 54 (Brasil, 2012), which recommends a minimum of 2.5 g of fiber per portion of food, it could be classified as a high-fiber food. Sousa et al. (2020) showed that the addition of 10% pineapple peel flour in the formulation of cookies also classifies the product as a high-fiber food (24.52 g $100g^{-1}$). Lima et al. (2021) also found a high fiber content in passion fruit peel flour (58.3 g $100g^{-1}$).

Regarding the Vitamin C content, Ressutte et al. (2019) obtained a result of 40.72 mg $100g^{-1}$ in the acerola residue cereal bar, stating that the product can be considered a source of Vitamin C. The samples in this study showed a result of between 0.007 and 0.021 mg $100g^{-1}$, which is considered low given that the daily requirement for Vitamin C is 40 mg (Chaves, 1978). ANVISA recommends a daily intake of 45 mg of Vitamin C for adults RDC No. 54 of November 12, 2012 (Brasil, 2012). This low content may be due to the possibility of a lower Vitamin C content found in the acerola pulp residue, as it has already been processed in the industry. Future studies could be carried out in order to verify the Vitamin C content of the residue from the extraction of acerola pulp, determining the effect of this processing. In addition, the heat treatment used in this study is another factor to consider, since higher temperatures degrade Vitamin C, resulting in lower values for this parameter.

Therefore, more in-depth studies are needed to understand the reason for these results, since what was expected was an improvement as the percentage of flour increased, assuming that acerola residue flour is considered to have a high value for this nutrient.

Microbiological quality

The products analyzed meet the standards of current legislation and presented ideal hygienic production conditions, as shown in Table 4.

Table 3. Total dietary fiber and Vitamin C values in the different formulations with acerola residue flour (ARF).

Parameters	F1 (0%)	F2 (10%)	F3 (15%)	F4 (20%)
Total dietary fiber (g $100g^{-1}$)	30.28	21.08	20.93	27.11
Vitamin C (mg $100g^{-1}$)	0.021	0.018	0.007	0.007

Table 4. Microbiological analysis of the different formulations.

Formulations	Coliforms/g 30°/45°C	Molds and yeast/g	Salmonella $25g^{-1}$
F1 (0%)	< 3.0 MPN/g	$<1.0 \times 10^1$ est.	Absent
F2 (10%)	< 3.0 MPN/g	$<1.0 \times 10^1$ est.	Absent
F3 (15%)	< 3.0 MPN/g	$<1.0 \times 10^1$ est.	Absent
F4 (20%)	< 3.0 MPN/g	$<1.0 \times 10^1$ est.	Absent
*** Standard Legislation	1.0×10^2	1.0×10^4	Absent

The compliance with the legal criteria shows that the products followed good manufacturing practices at all stages and could therefore be safely consumed by the evaluators.

Sensory analysis

Profile of the evaluators

The sensory analysis was carried out with 102 untrained evaluators. According to the data obtained, 44.12% of the evaluators were female and 53.92% male, with 1.96% preferring not to declare. With regard to age, it was found that the largest audience was between 18 and 25 years old (64.7%), followed by 26 to 35 years old (16.67%), 46 to 55 years old (11.77%), 36 to 45 years old (4.9%) and 1.96% over 55 years old (Figure 3).

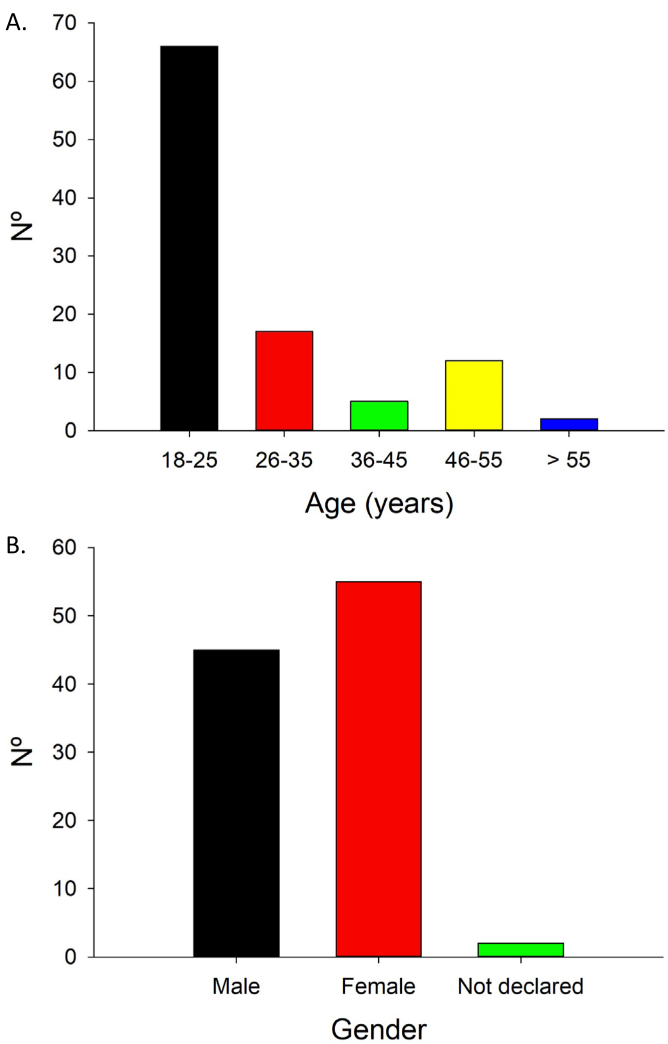

Figure 3. Characteristics of the evaluators (N=102).

Sensory acceptance and purchase intention

The samples obtained average scores for overall acceptance, ranging from 5.36 to 6.82 (Table 5), which corresponds between "I liked it slightly" and "I liked it moderately" on the 9-point hedonic scale. For purchase intention, the average scores ranged from 2.75 to 3.47 (Table 5), which corresponds between "Maybe yes / Maybe no" and "Probably would buy" on the 5-point hedonic scale.

Table 5. Overall acceptance and purchase intention scores of the fruit bar (means ± standard deviation), in the different formulations with acerola residue flour (ARF).

Formulations	Overall acceptance	Purchase intention
F1 (0%)	6.82 a ± 1.52	3.47 a ± 1.06
F2 (10%)	6.28 b ± 1.63	3.02 b ± 0.96
F3 (15%)	5.36 c ± 1.89	2.75 b ± 1.02
F4 (20%)	5.55 c ± 1.95	2.88 b ± 1.13

* Averages followed by different lowercase letters in the same column differ according to the Tukey test ($p < 0.05$).

The results indicated that the addition of ARF to the fruit bar alters its sensory characteristics, with the higher the percentage of ARF, the lower the overall acceptance and purchase intention (Table 5).

The samples showed no significant differences ($p < 0.05$). Followed by the control sample, the formulation with 10% added ARF (F2) was the one that obtained the second best score for overall impression, as well as purchase intention. The values obtained may be related to the employees habit of consuming fruit bars, as the F1 and F2 formulations had a very malleable appearance in relation to the fruit bar characteristic.

It's important to note that no artificial sweeteners such as crystal sugar, brown sugar, honey, syrups or others were added to the formulations in this study, leaving only the sweetness naturally present in the ingredients used. In contrast, according to Ressutte et al. (2019) a percentage of 6.86 to 7.44% sugar was used in cereal bar formulations and Cesar et al. (2019) used 57% rapadura honey in their cereal bar formulation. RDC No. 429 (Brasil, 2020) provides for the offer, advertising, publicity, information and other related practices aimed at publicizing and commercially promoting foods considered to contain high amounts of sugar.

These results show that the fruit bar formulated with 10% acerola processing residue flour could be commercially viable, as it showed good acceptance (scores above 6), requiring further study in order to give the final product better sensory characteristics. A similar study used flour addition percentages of less than 20% (Ressutte et al., 2019).

According to the results, regardless of the sensory attributes evaluated, the control sample (F1) and the sample (F2) with 10% ARF obtained the highest scores compared to the other formulations (Table 6). Thus, in terms of acceptance, samples F1 and F2 obtained scores above 6, which indicates "I liked it slightly", according to the hedonic scale (Table 6), concluding that these two samples were accepted. It should be noted that for the flavor evaluation, although the average score was below 6 for the F2 formulation, the value is statistically the same as the F1 formulation, which shows that this formulation can be classified as acceptable by sensory analysis.

Internal preference map

The internal preference map of the four fruit bar formulations for the overall impression and purchase

Table 6. Sensory acceptance (means ± standard deviation) of the different formulations with acerola residue flour (ARF).

Formulations	Appearance	Color	Texture	Flavor	Aroma
F1 (0%)	6.95 a ± 1.58	6.90 a ± 1.46	7.06 a ± 1.72	6.41 a ± 1.90	6.96 a ± 1.59
F2 (10%)	6.49 ab ± 1.64	6.62 ab ± 1.60	6.59 a ± 1.61	5.95 a ± 1.86	6.62 ab ± 1.68
F3 (15%)	5.61 c ± 1.97	5.99 c ± 1.96	5.37 b ± 2.04	5.30 b ± 1.95	6.20 bc ± 2.01
F4 (20%)	6.22 b ± 1.98	6.37 bc ± 1.83	5.81 b ± 2.03	5.33 b ± 2.14	6.15 c ± 1.93

* Averages followed by different lowercase letters in the same column differ according to the Tukey test ($p < 0.05$).

intention attributes are shown in Figure 4. Each vector is equivalent to the correlation of a consumers acceptance data with the two main components.

The graph representing the overall impression has its main components explaining 75.14 % of the variability of the responses, with the vectors being more concentrated near sample F1, followed by sample F2. The purchase intention graph, on the other hand, has its main components explaining 74.21% of the variability of the responses and its vectors were more concentrated near sample F1, followed by samples F2 and F3, confirming the data analyzed by the Tukey test in which the samples showed a significant difference.

Representing the projection of the results obtained in the internal preference map analysis of the four fruit bar formulations for the appearance, aroma, flavor and texture attributes are Figure 5.

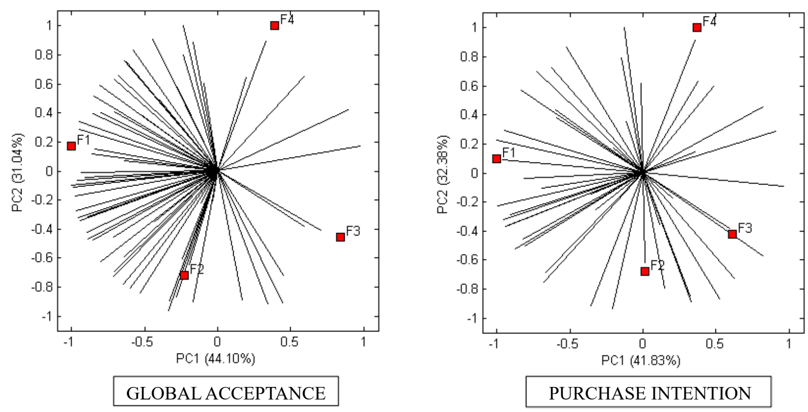

Figure 4. Preference map for global acceptance and purchase intention.

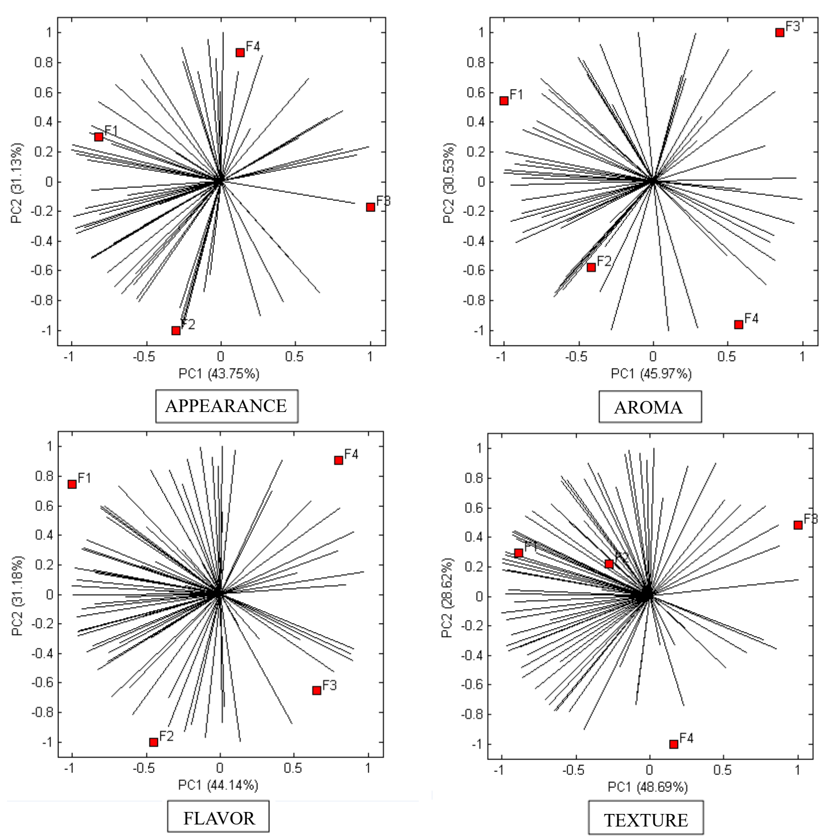

Figure 5. Preference map for appearance, aroma, flavor and texture.

With regard to appearance, (F1) was the most preferred, followed by (F2) and (F4); with regard to aroma, (F1) stood out, followed respectively by (F2), (F3) and (F4). With regard to flavor, it can be said that (F1) and (F2) were apparently tied, followed by (F3) and (F4) also tied, for texture (F1) and (F2) were tied with the highest density of vectors, followed by (F3) and then (F4), according to the predilection shown in Figure 5.

According to the data obtained, the sensory analysis was favorable to all the formulations, with the samples with a higher percentage of ARF causing lower consumer acceptance.

Although (F1) and (F2) were preferred by the evaluators, all four formulations were well accepted, with average scores above 5 for all the attributes tested (Table 5). These results indicate that the tasters were between "I liked it slightly" and "I liked it moderately" and that, although there was no rejection, there needs to be other attractions for consumers to buy it.

Conclusions

The study proved that it is feasible to use flour from the by-product of acerola juice processing (ARF) to add value and improve product quality. The use of ARF promotes the reduction of food residue, enabling its full use, and is a sustainable practice for reusing agro-industrial processing residues, which can also be a model of sustainability and care for the environment.

The product formulated with ARF can be considered a food with a high fiber and protein content. In the color analysis, the L*, a* and b* coordinates showed no significant differences, indicating that the addition of ARF did not interfere with these parameters. All the formulations have microbiological results in accordance with current legislation.

It can be concluded that ARF in a proportion of 10% is a good alternative for making fruit bars. However, it is suggested that further studies be carried out with ARF, not only in fruit bars, but also in other potential products, checking shelf life and storage.

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Compliance with Ethical Standards

Author contributions: Conceptualization: ROG, GHHO; Data curation: ROG; Formal analysis: ROG, GHHO, VROS; Funding acquisition: ROG, GHHO; Investigation: ROG; Project administration: ROG, VROS, ACMSA; Methodology: GHHO; Resources: ROG, GHHO; Supervision: GHHO, VROS, ACMSA; Validation: EMFM, BRCLJ; Visualization: ROG, GHHO, VROS, ACMSA, EMFM, BRCLJ; Writing – original draft: ROG; Writing – review & editing: GHHO, VROS, ACMSA, EMFM, BRCLJ.

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Literature Cited

Andrews, W.H.; Flower, R.S.; Silliker, J.; Bailey, J.S. Salmonella. In: Downes, F.P.; Ito, K. (Eds.). Compendium of methods for microbilological examination of foods. 4. ed. Washington: American Public Health Association, 2001. p.357-380.

Aquino A. C. M. S.; Móes R. S.; Leão K. M. M.; Figueiredo A. V. D.; Castro A. A. Avaliação físico-química e aceitação sensorial de biscoitos tipo cookies elaborados com farinha de resíduos de acerola. Revista do Instituto Adolfo Lutz, v. 69, n. 3, p. 379-86, 2010. https://doi.org/10.53393/rial.2010.v69.32640.

Association of Official Analytical Chemists - AOAC International. Official methods of analysis**.** 12.ed. Washington: AOAC International, 1992. 1115p.Association of Official Analytical Chemists - AOAC International. AOAC official method 991.43. Total, soluble, and insoluble dietary fiber in foods. In: AOAC (Ed.). Official methods of analysis. 18.ed. Gaithersburg: AOAC International, 2005.

Association of Official Analytical Chemists - AOAC International. AOAC official method 2011.25. Insoluble, soluble and total dietary fiber in foods. In: AOAC (Ed.). Official methods of analysis. 19.ed. Gaithersburg: AOAC International, 2012.

Barros, L. S., Ribeiro, N. L. A., Ferreira, W. C. O., Nobre, M. L. M., Alves, T.L., Lima, A. C. S., & Figueredo, R. W. Utilização de farinha de resíduo de abacaxi aromatizada na produção de Cookies. Brazillian Journal of Development, v. 5, n. 10, p 21926-21937, 2019. https://doi.org/10.34117/bjdv5n10-329.

Beuchat, I. R.; Cousin, M. A. Years and molds. In: Downes, F. P.; Ito, K. (Eds.). Compendium of methods for the microbiological examination of foods. 4.ed. Washington: American Public Health Association, Chap. 20, p.209-215, 2001.

Brasil. Agência Nacional de Vigilância Sanitária - ANVISA. RDC nº 263, de 22 de setembro de 2005. Aprova o Regulamento técnico para produtos de cereais, amidos, farinhas e farelos. Diário Oficial da União, v. 142, n. 184, seção 1, p.368-369, 2005. https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?jornal=1&pagina=368&data=23/09/2005. 10 Jul. 2023.

Brasil. Agência Nacional de Vigilância Sanitária – ANVISA. Instrução Normativa N° 60, de 23 de dezembro de 2019. Estabelece as listas de padrões microbiológicos para alimentos. Diário Oficial da União, v. 157, n. 249, seção 1, p.133-139, 2019. https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=26/12/2019&jornal=515&pagina=133&totalArquivos=149. 10 Jul. 2023.

Brasil. Agência Nacional de Vigilância Sanitária - ANVISA. RDC Nº 429, de 8 de outubro de 2020. Dispõe sobre a rotulagem nutricional dos alimentos embalados. Diário Oficial da União, v. 61, n. 195, seção 1, p.106-110, 2020. https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?jornal=515&pagina=106&data=09/10/2020. 10 Jul. 2023.

Brasil. Agência Nacional de Vigilância Sanitária - ANVISA. RDC nº 712, de 1 de julho de 2022. Dispõe sobre os requisitos de composição e rotulagem dos alimentos contendo cereais e pseudocereais para classificação e identificação como integral e para destaque da presença de ingredientes integrais. Diário Oficial da União, v. 160, n. 126, seção 1, p.183-184, 2022. https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?jornal=515&pagina=183&data=06/07/2022. 10 Jul. 2023.

Brasil. Agência Nacional de Vigilância Sanitária - ANVISA. RDC nº 54, de 12 de novembro de 2012. Dispõe sobre o Regulamento Técnico sobre Informação Nutricional Complementar. Diário Oficial da União, v. 149, n. 219, seção 1, p.122-126, 2012. https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=13/11/2012&jornal=1&pagina=122&totalArquivos=232. 10 Jul. 2023.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento - MAPA. Métodos oficiais para análise de produtos de origem animal. Brasília: MAPA, 2022. 174p. https://wikisda.agricultura.gov.br/dipoa_baselegal/in_30-2018_manual_de_metodos_oficiais_de_analises.pdf. 22 Jun. 2023.

Cano-Chauca, M. N.; Rodrigues, D. S.; Freitas, A. G.; Fonseca, H. C.; Fonseca, K. S.; Desenvolvimento de barras alimentícias utilizando misturas de frutas desidratadas. In: Scaglioni, P. T. (Org.). Ensino e pesquisa no campo da engenharia e tecnologia de alimentos 2. Ponta Grossa: Atena, 2021. Chap.15, p. 127-136. http://hdl.handle.net/1843/51274. 22 Jun. 2023.

Carvalho, J. B.; Marques, K. H. S. R.; Mesquita, A. A.; Paula, G. H.; Lima, M. S.; Ferreira, S. V.; Medeiros, J. S.; Teixeira, P. C.; Nicolau, E. S.; Silva, M. A. P. Propriedades químicas e funcionais da casca do mamão verde submetida da secagem em diferentes temperaturas e aplicação em pães. Research Society and Development, v. 9, n.5, e29953154, 2020. https://doi.org/10.33448/rsd-v9i5.3154.

Cesar, E. L.; Felix, A. C. F.; Barreto, H. C.; Ferreira Neto, J.; Gomes, D. J.; Andrade, M. W. Avalição física, química e microbiológica de barra de cereais elaborada a partir de uma multimistura. Revista de Agroecologia no Semiárido, v. 3, n.2, p.20- 26, 2019. https://doi.org/10.35512/ras.v3i2.3095.

Chaves, N. Nutrição básica e aplicada. Rio de Janeiro: Guanabara Koogan, 1978. p.120-122.

Food and Agriculture Organization - FAO. Food wastage footprint: impacts on natural resources. Rome: FAO, 2013. 61p. http://www.fao.org/docrep/018/i3347e/i3347e.pdf. 22 Jul. 2023.

Friedrichsen, J. S. A.; Saqueti, B. H. F.; Bruni A. R. S.; Gomes E. S.; Silva J. F.; Ientz G. A. S.; Baeta F. S.; Piacquadio, N. M.; Bulla, M. K.; Santos, O. O. Development of a cereal bar with the addition of sweet potato flour, collagen and betaine: review of the ingredients used and feasibility. Research, Society and Development, v. 11, n. 13, e449111335665, 2022. https://doi.org/10.33448/rsd-v11i13.35665.

Lima, E. R.; Pereira, I. de O.; Milagres, M. P.; Pereira, R.; Paula, S. A. de; Matos, T. B.; Sousa, T. R. Desenvolvimento e caracterização de biscoito de maracujá da caatinga (*Passiflora cincinnata Mast.*). Food Science and Technology, n. 42, e56220, 2022. https://doi.org/10.1590/fst.56220.

Lima, E. R.; Pereira, B. G.; Pereira, I. O.; Santos, K. S.; Milagres M. P. Desenvolvimento e caracterização físico-quimica de farinha de casca de maracujá de caatinga (*Passiflora cincinnata Mast.*). In: Barbosa Júnior, S. A. (Org.). As vicissitudes da pesquisa e da teoria nas ciências agrárias 3. Ponta Grossa: Atena, 2021. p.68-72. https://doi.org/10.22533/at.ed.4272101037.

Magalhães, M. P. D.; Gandra, K. M. B.; Cunha, L. R.; Lima, E. M. F. Obtaining flour from acerola processing residue and evaluating bioactive and nutritive compounds. Research, Society and Development, v. 10, n. 14, e 188101420714, 2021. https://doi.org/10.33448/rsd-v10i14.20714

Monteiro, S. A.; Barbosa, M. M.; Silva, M. F. F.; Bezerra, R. F.; Maia, K. S. Preparation, phytochemical and bromatological evaluation of flour obtained from the acerola (*Malpighia punicifolia*) agroindustrial residue with potential use as fiber source. LWT - Food Science and Technology, v. 134, e110142, 2020. https://doi.org/10.1016/j.lwt.2020.110142.

Nogueira, G. D. R.; Silva, P. B.; Souza, G. F. M. V.; Duarte, C. R.; Barrozo, M. A. S. Vacuum Microwave Drying of Acerola Residue: Effects of Pre-treatment and Operating Variables on Main Bioactive Compounds. Waste and Biomass Valorization, v. 14, p.1281-1292, 2023. https://doi.org/10.1007/s12649-022-01925-4.

Oliveira, E. S. F.; Soares, J. O.; Silva, M. S.; Orqis, M. G.; Azevedo, M. L.; Gautério, F. A. G. Perfil de textura de barras de cereal elaboradas com farinha de bagaço de azeitona contendo xantana e guar. In: Simpósio de Segurança alimentar, 7., 2020, on line. Anais... Porto Alegre: SBCTA-RS, 2020. Disponível em: http://schenautomacao.com.br/ssa7/envio/files/trabalho3_205.pdf . 02 Abr. 2023.

Reis, D. S.; Figueiredo Neto, A.; Ferraz, A. V.; Freitas, S. T. Produção e estabilidade de conservação de farinha de acerola desidratada em diferentes temperaturas. Brazilian Journal of Food Technology, v. 20, e2015083, 2017. https://doi.org/10.1590/1981-6723.8315.

Ressutte, J. B.; Chavante, A. R.; Almeida-Couto, J. M. F.; Belluco, C. Z.; Nascimento, M. G.; Scapim, M. R. S. Barra de cereais de Resíduo de acerola isenta de glúten. In: Encontro Internacional de Produção Cientifica, 9., 2019, Maringá. Anais... Maringá: UNICESUMAR, 2019. https://rdu.unicesumar.edu.br/bitstream/123456789/3274/1/J%C3%A9ssica%20Maria%20Ferreira%20de%20Almeida%20Do%20Couto.pdf. 22 Jun. 2023.

Santos, J. L.; Gomes, L. R.; Neves, N. A.; Schmiele, M. Desenvolvimento de barra de cereais com aproveitamento de resíduo de mosturação de cerveja desidratado e incorporação de proteína hidrolisada de soja e gelatina. Research, Society and Development, v. 11, n. 2, e8811225572, 2022. https://doi.org/10.33448/rsd-v11i2.25572.

Schiassi, M. C. E. V.; Souza, V. R.; Lago, A. M. T.; Campos, L. G.; Queiroz, F. Fruits from the Brazilian Cerrado region: Physico-chemical characterization, bioactive compounds, antioxidant activities, and sensory evaluation. Food Chemistry, v. 245, p. 305 – 311, 2018. https://doi.org/10.1016/j.foodchem.2017.10.104.

Silva, M. S.; Silva, S. N.; Wanderley, R. O. S.; Paiva, A. C. C.; Medeiros, A. P. Caracterização química e colorimétrica de farinhas de cascas de laranja, melão e abacaxi. Research, Society and Development, v. 9, n. 7, e139973912, 2020. https://doi.org/10.33448/rsd-v9i7.3912.

Sousa, R. S.; Novais, T. S.; Batista, F. O.; Zuniga, A. D. G. Análise sensorial de cookie desenvolvido com farinha da casca de abacaxi (*Ananas comosus* (L.) Merril). Research, Society and Development, v. 9, n. 4, e45942816, 2020. https://doi.org/10.33448/rsd-v9i4.2816.

Storck, C. R.; Basso, C.; Favarin, F. R.; Rodrigues, A. C. Qualidade microbiológica e composição de farinhas de resíduos da produção de suco de frutas em diferentes granulometrias. Brazilian Journal of Food Technology, v. 18, n. 4, p. 277-284, 2015. https://doi.org/10.1590/1981-6723.1615.

Udugama, I. A.; Petersen, L. A. H.; Falco, F. C.; Junicke, H.; Mitic, A.; Alsina, X. F.; MansourI, S. S.; Gernaey, K. V. Resource recovery from waste streams in a Water-Energy-Food nexus perspective: toward more sustainable food processing. Food and Bioproducts Processing, v. 119, p. 133 – 147, 2019. https://doi.org/10.1016/j.fbp.2019.10.014.

Vieira, D. A. P.; Duarte, M. D. G.; Ribeiro, G. B.; Souza, E. R. B.; Vera, R. Aceitabilidade de barra de cereal com adição de okara e farelo de casca de abacaxi. Scientia Tec: Revista de Educação, Ciencia e Tecnologia do IFRS, v. 6, n. 2, p.3-15, 2019. https://doi.org/10.35819/scientiatec.v6i2.3153.