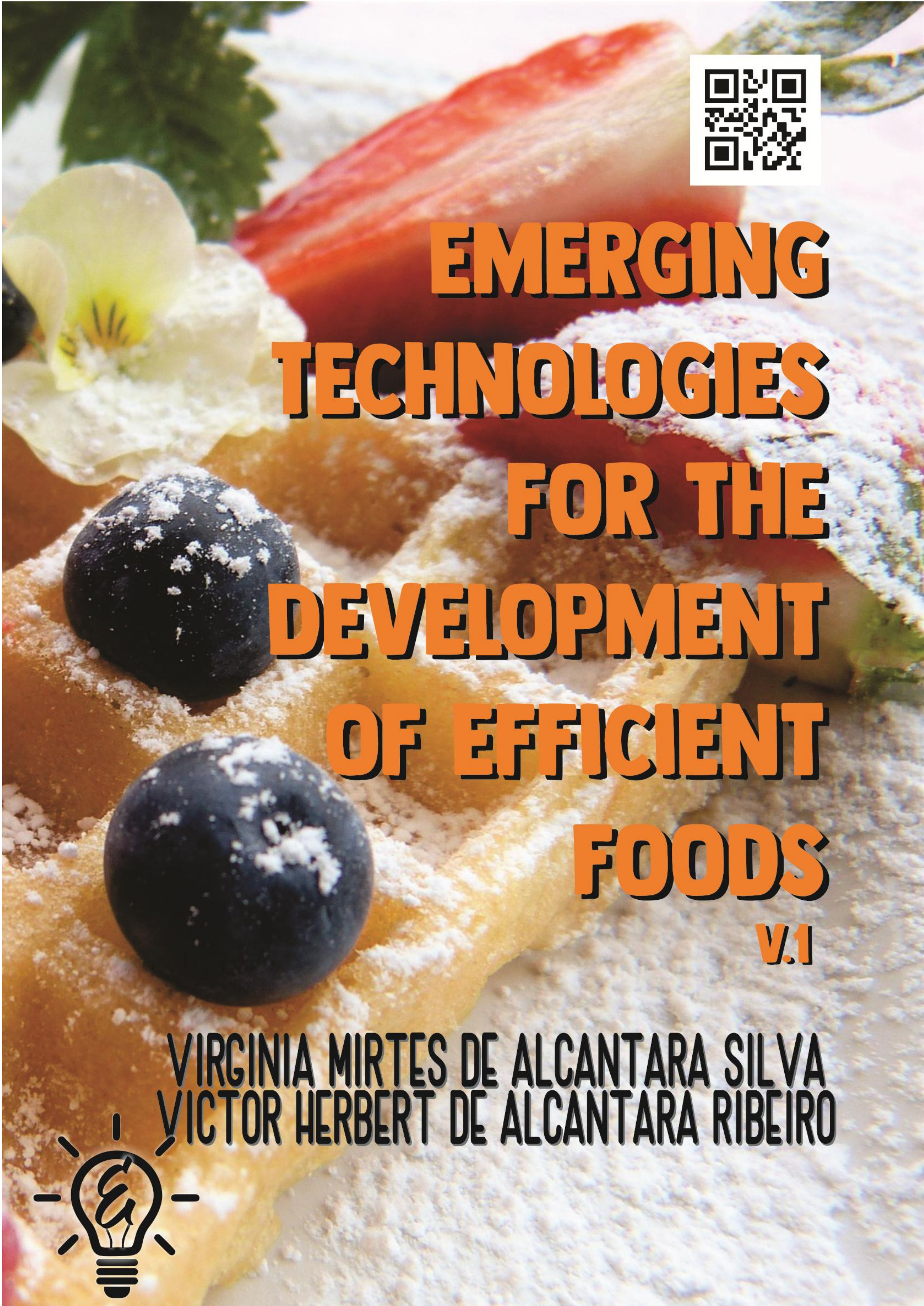

EMERGING TECHNOLOGIES FOR THE DEVELOPMENT OF EFFICIENT FOODS

V.1

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Summary

Preface

The collection EMERGING TECHNOLOGIES FOR THE DEVELOPMENT OF EFFICIENT FOODS – Vol. 1 emphasizes the importance that food science plays around the world in the development of new foods using emerging technologies and the use of raw materials of high nutritional value, with emphasis on this first volume with food and beverage formulations based on plants that is a worldwide reality. This first volume was a challenge because developing plant-based product formulations requires a lot of research regarding appearance, texture, flavor and aromas. Currently, research is advancing in the development of plant-based products such as hamburgers, nuggets, meatballs, mayonnaise, sausage, curd, yogurt, fish and chicken strips that have characteristics such as flavor, texture, aroma equal to analogues of animal origin.

With regard to beverages, “milk”, that is, the aqueous plant-based extract does not contain lactose or cholesterol, has a high protein content and many contain added calcium and vitamin B. The most consumed today are milk, milk almond, soy, rice and coconut, as well as others such as pea milk, lupine, lingho, hazelnut, cashew and hemp.

Brazil has stood out in this regard, the development of new foods and ingredients revealing the scientific potential of its researchers, increasingly encouraging innovation and the use of local raw materials such as fruits, vegetables, legumes, grains, nuts and seeds, revealing its mega biodiversity. In each chapter of the collection, new product formulations were developed using emerging processing technologies such as ultrasound, ultra-high pressure homogenization (UHPH), enzyme-assisted extraction among others, with a lot of creativity to develop new food structures.

Throughout the collection, research effectively contributes to the implementation of the circular economy in food systems, in the search for nutritious, quality and safe food and, above all, in the reduction of food waste. The effect of climate change, the crisis in food systems and the earth's ability to regenerate its own resources are decreasing dramatically and the population growth estimated for 2050 will demand an increase in the consumption of animal and plant protein.

In this way, food science combined with new emerging processing technologies using strategic raw materials is essential to ensure food safety, contributing to the transition from the current food system to a more efficient and cleaner food system combined with a zero carbon economy. In this way, food science is strongly present to ensure food safety and decisions must take into account what is technologically most efficient, from the choice of raw material to the final product. In this sense, scientific research has a fundamental and strategic role. All the versatility of this new collection evidences the seriousness of all researchers in each chapter, I consider the work fundamental, deserves to be read and appreciated by all those interested in the area. I feel professionally gratified to have been chosen to preface this work, which I do with great honor.

Marcelo Bregagnoli

Rector of the Federal Institute of Education, Science and Technology of the South of Minas Gerais

Presentation

Dr. Renato Ferraz de Arruda Veiga

Brazilian Society of Genetic Resources

According to Ordóñez et al. (2005), the Institute of Food Technologists, defines Food Science in the United States as a discipline that uses biological, physical, characterized, and engineering sciences to study the nature of the United States and the principles on which food processing rests food, while Food Technology is the application of Food Science for the selection, preservation, processing, conditioning, distribution and use of nutritious and safe food.

In this context, plant genetic resources (GFR) that are the basis of agriculture and planned food production, by providing a variability of genes needed for new cultivars, have a relevant role. When working with accessions of cultivated plants, deposited in active germplasm banks, they become vital to domestication, pre-breeding and genetic improvement programs.

The Food Technology of physical resources, mathematics, is a biology, being clear (already fascinating area of development, use of food with quality and safety). The accelerated growth of the world population is generating a significant increase in the demand for food, giving rise to concern about the production of plant and animal protein to meet world demand (FAO, 2017), further aggravated by the Covid-19 pandemic and the war between Russia and Ukraine, in 2022, and Brazil has been, more than ever, essential for humanity, at this critical moment, as it feeds approximately one billion people.

It is predicted that, by 2050, the demand for animal products will increase by 70% compared to the current one (YITBAREK, 2019). Although there is a global crisis, as is the case with livestock farmers in the Netherlands, harming the world supply of beef, in 2022, still, to meet and minimize such demand for meat, more investment must be made in plant protein products that emerge as healthy and sustainable possibilities and alternatives.

Different plant-derived ingredients such as globular proteins, oligosaccharides, dietary fiber, starch, amylopectin, short and long-chain unsaturated fatty acids, are used to develop plant-based foods, and the selection of the most essential is critical for creating a successful final product (SONI et al., 2022).

Thus, plant-based proteins are increasingly being explored as supplements and functional food ingredients, representing an inexhaustible source for the production of new nutritious foods for modern humans.

It is known that we underutilize our Brazilian mega diversity, especially in our diet, since we are dependent on foods from the food habits of our colonizers, such as the fifteen species that nourish humanity: fruit (banana and coconut - exotic), cereals (rice , wheat, corn, sorghum and barley - exotic); roots and tubers (potatoes, sweet potatoes and cassava – the last two are native); legumes (peanuts - native, beans and soybeans - exotic); sugar plantations (sugar cane and beet - exotic). What is most surprising is that of the approximately 2,500 spp. partially domesticated worldwide, only seven: rice, potato, beet, sugar cane, corn, soy and wheat – all exotic, they together account for 55% of our entire diet (LEÓN, 1989; WALTER et al., 2005; FAO, 2017).

Our plant food matrices are made up of: leaves, fruits, grains, vegetables, nuts and seeds, composed of macronutrients (carbohydrates, proteins and lipids), micronutrients (minerals, trace elements and vitamins) and phytonutrients (carotenoids, polyphenols, etc.) of bioactive compounds (vitamins A, C and E), phenolic compounds, fibers, lignins and tannins, which differs from animal food matrices.

Thus, alternative foods, such as beverages, hamburgers, milks, mayonnaise and cheeses, derived from plants, are similar in palatability to conventional foods, although they are nutritionally distinct, they are healthy and highly nutritious due to the content of bioactive and mineral compounds and, of course, free from of animal fats and nutrients.

Such emerging technologies are being used to develop foods, without the use of heat or chemical additives, in order to preserve their value and, at the same time, the aroma, color, shape, taste and texture. Thus, for the development of plant-based foods and beverages, it is essential to choose efficient processing such as: ultrasound, ultra-high pressure homogenization (UHPH), enzyme-assisted extraction and fermentation to obtain products with stability satisfactory physical, preservation of physicochemical and nutritional properties.

Ultrasound-assisted technology has several advantages such as: shorter extraction time, lower consumption of organic solvents, reduced temperatures and selectivity.

In ultra-high pressure homogenization (UHPH) the material is subjected to high pressures, being a non-thermal technique, which combines the effects of homogenization and pressure during the passage of food through a valve; promoting physical phenomena that include shear forces, cavitation and turbulence.

Enzyme-assisted extraction represents an alternative to chemical extraction; demonstrating advantages such as mild reaction conditions, lower energy consumption, greater recovery and less use of solvents and finally, we emphasize fermentation, as it allows numerous nutritional benefits to derived products, in addition to the functional and sensory properties that may be desirable to consumers in replacement for dairy products.

The evolution of food science and technology has increasingly generated research on methodologies and equipment in the various food and related areas.

Thus, for the development of this edition, it is observed that raw materials of high nutritional value were chosen, from the following species: pumpkin, peanut, plum, cashew, fava bean, lentil, strawberry, ora-pro-nóbis, biquinho pepper and Soy.

Among the various technologies used for processing, value-added by-products were included, which are easily integrated into current production, such as those that can create bioactive foods with pharmaceutical value.

The chapters of this work present us with unpublished data from scientific research, with emerging processing technologies, carried out in the great scientific center that is the Northeast region of Brazil.

For the development of each chapter, the use of biological, physical, chemical and thermal modeling methods is observed to validate the efficiency of the process. The methods applied, chapter by chapter, for the heat treatment and mathematical models used, can be very useful for the innovation of technical processes in each treatment of nutrients, quality and utility, as described below:

Chapter I – evaluated the use of pre-treatment with ethanol (in different volumetric fractions ET50 and ET100) and ultrasound in strawberry drying. The fruit represents a strategic matrix due to the amount of bioactive compounds, such as phenolic compounds such as anthocyanins, which are natural antioxidants, but are highly perishable and foodstuffs. The use of pre-treatments with ethanol aims at the evaporation of water and optimization of the process time, in addition to greater rehydration in the product.

Chapter II - analyzed the ultrasonic pretreatment in leaves of the unconventional food plant (PANC) “Ora-pro-nóbis” evaluating its influence on phenolic compounds, antioxidant activity and effective diffusivity. Regarding its nutritional composition, the leaves of "Ora-pro-nóbis" have a high level of essential amino acids, iron and carotenoids, a source of fiber and low lipids. Ultrasound technology has mechanics, promotes the enhancement of bioactive compounds, is easily reproducible and feasible. Physically, shock waves of sound waves and micro jets occur, while chemically, the formation of radicals occurs through sound waves and water vapor (LINO et al., 2020).

Chapter III - presents the development of hamburger formulations with different (textured soy PTSJ) and fava bean flour (FFR) and these formulations in terms of protein of approximate and different parameters. In this way, it was possible to develop a plant-based food product with high quality protein sources, such as fava beans and soybeans.

Chapter IV - analyzed the proximate composition, total phenolic compounds and water activity of pumpkin, peanut and lentil sprouts. The sprouted sprouts are sources of proteins, vitamins and minerals, besides having several activities such as: antioxidant, antifungal, anticarcinogenic, anti-inflammatory, antiviral, antiproliferative, among others (FERREIRA, 2002).

Chapter V – presents the development of different requeijão formulations, seasoned with biquinho pepper flour, and characterizes the formulations developed in relation to proximate, physical and microbiological parameters. For this product, we emphasize the importance of using natural compounds that highlight the reach of microbial stability and antioxidant effects, favoring the conservation and nutrition of the product.

Chapter VI - refers to the development of a water-soluble extract of cashew nut kernels, flavored with plum pulp, in addition to characterizing their proximate composition, total phenolic compounds and microbiological parameters. Beverages based on aqueous extracts, soluble in water, of vegetable origin, are highly nutritious, due to their high content of bioactive and mineral compounds. The growing search for products that suit the health conditions or differentiated diet of people allergic to proteins, lactose intolerant and vegans, is something emerging in the present century (CAMPOS, 2019).

Finally, when presenting this collection, it can be said that this volume contains unpublished texts and data that greatly contribute to the development of science and the technological and productive evolution of the country, by implementing an adequate system and model for the production of functional foods.

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To our friend Marcelo Bregagnoli – Magnificent Rector of the Instituto Federal Sul de Minas, who has always believed in our effort and competence.

To our professor Alexandre Santos de Souza for the inspiration and guidance on applied techniques and industrial processes in all chapters of this new collection and for the ideas for new beverage formulations using our Brazilian raw materials.

To the National Council for Scientific and Technological Development (CNPq) and the Coordination for the Improvement of Higher Education Personnel (CAPES) for the authors' master's and doctoral scholarships.

The Collection reflects all the efforts of our team of researchers in line with the guidelines of the Global Food Safety Initiative (GFSI) whose objective is the alignment of food safety standards that improves process efficiency throughout the global supply chain. Our main objective is to comply with the BRCGS, SQF and IFS Food Standard protocols simultaneously as it is imperative that we need transform our food systems to provide better health, and we need to do so efficiently within the industry.

This volume reflects our commitment as researchers to the importance of developing nutritious and safe food and beverage formulations, primarily based on whole grains, fruits, almonds, fiber, protein and vitamins. This first volume highlights

the first formulations using plant-based raw materials, as plant-based protein products emerge as healthy and sustainable possibilities and alternatives. Different plant-derived ingredients mainly proteins, oligosaccharides, dietary fibers, starch, amylopectin among others are used to develop plant-based foods and the selection of the most essential is fundamental for creating an efficient final product.

Therefore, this volume represents the continuous effort of our group in the production of different formulations of new products using raw materials from plant sources for the development of safe, nutritious and functional foods. In addition, we efficiently use mathematical models that are fundamental in the processing of these emerging techniques and formulations.

Our simple acknowledgment to all,

With affection,

The authors

INFLUENCE OF ETHANOL AND ULTRASOUND ON DRYING OF STRAWBERRIES (*Fragaria×ananassa*)

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Introduction

Strawberry (*Fragaria×ananassa*) is a fragile fruit, subject to rotting and deterioration, and vulnerable to physical damage, which adversely affects its sensory acceptability and commercial value (JIANG et al., 2021). Fresh strawberries are difficult to be stored and carried, which require the application of conservation techniques (ZHANG et al., 2020). Among the conservation methods, convective drying has been suggested as a good option to reduce the moisture content, which influences the perishability and ensures adequate conditions for its storage (SUJINDA et al., 2021).

Drying is a process that involves simultaneous heat exchange and mass transfer, where several parameters affect the process, many of which depend on the structure of the solid and can vary for the same product subjected to different processes (BARBOSA & LOBATO, 2016; MOURA et al., 2021).

According to Silva et al. (2020), to obtain a final product at a competitive price, in addition to quality, the process needs to be optimized and have low energy consumption. Thus, numerous pre-treatments, such as ultrasound (SANTOS et al., 2020), vacuum (SILVA et al., 2018), osmotic dehydration (LI et al., 2021), pulsed electric fields (NERI et al., 2021), ethanol (SANTOS et al., 2022) and carbonic maceration (WANG et al., 2014) have been applied before drying,

According to Freitas et al. (2021), ethanol (ET) is not harmful to humans, and ethanol residues in dry materials have not been reported. Thus, it can be used as a propagation medium instead of water during the ultrasonic stage. Inside the material, ethanol evaporates before water, its vapor moves towards the surface, which facilitates the evaporation of water (TATEMOTO et al., 2015; FENG et al., 2019).

In ultrasound (US) mechanical and cavitation effects are responsible for reducing the internal and external diffusion resistance of materials in mass transfer during drying. As a result, the drying rate can be improved, with a reduction in drying time and, consequently, in energy expenditure (GUO et al., 2020).

Some studies with the application of pre-treatments to strawberry convective drying processes are available in the literature, such as: ultrasound (WANG et al., 2022), high hydrostatic pressure (ZHANG et al., 2020), pulsed electric field (RODRÍGUEZ-RAMÍREZ et al., 2020) and osmotic dehydration (MACEDO et al., 2022).

However, no studies reporting convective drying of strawberry with application of pre-treatments with ethanol and ultrasound. To date, the combination pre-treatments of ethanol and ultrasound were applied to: banana (GRANELLA et al., 2022), apple (ROJAS et al., 2020), potato yacon (MARTINS et al., 2022) and celery (MIANO et al., 2021). However, did not evaluate the effect of different volume fractions of ethanol.

Considering the importance of drying studies with new food matrices through the application of pre-treatments, the objective of this work was to evaluate the use of ethanol (in different volume fractions, ET50 and ET100) and ultrasound in drying strawberries.

Materials and Methods

Strawberries (*Fragaria × ananassa*) were hand-picked and bought at a local market on Natal, Rio Grande do Norte, Brazil. Only ripe, intact, and with no surface lesions fruits were chosen. Cleaning and sanitizing were performed using an aqueous solution of sodium hypochlorite with a concentration of 200 mg L^{-1} of free chloride for 10 min and then rinsed with running water. Strawberries were cut longitudinally into slices with a thickness of 0.005 m and an average radius of 0.0395 m, obtained from the average of the largest longitudinal diameter. The dimensions were measured with a digital caliper (Digmess®).

Pre-treatments

Strawberry samples were submitted to different pre-treatments: immersion in aqueous solution with 50% ethanol (ET50) and with ultrasonic treatment (ET50US), 100% ethanol (ET100), and with ultrasonic treatment (ET100US). For all pre-treatments, samples were immersed in absolute ethanol (99.5%, Dinâmica Química Contemporânea, Indaiatuba, Brazil) or ethanol solution (50%) for 10 min, kept at 30°C, in the sample/solution ratio of 1:4 (m/m) according to studies previously carried out by Freitas et al. (2021), Cunha et al. (2020) and Rojas e Augusto (2018).

For the samples submitted to ultrasound, the recipients were placed in an ultrasonic bath (Unique, USC-2850A, Brazil) with a frequency of 25 kHz, intensity of 4870 W m-2 following the methodology proposed by Santos et al. (2020). In Figure 1 shows the main steps for the development of the research.

Figure 1. Shows the main steps for the development of the research.

Drying kinetics

Drying kinetics was performed for samples with and without (control) pre-treatment. The strawberries slices (300g) were uniformly distributed on metallic trays of stainless steel (dimensions of 15 x 30 cm). The drying was performed using a dryer with air circulation (Tecnal, model TE-394/2-MP) constant velocity of 1.5 m s^{-1} (airflow was perpendicular to the material). The drying temperature used was 60°C, and the temperature was controlled using a thermostat.

The temperature was chosen after the results of kinetics studies carried out beforehand by Freitas et al. (2021), Cunha et al. (2020), and Sakooei-Vayghan et al. (2020). The moisture loss was recorded by using a digital balance of 0.001g accuracy (Bel®, model M214AIH). Briefly, the time intervals for recording the sample weighing followed the order: during the first 30 min of the process, weighings were performed every 5 min. From this time on, weighings were performed every 10 min for 1 h. Then, weighings were performed every 15 min for another 1 h, then at 30 min intervals for 2.5 h, and finally, every 1 h, until there was no more significant variation in the sample mass. The drying process continued until the constant reading of mass (equilibrium) was recorded.

The drying kinetic curves and different mathematical models were fitted to the experimental data (Table 1), using the computer program LAB Fit® (SILVA & SILVA, 2008) through non-linear regression, by the Quasi-Newton method. The model fitting was evaluated by the determination coefficient (R^2) and the chi-squared (χ^2).

Table 1. Models used for mathematical modelling of strawberries drying

Model	Equation
Handerson and Pabis	$X^{*} = a \times \exp(-b \times t)$
Page	$X^{*} = \exp(-a \times t^{b})$
Lewis	$X^{*} = \exp(-a \times t)$
Silva et al.	$X^{*} = \exp\left(-a \times t - b\sqrt{t}\right)$
Peleg	$X^{*} = 1 - t/(a + b \times t)$

Diffusion model

The ideal model to define the diffusion of the water in the strawberry slices, assuming the infinite plate geometry, since the slice thickness was much greater than the other dimensions (SILVA et al., 2013). The model follows the boundary conditions of the third type and, thus, the analytical solution of the diffusion equation is described according to Equation 1.

$$X^{*}(t) = X_{eq} - \left(X_{eq} - X_{i}\right)\sum_{n=1}^{16}\left(\frac{2\left(\frac{h(L/2)}{D}\right)^{2}}{\mu_{n}^{2}\left(\left(\frac{h(L/2)}{D}\right)^{2} + \left(\frac{h(L/2)}{D}\right) + \mu_{n}^{2}\right)}\right)\exp\left(-\mu_{n}^{2}\frac{D}{(L/2)^{2}}t\right)$$

(Eq.1)

Where: D corresponds to diffusivity and it is time; h is the convective mass transfer coefficient; L is the thickness; μ_{n} are the roots of Equation 2 being called the characteristic equation for the infinite wall.

$$\cot\mu = \frac{\mu}{\frac{h\left(L/2\right)}{D}} \quad \text{(Eq.2)}$$

The third-type boundary condition was used to calculate the mass transfer Biot number in relation to drying, without a previous stipulation, according to the optimization methodology proposed by Silva et al. (2010) and optimization was performed using Convective software (SILVA & SILVA, 2009).

Results and Discussion

Drying kinetics and empirical models

The drying kinetics is shown for the different pre-treatments in Figure 1. It can be seen when evaluating Figure 1 that the application of the pre-treatments reduced the drying time from 1230 min in the control sample to 1050, 870, 690, and 570 min for the samples treated with ET50, ET100, ET50US, and ET100US, respectively. The use of pre-treatment with ethanol and ultrasound proved to be efficient in reducing drying time, which consequently leads to a reduction in energy consumption.

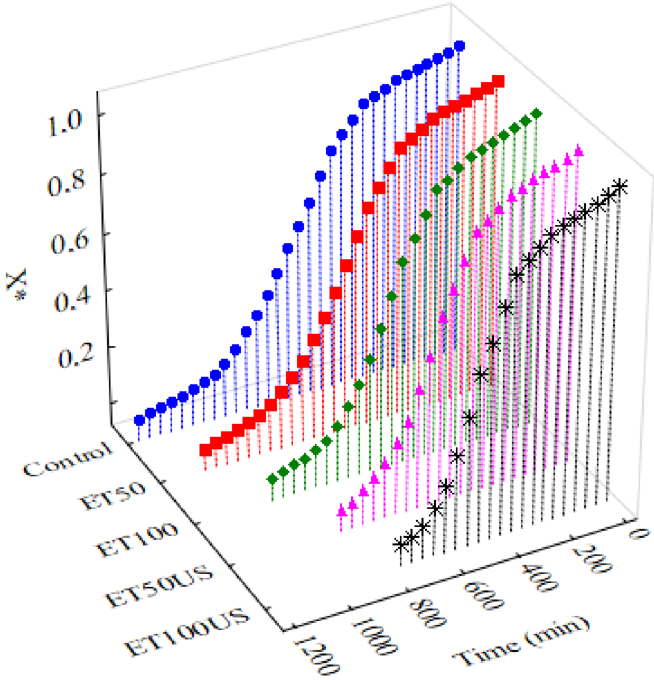

Figure 1. Drying kinetics of strawberry under different pre-treatment conditions as a function of drying time at 60°C, from initial to equilibrium moisture content.

Jiang et al. (2016), explain that the fact that the high ultrasonic power used in the pre-treatment severely damages the cell wall, resulting in a more porous structure, facilitates the diffusion of water in the sample, thus reducing the processing time. Drying time was also reduced with the application of pre-treatment with ultrasound on guava slices (SANTOS et al., 2020), potato slices (ROJAS & AUGUSTO, 2018b), and sweet potato (WU et al., 2020).

The significant reduction in drying time is associated with changes in the thickness of the diffusion boundary layer, as well as the mechanisms that explain the improvement in drying with the application of ethanol, which is based on inducing the liquid to flow from low regions to regions high surface tension (ROJAS & AUGUSTO, 2018b). In addition, the time the food is exposed to drying conditions leads to an increase in enzymatic and non-enzymatic oxidation reactions that influence the quality of the product (SZADZIŃSKA et al., 2016).

The mass transfer process over time was modeled by applying the models of Henderson and Pabis, Page, Lewis, Silva et al and Peleg. The parameters estimated by the empirical models evaluated in this study are summarized in Table 2.

Table 2. Parameters of mathematical models fitted to experimental data of strawberry drying, determination coefficients (R^2) and chi-square function (χ^2)

Pre-treatment	Parameters	Models				
		Handerson and Pabis	Page	Lewis	Silva et al	Peleg
Control[1]	a	1.0273	0.4393x10^{-3}	0.2352x10^{-2}	0.2863x10^{-2}	0.4715x10^{3}
	b	0.2430x10^{-2}	1.2721	-	-0.1037x10^{-1}	0.5659
	R²	0.9902	0.9974	0.9916	0.9929	0.9954
	X²	0.5219 x10^{-1}	0.1522 x10^{-2}	0.5909x10^{-1}	0.3706x10^{-1}	0.2107x10^{-1}
ET50	a	1.0222	0.9752x10^{-3}	0.2880 x10^{-2}	0.3365x10^{-2}	0.3638x10^{3}
	b	0.2926x10^{-1}	1.1826	-	-0.8660x10^{-2}	0.6115
	R²	0.9947	0.9982	0.9956	0.9961	0.9974
	X²	0.2626x10^{-1}	0.8116x10^{-2}	0.3039x10^{-1}	0.1864x10^{-1}	0.1087x10^{-1}
ET100	a	1.0263	0.1263x10^{-2}	0.3593 x10^{-2}	0.4265x10^{-2}	0.2894x10^{3}
	b	0.3726x10^{-2}	1.1847	-	-0.1037x10^{-1}	0.6187
	R²	0.9948	0.9983	0.9959	0.9963	0.9967
	X²	0.2320x10^{-1}	0.7372x10^{-2}	0.2841x10^{-1}	0.1576x10^{-1}	0.1285x10^{-1}
ET50US	a	1.0316	0.1447 x10^{-2}	0.4123 x10^{-2}	0.5026x10^{-2}	0.2602x10^{3}
	b	0.4320x10^{-2}	1.1923	-	-0.1248x10^{-1}	0.5841
	R²	0.9950	0.9988	0.9964	0.9970	0.9979
	X²	0.1842x10^{-1}	0.4088x10^{-2}	0.2532x10^{-1}	0.1064x10^{-1}	0.7462x10^{-1}
ET100US	a	1.0441	0.1154x10^{-2}	0.4823x10^{-2}	0.6308x10^{-2}	0.2331x10^{3}
	b	0.5154x10^{-2}	1.2735	-	-0.1842x10^{-1}	0.5375
	R²	0.9915	0.9987	0.9940	0.9955	0.9958
	X²	0.2785x10^{-1}	0.3877x10^{-2}	0.4014x10^{-1}	0.1462x10^{-1}	0.1330x10^{-1}

Note: [1]Samples no pretreated; ET50 and ET100: samples pretreated with ethanol=50 and 100 %, respectively; US: samples ultrasound treated.

Assessing the results in Table 2, it is observed that the Page model had the highest coefficients of determination (R^2) and lowest chi-squares. Therefore, it was more suitable to describe the drying behavior of strawberry slices. The fit of the Page model to the experimental data can be seen in Figure 2A. This model, although empirical, has been applied to drying processes over the years and has recently been shown that the anomalous diffusion approach, based on fractional calculus, can attribute phenomenological meanings to the Page model (ROJAS & AUGUSTO, 2018B; SIMPSON et al., 2017).

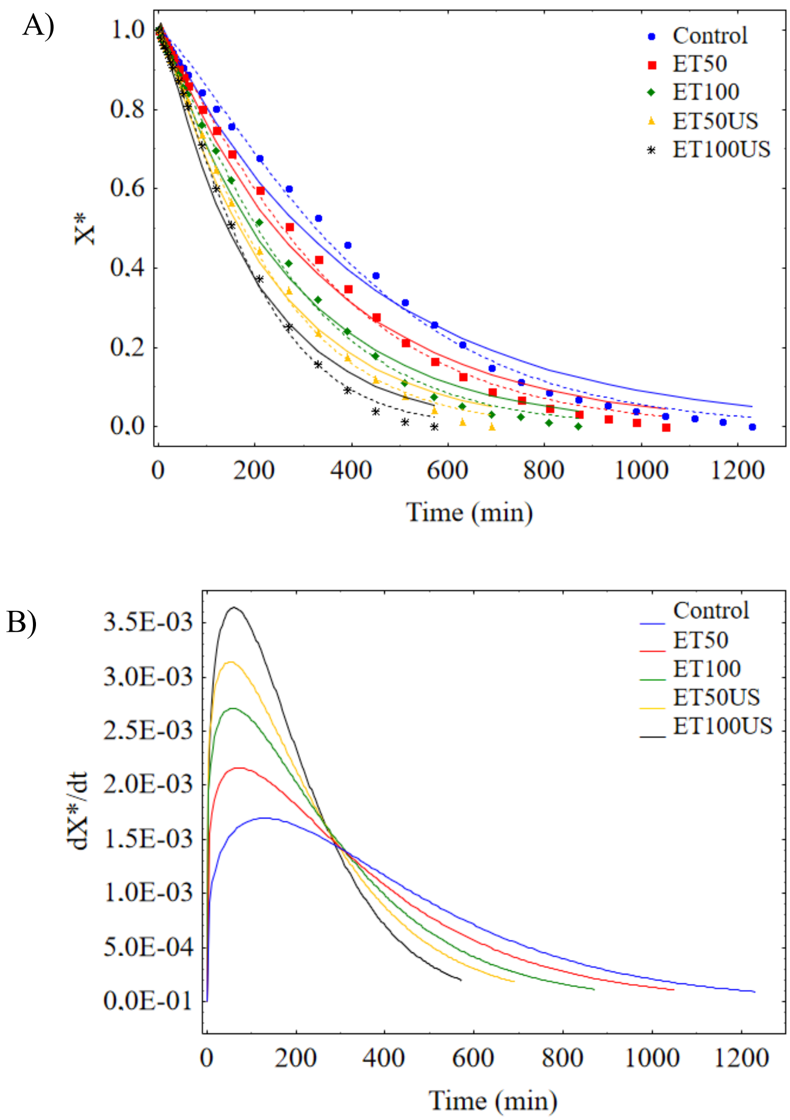

Figure 2. Drying kinetics simulations using A) Empirical Page model (—), and diffusion model (···), and B) drying rate determined using the model of Page at a temperature of 60°C for the applied conditions.

Each parameter in Page's equation can be related, 'a' to the diffusion coefficient and sample geometry, and 'b' related to the type of diffusion and microstructure of the food, where $b>1$ indicates super-diffusion and $b<1$ sub-diffusion (SIMPSON et al., 2017).

Analyzing the results of the Page model in Table 2, it is observed that the 'a' parameter increases with the application of pre-treatments compared to the control sample, reflecting the increase in the drying rate. Furthermore, all pre-treatments showed a super-diffuse behavior ($b>1$) during drying. As observed in this study, Rojas and Augusto (2018b) in the study of ethanol and ultrasound pre-treatments to improve infrared drying of potato slices, it was observed that the value of 'b' for the Page model was greater than 1, which is expected due to the importance of capillarity.

Diffusion model

Although the Page model provides an idea of the type of diffusion that occurs during the drying process, the diffusion model with boundary condition of the third type (Equation 4) was established as the most adequate to describe the diffusion process during drying (Figure 2A) with the advantage of obtaining the effective diffusion coefficient (D), convective mass transfer coefficient (h), and the Biot number (Bi), whose results are mentioned in Table 3.

Table 3. Effective diffusivity, convective mass transfer coefficient and Biot number (Bi) for strawberry drying

Pre-treatment	D x 10^6 (m^2 min^{-1})	h x 10^6 (m min^{-1})	Bi x 10^3	R^2	χ^2 x 10^2
Control[1]	8.86	6.20	1.75	0.9905	5.1404
ET50	10.88	7.61	1.75	0.9947	2.5760
ET100	13.60	9.52	1.75	0.9951	2.2437
ET50US	22.13	11.22	1.25	0.9952	1.7293
ET100US	22.45	13.28	1.50	0.9927	2.5880

Note: [1]Samples no pretreated; ET50 and ET100: samples pretreated with ethanol=50 and 100 %, respectively; US: samples ultrasound treated.

The results found using the diffusion model were superior to those observed by Santos et al. (2020) for guava slices treated with ultrasound, where diffusivity values were reported between 1.5061×10^{-7} m^2 min^{-1} for the control sample to 2.0631×10^{-7} m^2 min^{-1} for the sample treated with ultrasound for 20 min. This behavior observed for slices of strawberries can be attributed to the combined application of pre-treatment with ethanol and ultrasound, in addition to other factors, such as the structural difference of the material and the initial water content.

The effective diffusivity (D) and the convective mass transfer coefficient (h) increased with the application of pre-treatments. The increase in ethanol concentration resulted from the increase in effective diffusivity, being even greater in samples that combined pre-treatment with ethanol and ultrasound (ET50US - 22.13×10^{-6} m^2 min^{-1} and ET100US - 22.45×10^{-6} m^2 min^{-1}).

The increase in these values corresponds to the increase in the drying rate (Figure 2B). The data agree with the studies by Rojas and Augusto (2018b) and

Rojas and Augusto (2018a), who observed for potato slices and pumpkin cylinders that the application of ethanol resulted in an increase in the drying rate and, consequently, a reduction in the drying time.

According to Rojas and Augusto (2018a), a possible mass transfer mechanism during drying of materials treated with ethanol can be described considering the principles of the Marangoni effect, which assumes that the ethanol superficially remained in the sample is quickly vaporized. Consequently, a surface tension gradient is generated within the samples.

The drying rate and the effective diffusivity, as well as the convective mass transfer coefficient, were higher when the effect of ethanol pre-treatment and ultrasound application were combined. The effect of ultrasound in increasing the drying rate was observed in studies of the drying process of foods such as guava (Santos et al., 2020), sweet potato (WU et al., 2020), and persimmon (BOZKIR et al., 2019).

Conclusions

Ethanol and ultrasound as a pre-treatment for convection drying are promising.

The Page model proved to be more adequate to describe the drying behavior of strawberry slices (R^2>0.99) and smaller chi-squares.

The use of the ET100US combination promoted shorter drying time (570 min), higher diffusivity values (22.45 x 10^{-6} m^2 min^{-1}) and the convective mass transfer coefficient (13.28 x 10^{-6} m min^{-1}), lower water content (6.78%).

Therefore, this prepayment has great potential for application in the development of high value-added foods.

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EFFECT OF ULTRASOUND TIME ON PHENOLIC COMPOUNDS, ANTIOXIDANT ACTIVITY AND EFFECTIVE DIFUSIVITY OF ORA-PRO-NÓBIS LEAVES

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Introduction

Pereskia aculeata Mill, more popularly known as ora-pro-nóbis, carne-de-poor, carne-de-negro or lemon creeper, is a plant of the Cactacea family, one of the few with developed leaves. It is native to the Americas, being native from Florida to Brazil. Its leaves are elliptical and symmetrical in shape, about 7 cm long and 3 cm wide. Its petiole is short, grouping from two to six leaves on lateral branches. It also has axillary spines, characteristic of its family, and has small white flowers and fruits in small yellow berries (MARTINEVSKI et al., 2013).

Foods of plant origin encompass a wide variety of categories, including fruits, vegetables and legumes, and several biological properties have already been scientifically proven, such as antifungal, antibacterial, antioxidant, anti-inflammatory, cardioprotective, anti-cancer, among others. The use of synthetic functional food ingredients raises health and ecological concerns. Thus, natural ingredients have become an ecologically important alternative (CODEVILLA et al., 2015). According to Yildiza et al. (2019), the consumption of foods rich in bioactive compounds is a habit that helps to maintain health, being efficient in the treatment and prevention of cardiovascular diseases, metabolic, inflammatory and carcinogenic diseases.

Phenolic compounds are substances belonging to the class of bioactive compounds, resulting from the secondary metabolism of plant organisms, found mainly in seeds, leaves and plant skins. These compounds are responsible for regulating the structure and function of plants, acting on the growth and development of plant pigments. In the human body, phenolic compounds act as antimicrobials and antioxidants, preventing degenerative diseases (SILVA et al., 2021).

Ultrasound technology has a mechanical action, promotes the improvement of bioactive compounds, is easily reproducible and economically viable. Physically, shocks of acoustic cavitation waves and microjets occur, while chemically, possible formation of free radicals occurs through the lysis promoted by sound waves and water vapor (LINO et al., 2020). Furthermore, according to Santos et al. (2022) mechanical and cavitation effects are also responsible for reducing the resistance to internal and external diffusion of materials in mass transfer during their drying processes.

In this context, the present study aims to apply ultrasound pre-treatment on oro-pro-nóbis leaves at different times and evaluate its influence on phenolic compounds, antioxidant activity and effective diffusivity.

Materials and Methods

Raw material and hygiene

Leaves of ora-pro-nóbis (*Pereskia aculeata*) were acquired in the city of João Pessoa in the state of Paraíba, Brazil. The fresh leaves were cleaned and sanitized with an aqueous solution of sodium hypochlorite with a concentration of 200 mg/L of free chloride for 10 min and then rinsed with running water. In the figure 1 Main steps taken for the development of the work.

Figure 1. Main steps taken for the development of the work.

Ultrasound pre-treatment

The ora-pro-nóbis leaves were treated by ultrasound, being kept in a bath at two different sonication times, 10 min (T1), 20 min (T2) and 30 min (T3). The ultrasound was transmitted in an ultrasonic bath with thermostat (Unique, model USC-2850A, Brazil) without mechanical agitation, frequency of 25 kHz and intensity of 4870 W m^{-2}.

Analysis of bioactive compounds and antioxidants

In the fresh (control) and pre-treated (T1, T2 and T3) leaves, the levels of total phenolic compounds (TPC) and antioxidant activity were determined as described in the following items.

Total phenolic compounds (TPC)

Aqueous extract was prepared in a 1:10. The total phenolic content in the extracts was quantified by the spectrophotometric method with Folin-Ciocalteu (WATERHOUSE, 2006). The absorbance was measured at 750 nm in a SP-2000 UV spectrophotometer (Spectrum, Shanghai, China). The standard curve was prepared using gallic acid as standard at a concentration of 100 µg mL^{-1}.

Antioxidant activity (AA)

Method ABTS^{o+}

The determination of AA by the ABTS^{o+} (2,2'–AZINO-BIS (3-ethylbenzo-thiazoline-6-sulfonic acid)) was performed according to the experimental procedures proposed by Rufino et al. (2007a). 3 µL of the extract was mixed with 3.0 mL of the ABTSº+ radical. The absorbance was determined at 734 nm after 6 min of mixing.

Method DPPH

The determination of AA by the method DPPH (2,2-Diphenyl-1-picrylhydrazyl) was performed according to the experimental procedures proposed by Rufino et al. (2007b). For this, 0.1 mL aliquots of the extract were mixed with 3.9 mL of DPPH (0.06 mM). The absorbances of the samples were read at 515 nm every minute until stabilization.

Method FRAP

The determination of AA by the FRAP method (Ferric antioxidant power reduction) was performed according to Benzie et al. (1996). For this, 90 mL aliquots of the extract were mixed with 270 mL of deionized water and 2.7 mL of FRAP reagent. The solutions were homogenized and abundant in a water bath at 37°C for 30 min. Absorbance was determined at 595 nm and the FRAP reagent was used as a blank.

Effective diffusivity

The ora-pro-nóbis leaves were submitted to drying kinetics at a temperature of 60°C in an air circulation oven with a fixed speed of 1.5 m/s. The drying process was continued until the constant mass reading was recorded. With the data obtained experimentally, the diffusivity and effective diffusivity (Def) of the leaves under different conditions (T1, T2 and T3) were calculated using the diffusion equation (Equation 1) for rectangular coordinate systems (CRANK, 1975). In the Def calculus, the analytical solution to Fick's second diffusion law was applied in the form of an infinite series (Equation 2).

$$\frac{\partial X}{\partial t} = \frac{\partial}{\partial x}\left(Def \frac{\partial X}{\partial x}\right) + \frac{\partial}{\partial y}\left(Def \frac{\partial Y}{\partial y}\right) + \frac{\partial}{\partial z}\left(Def \frac{\partial Z}{\partial z}\right) \quad \text{(Eq.1)}$$

$$X^* = \frac{X(t) - X_{eq}}{X_i - X_{eq}} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)}\exp\left[-(2n+1)^2\pi^2\frac{Def}{L^2}t\right] \quad \text{(Eq.2)}$$

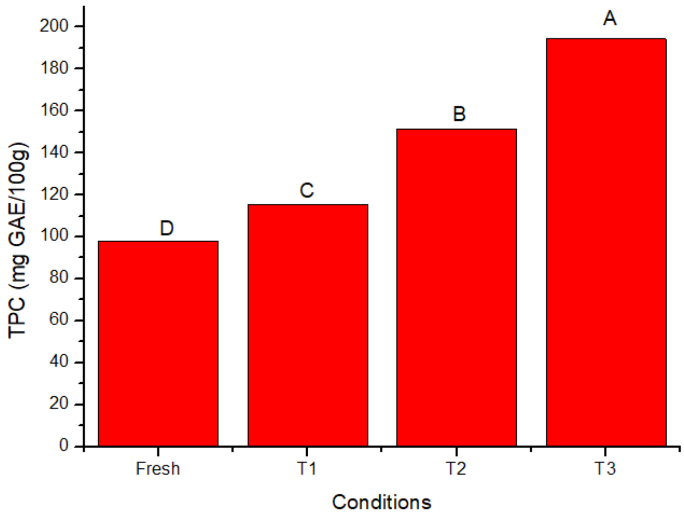
Where: X* is the dimensionless moisture ratio; n is the number of terms; Def is the effective diffusivity (m^2 min^{-1}); L is the wall thickness (m); t is the time (min).

Statistical analysis

Statistica software version 7.0 was used to perform statistical tests (ANOVA) and Tukey's test, having a 5% significance level (STASOFT, 2007).

Results and Discussion

In Figure 1, the average values obtained for the content of total phenolic compounds of the leaves of ora-pro-nóbis fresh and submitted to ultrasound pre-treatment are expressed. According to Barbalho et al. (2016), the content of bioactive compounds in ora-pro-nóbis leaves explains its potential to complement the human diet.



Note: T1: 10 min of ultrasound; T2: 20 min of ultrasound; T3: 30 min of ultrasound; Different letters in the same bar differ significantly ($p \leq 0.05$).

Figura 1. Teor de compostos fenólicos totais das folhas ora-pro-nóbis frescas e submetidas a diferentes tempos de sonicação.

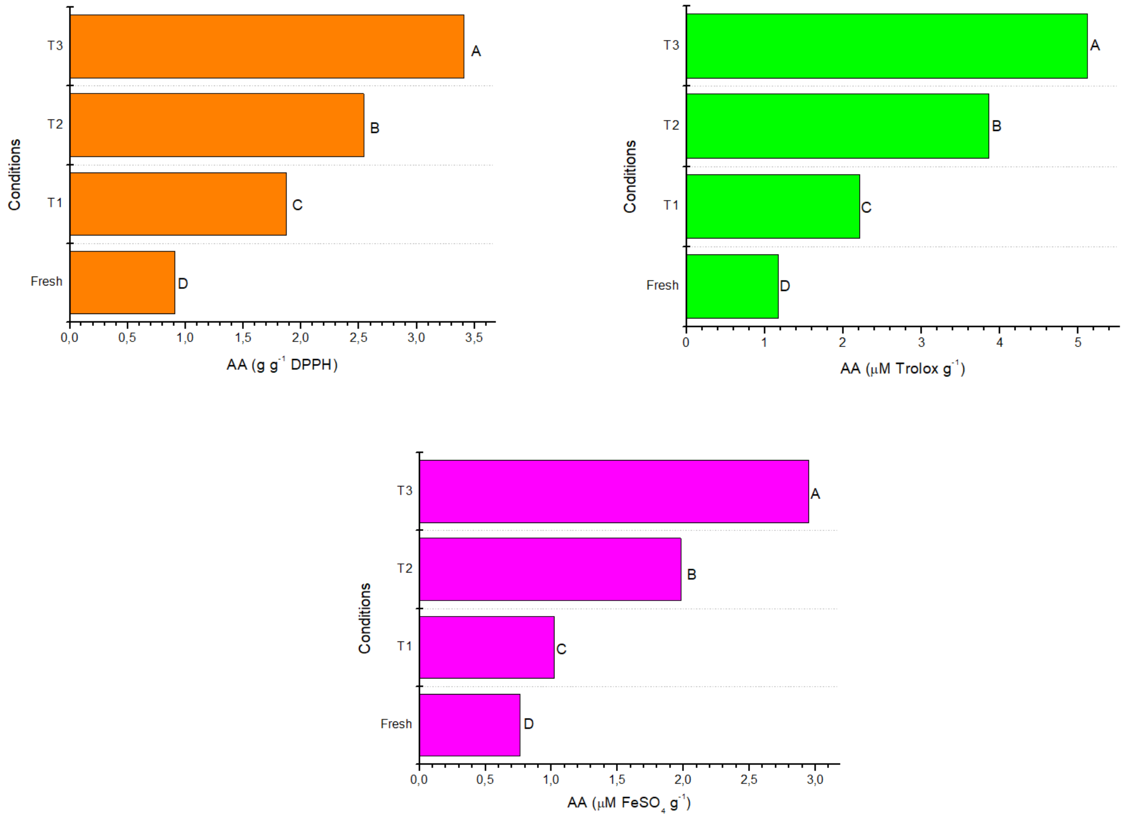
The total phenolic compounds content of ora-pro-nóbis leaves showed significant statistical differences when compared to each other ($p \leq 0.05$). It is observed that the values increased when the sonication time was increased. The fresh leaves that did not go through the ultrasound pre-treatment showed a value of 98.16 mg GAE/100g and the leaves pre-treated for 30 min in an ultrasonic bath (T3) presented a value of 194.32 mg GAE/100g, representing an increase of approximately 50% in the content of total phenolic compounds.

According to Chemat et al. (2017), the ultrasound extraction process expands the possibility of removing micronutrients from the interior of the plant matrix, breaking the fibers, due to the cavitation process, making compounds of interest more easily available to the extractor medium.

Silva et al. (2018) in their studies with ora-pro-nóbis fruits at different stages of maturation, obtained phenolic compounds contents of 113.42 mg GAE/100g (green stage), 124.03 mg GAE/100g (intermediate stage) and 120.09 mg GAE/100g (mature stage). Covarrubias-Cárdenas et al. (2018) when evaluating the extraction of phenolic compounds from dry stevia leaves using the ultrasound technique, found that the minimum extraction time (5 min) was sufficient to obtain the highest content of bioactive compounds.

Figure 2 shows the values obtained for the antioxidant activity of ora-pro-nóbis leaves by the DPPH, ABTS+ and FRAP methods. According to Silva et al. (2021) the antioxidant action of a compound is directly related to the bioactive components present and depends on the chemical structure and concentrations of these phytochemicals in the food.

Regarding antioxidant activity, low values were observed for the three methods analyzed, however, the FRAP method obtained the highest values ranging from 1.17 μM $FeSO_4$ g^{-1} to 5.12 μM $FeSO_4$ g^{-1}. It was also observed that the antioxidant activity values were significantly higher when the sonication timce was increased, regardless of the quantification method.



Note: T1: 10 min of ultrasound; T2: 20 min of ultrasound; T3: 30 min of ultrasound. Different letters in the same bar differ significantly ($p \leq 0.05$).

Figure 2. Antioxidant activity (AA) of fresh ora-pro-nóbis leaves submitted to different sonication times, determined by different methods: A) DPPH, B) ABTS+ and C) FRAP.

Table 1 presents the values of the statistical parameters (Coefficient of determination (R^2) and chi-square function (χ^2), obtained by adjusting the diffusion model, considering the geometry of a flat plate.

Table 1. Coefficient of determination (R^2) and chi-square function (χ^2), obtained by fitting the diffusion model

Conditions	R^2	χ^2
Control	0,9915	1,6849x10^{-2}
T1	0,9963	1,3810x10^{-2}
T2	0,9991	2,7809x10^{-2}
T3	0,9945	2,1846x10^{-2}

Note: T1: 10 min of ultrasound; T2: 20 min of ultrasound; T3: 30 min of ultrasound.

It is observed that the adjustment of the diffusive model with analytical solution for Fick's second law of diffusion presented values of the coefficient of determination above 0.99 (R^2>0.99) and low values of the chi-square function with values in the order of 10^{-2}, ranging from 1.3810 x 10^{-2} a 2.7809 x 10^{-2}. Thus, it can be considered that the model was satisfactorily adjusted to the set of experimentally obtained data. Table 2 shows the mean values of effective diffusivity of ora-pro-nóbis leaves submitted to different sonication times and dried at 60°C.

Table 2. Effective diffusivity (*Def)* of ora-pro-nóbis leaves submitted to the convective drying process

Conditions	***Def* (m^2 s^{-1})**
Controle	1.02 x 10^{-10} A
T1	1.75 x 10^{-10} A
T2	2.58 x 10^{-10} B
T3	3.15 x 10^{-10} C

Note: T1: 10 min of ultrasound; T2: 20 min of ultrasound; T3: 30 min of ultrasound. Different letters in the same column differ significantly ($p \leq 0.05$).

As observed in Table 2, the magnitudes of the effective diffusion coefficients varied from 1.02 x 10^{-10} to 3.15 x 10^{-10} m^2 s^{-1}, when there was an increase of up to 30 min at the time of pretreatment with ultrasound. The effective diffusivity values increased significantly when the sonication time was increased, however, when comparing the control samples (without pre-treatment) with the samples (T1) it was verified that there was no statistically significant difference.

Silva et al. (2015) when performing the drying process of genipap leaves at temperatures of 35, 46 and 65°C, obtained diffusivity values ranging from 1.12 to 4.02 x 10^{-12} m^2 s^{-1}.

According to Gomes et al. (2018) diffusivity represents the speed with which water moves from the interior to the surface of the material, thus being vaporized (MENEZES et al., 2013). Therefore, the longer the sonication time, the faster the movement of water from the food to the environment.

Conclusions

Through the results obtained, it can be concluded that:

The pre-treatment with ultrasound was efficient for the processing of ora-pro-nóbis leaves, being the time of 30 min the most indicated;

The levels of total phenolic compounds had their values increased by approximately 50%, being significantly influenced by the sonication time;

The antioxidant activity showed higher values for the FRAP method;

The diffusion model showed a good fit to the experimental data (R^2 >0.99) and the process diffusivity ranged from 1.02 x 10 $^{-10}$ to 3.15 x 10^{-10} m^2 s^{-1}.

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PREPARATION OF TEXTURIZED SOY PROTEIN HAMBURGER WITH ADDED BEAN FLOUR: COMPOSITION AND TEXTURE

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Introduction

According to Normative Instruction nº 20 of 2000, the hamburger is defined as an industrialized meat product, obtained from the use of minced meat from animals for slaughter, with or without adipose tissue and other ingredients, molded and submitted to an appropriate technological process, where the texture, color, flavor and smell must be characteristic (BRASIL, 2000). The hamburger is one of the most consumed foods in the world and in all popular classes, due to its practicality of consumption and attractive sensory characteristics, standing out when compared to existing fast foods (TREVISAN et al., 2016; PAULA et al., 2019).

Due to the high demand for healthier foods and in view of the concern with the group of individuals, about food alternatives available in the market, the food industry has developed products, aimed at vegetarians and vegans, in which, it aims at the modification of meat by of plant origin (LIMA SEGUNDO et al., 2020; MORO et al., 2021).

Soy protein is an edible component of soybeans and is an important protein source. To obtain it, its lipids and non-digestible components are removed. It can be presented as: isolated, concentrated or as flour, depending on your process. In this way, it is transformed into textured soy protein (PEUCKERT et al., 2010).

The fava bean (*Phaseolus lunatus* L.) is an annual plant of the legume family, climbing and cultivated for having edible grains. The green and dry beans, the green pods, and the leaves of the fava bean, can be consumed by the man; it is one of the main legumes grown in the tropical region, which has the potential to supply vegetable protein to the population and reduce dependence, almost exclusively, on the common bean of the carioca group (GUIMARÃES et al., 2007).

In order to replace products of animal origin and increase the daily consumption of legumes, as well as worldwide awareness of the many benefits of fava-rajada beans. The present study aimed to develop different hamburger formulations with different concentrations of textured soy protein (PTSJ) and broad bean flour (FFR) and to characterize these formulations in terms of proximate and physical parameters.

Materials and Methods

Feedstock

For the development of this work, textured soy protein (Camil®), broad bean (Kicaldo®), corn oil (Liza®), carboxymethyl cellulose (Mix®), powdered seasonings and condiments were used, all ingredients were purchased commercially site of the city of João Pessoa in the state of Paraíba-PB, Brazil.

Preparation of flour

For the elaboration of the flour, the broad bean was used, in which the beans were dried in an air circulation oven at a temperature of 60°C and an air speed of 1.5 $m\ s^{-1}$. The drying process was continued until the grains reached constant mass (equilibrium). After the drying process, the dry grains were ground in a knife mill and sieved (60 mash), the flour obtained was stored in laminated packages at room temperature.

Mineral profile

The mineral profile was determined through the ash using an Energy Dispersive X-Ray Fluorescence Spectrometer, model EDX-720 (Shimadzu, Kyoto, Japan) using liquid nitrogen.

Centesimal composition

Moisture content was determined by drying in an oven at 105°C until constant weight (BRASIL, 2008).

Ash content was determined by muffle incineration (BRASIL, 2008);

Total protein content was quantified by the Micro-Kjeldahl method, which consisted in the determination of total nitrogen according to the methodology described by Brasil (2008);

Lipid content was quantified by the modified method of Blig and Dyer (1959).

Total carbohydrate content was calculated by difference to obtain 100% of the total composition (FAO, 2003).

Making the hamburger

The hamburgers were prepared with different concentrations of textured soy protein (PTSJ) and broad bean flour (FFR) as shown in Table 1.

Table 1. Concentrations of textured soy protein (PTSJ) and bean flour (FFR) used to prepare hamburger formulations

Ingredients	**Formulations**				
	A1	**A2**	**A3**	**A4**	**A5**
PTSJ (%)	100	95	90	80	75
FFR (%)	0	5	10	20	25

Note: PTSJ is textured soy protein; FFR is the flour of the broad bean.

The method of preparing the hamburger formulations followed the experimental procedures proposed by Moro et al. (2021). Briefly, initially PTSJ was prepared as described by the manufacturer, all other ingredients were weighed separately. 75% water and 1% carboxymethylcellulose were used, in which they were manually homogenized with the other ingredients and kept at rest for 30 minutes under refrigeration (6°C), to give better consistency. The products were molded in the hamburger former, using parchment paper and placed in polyethylene bags and stored under freezing (-14°C). In figure 1 are the main steps carried out for the preparation of hamburgers and in Figure 2 we present the four final samples of hamburgers.

Figura 1. Main steps taken for the development of the work.

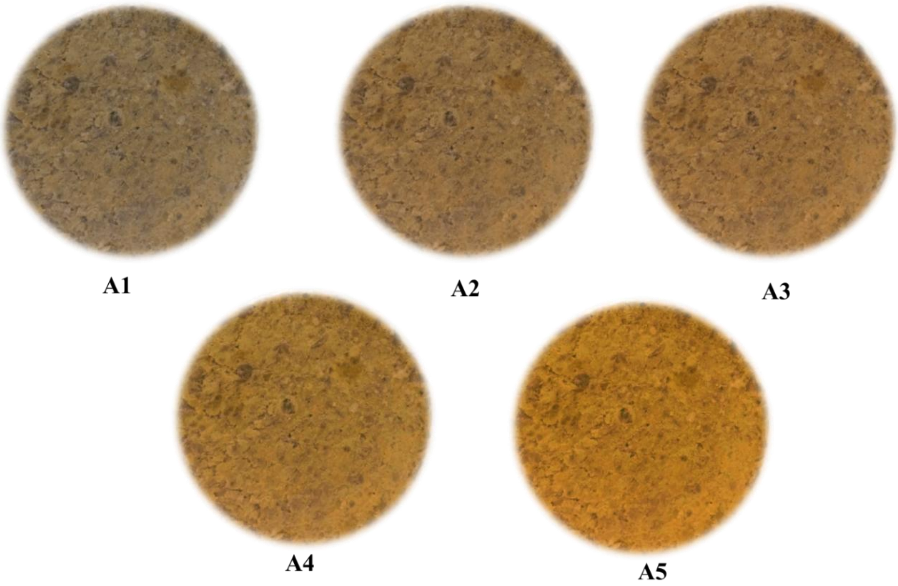


Figure 2. Final formulations of the burgers.

Parameters evaluated in hamburgers

The elaborated formulations were evaluated for their proximate composition (moisture content, ash, lipids, proteins and carbohydrates) as described above, in addition, their water activity and pH were also evaluated according to Brasil (2008).

Determination of firmness

To obtain the instrumental texture parameter of the different hamburger formulations, the TPA test was used in a TAXT plus Texturometer (Stable Micro Systems) (Figure 1), equipped with the Exponent Stable Micro Systems software, using the P/36R probe, speed pre-test speed 1.0 mm/s, test speed 2.0 mm/s, post-test speed 10.0 mm/s, and compression 70%. In the texture profile, the studied attribute was firmness.

Statistical analysis

The experimental data were analyzed in triplicate and the results were submitted to a 5% probability single-factor analysis of variance (ANOVA), and the significant qualitative responses were submitted to the Tukey test, adopting the same 5% significance level. For the development of statistical analyses, the Assistat 7.7 software was used (SILVA & AZEVEDO, 2016).

Results and Discussion

Table 2 shows the average contents of the proximate composition of the broad bean flour obtained by convective drying at 60°C.

Table 2. Centesimal composition of broad bean flour (FFR)

Parameters (%)	Bean flour
Moisture	6.34±0.12
Ashes	4.19 ±0.22
Lipids	1.15±0.09
Proteins	23.76±0.41
Carbohydrates	64.56±0.29

Based on the results presented in Table 2, FFR presented low moisture content (6.34%) and high protein content (23.76%), which is a good indication to be applied in the development of new products. Frota et al. (2008) when preparing cowpea flour, obtained values of 9.83% moisture, 3.14% ash, 24.28% protein and 1.49% lipid.

In Table 3, it is possible to observe the average values obtained for the mineral profile of the broad bean flour.

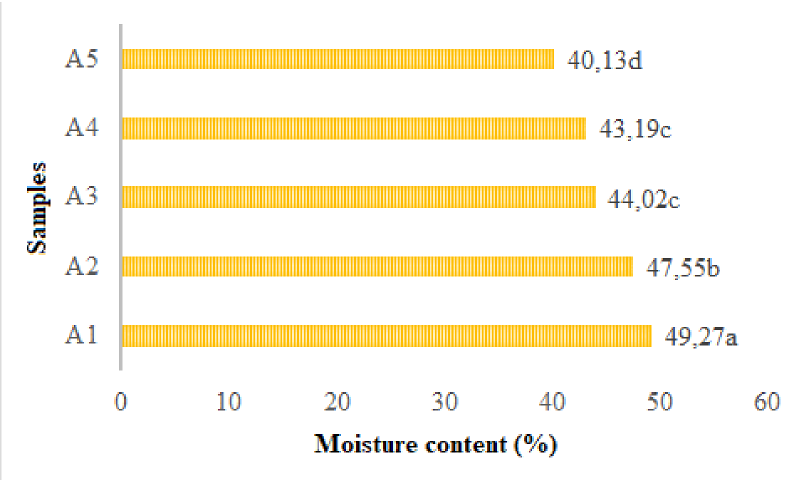
Table 3. Average mineral content of fava bean flour (FFR)

Mineral (mg/100g)	Bean flour
K	1221.37 ± 0.06
P	534.91 ± 0.01
Mg	52.15 ± 0.08
Fe	7.67± 0.02
Zn	4.66 ± 0.03

The value of potassium quantified in this study was 1221.37 mg/100g, thus, fava bean flour (FFR) is considered a rich source of this mineral. The highest concentrations of minerals present in the FFR followed the following order: K>P>Mg>Fe>Zn. Zinc is the mineral present in lower concentrations (4.66 mg/100g).

Silva et al. (2015), when determining the mineral profile of pumpkin seed flour, quantified the following levels of potassium (107.78 mg/100g), calcium (1578.12 g/100g), phosphorus (34.96 mg/100g), zinc (9.35mg/100g), manganese (5.39mg/100g), sodium (3.79mg/100g), magnesium (1.88mg/100g) and copper (1.68mg/100g).

Figure 2 shows the average values obtained for the moisture content of hamburgers made with PTSJ and FFR.

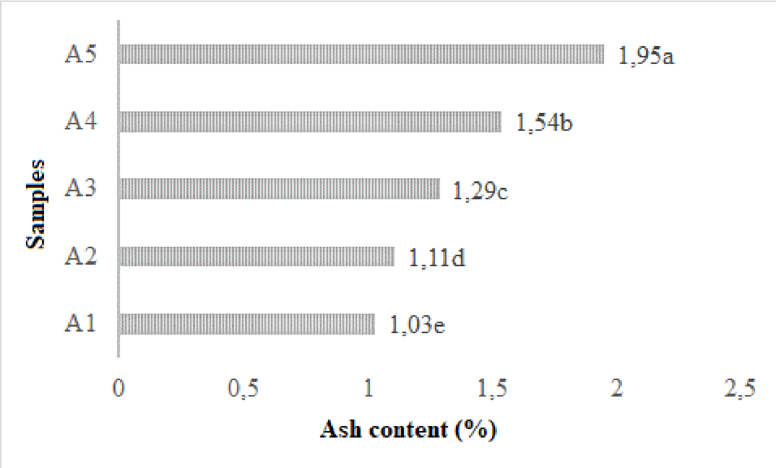


Note: Bars with the same letters do not differ significantly from each other in the test applied at the 5% probability level.

Figure 2. Moisture content of different hamburger formulations made with textured soy proteins and striped bean flour.

Observing the results presented in Figure 2, it is possible to affirm that the hamburgers had a high moisture content, ranging from 40.13 to 49.27%. It is also possible to observe that the reduction of the PTSJ concentration and the increase of the FFR provided a reduction in the values of these parameters. Statistically, only formulations A3 and A4 did not show significant differences between them ($p>0.05$). Values close to those of the present study were reported by Moro et al. (2021) when making chickpea hamburger with oro-pro-nóbis leaf, in which it presented a variation from 44.55 to 49.58%.

In Figure 3, the average values obtained for the ash content of the hamburgers made with PTSJ and FFR are shown.

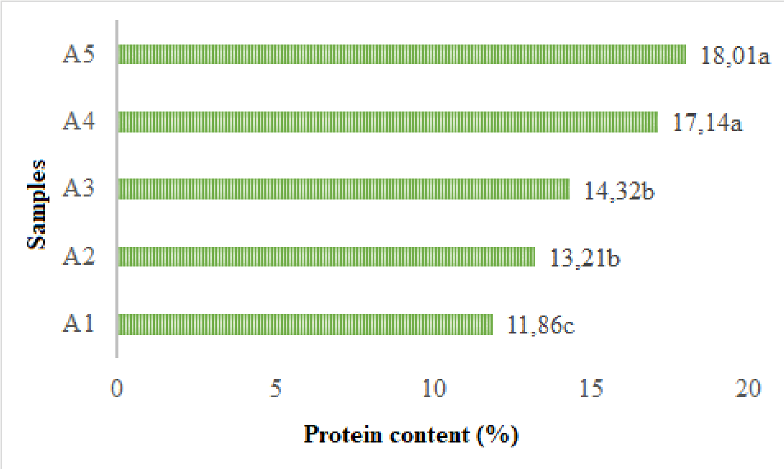


Note: Bars with the same letters do not differ significantly from each other in the test applied at the 5% probability level.

Figure 3. Ash content of the different hamburger formulations made with textured soy proteins and striped bean flour.

Regarding the ash content, it can be seen in Figure 2 that there was a significant increase in the ash contents when the FFR concentration increased ($p<0.05$). The ash content ranged from 1.03 to 1.95%, the highest value being the formulation that contained 25% FFR. A value close to that of the present study was reported by Carlesso et al. (2021) when making beef burgers added with eggplant, in which they quantified 1.9% ash.

Figure 4 shows the average values obtained for the protein content of hamburgers made with PTSJ and FFR.

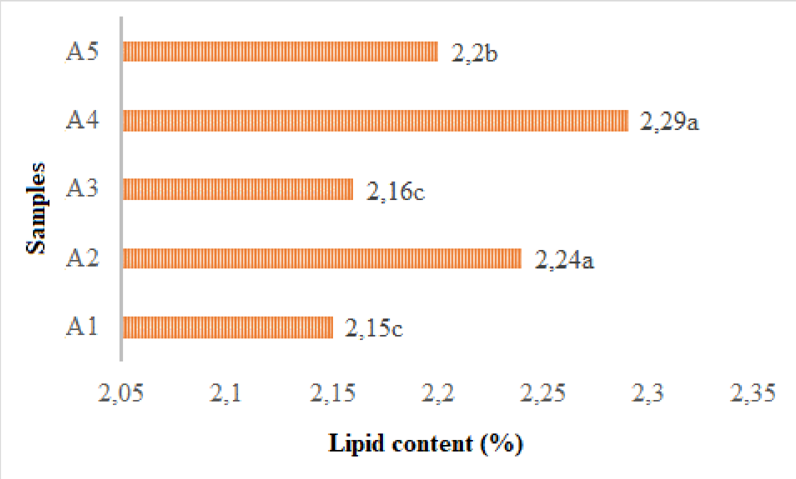


Note: Bars with the same letters do not differ significantly from each other in the test applied at the 5% probability level.

Figure 4. Protein content of the different hamburger formulations made with textured soy proteins and striped bean flour.

Protein values ranged from 11.86 to 18.01%, when the percentage of FFR ranged up to 25%. Statistically, formulations A2 and A3 were not significantly different from each other (p>0.05), as were formulations A4 and A5. Seabra et al. (2002) when developing sheep meat hamburger formulations with cassava starch and oat flour, obtaining protein contents ranging from 17.02 to 18.88%.

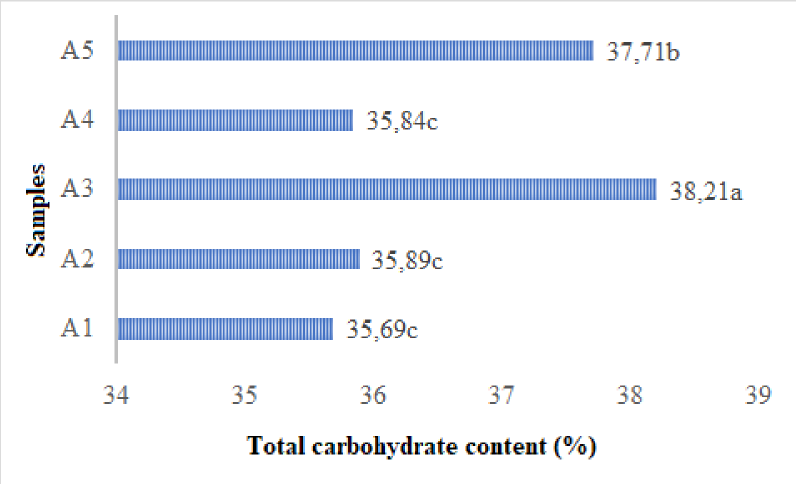
Figure 5 shows the average values obtained for the lipid content of hamburgers made with PTSJ and FFR.



Note: Bars with the same letters do not differ significantly from each other in the test applied at the 5% probability level.

Figure 5. of different hamburger formulations made with textured soy proteins and broad bean flour.

It can be observed that the elaborated formulations presented low levels of lipids with values ranging from 2.15 to 2.29%, with no direct relationship between the percentages of PTSJ and FFV. Statistically, formulations A2 and A4 were not significantly different from each other (p>0.05), as were formulations A1 and A2. Farias et al. (2016) when preparing different hamburgers added with fruit pulp, quantified lipid levels ranging from 0.91 to 11.2%. Figure 6 shows the average values obtained for the total carbohydrate content of the hamburgers made with PTSJ and FFR.



Note: Bars with the same letters do not differ significantly from each other in the test applied at the 5% probability level.

Figure 6. Total carbohydrate content of the different hamburger formulations made with textured soy proteins and broad bean flour.

The total carbohydrate contents of the hamburgers prepared in the present study presented values in which they ranged from 35.69 to 38.21%. Statistically, only formulations A3 and A5 were significantly different when compared to each other. Lima (2018), when preparing chickpea burgers with acerola residue, observed carbohydrate values ranging from 23.46 to 27.96%, where the lowest carbohydrate content was in the formulation with the highest addition of acerola residue (50%).

Table 4 shows the results of the physical parameters (water activity and pH) of the hamburgers made with PTSJ and FFR

Table 4. Physical parameters (water activity and pH) of the different hamburger formulations made with textured soy proteins and broad bean flour

Samples	Water activity	pH
A1	0.931±0.001a	6.10±0.000a
A2	0.927±0.000b	6.20±0.001a
A3	0.924±0.001c	6.20±0.000a
A4	0.918±0.002d	6.10±0.000a
A5	0.916±0.001d	6.20±0.001a

Note: Equal letters in the same column, the formulations do not differ significantly from each other in the test applied at the 5% probability level.

High water activity values (aw>0.9) were determined in the elaborated formulations, evidencing the high perishability of the product and confirming the need for a quick conservation step, which is the freezing of the samples. Statistically, formulations A4 and A5 did not show significant differences. The values of water activity were related to the moisture content of the samples, that is, the lower the moisture content, the lower the value of its water activity. Moro et al. (2021) determined water activity values ranging from 0.938 to 0.965 for chickpea burger with oro-pro-nóbis leaf

The results obtained in the determination of pH, showed statistically non-significant values (p>0.05) ranging from 6.10 to 6.20, not showing a direct relationship with the concentrations of PTSJ and FFV. Trevisan et al. (2016), in their studies with hamburgers with the addition of oat fiber, observed a pH value in the range of 6.02 to 6.32 during 60 days of storage under freezing.

Table 5 shows the results of the instrumental firmness parameter of hamburgers made with PTSJ and FFR. The determination of the texture of a food is carried out through the use of a texturometer, which is an equipment that allows the analysis of numerous rheological parameters that simulate the conditions existing during the tasting process, and constitutes an important quality attribute. of food together with appearance and taste (SILVA et al., 2019).

Table 5. Firmness attribute of different hamburger formulations made with textured soy proteins and broad bean flour

Samples	Firmness (N)
A1	8.96± 1.22d
A2	11.10 to ± 0.37c
A3	12.83d ± 0.06bc
A4	13.76b ± 1.59b
A5	15.33d ± 0.76a

Note: Equal letters in the same column, the formulations do not differ significantly from each other in the test applied at the 5% probability level.

It is observed in Table 5 that the firmness parameter varies from 8.96 to 15.33 N, and the highest value obtained is in the sample (A5), in which it contained the highest concentration of FFR, indicating that it is necessary the application of a greater force to achieve its deformation.

From the statistical analysis, it can be said that the A3 sample does not present a significant statistical difference when compared to the A2 and A4 samples at the level of 5% probability. According to Huang et al. (2011), firmness represents one of the most important texture parameters influencing consumer preference. Lower firmness value was obtained for sample A1 with 8.96 N, which differs statistically from all analyzed samples. According to Keeton (1994), this low value may be related to its low lipid content, as shown in Figure 3.

Conclusions

Through the results obtained, it can be concluded that:

FFV presented low moisture content, high protein content and potassium was the mineral present in higher concentration;

The formulated formulations showed a reduction in the moisture content and water activity, when there was an increase in the concentration of FFV, however, this increase provided higher levels of protein, ash and greater firmness to the product.

PTSJ and FFV presented themselves as a good alternative for the development of new products aimed at the group of vegans and vegetarians.

As a suggestion for future work, a product stability study and sensory analysis can be carried out.

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DETERMINATION OF CENTESIMAL COMPOSITION AND TOTAL PHENOLIC COMPOUNDS OF PEANUT, LENTIL AND PUMPKIN SPROUTS

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Introduction

It is called germinated food or sprouts any seed that is stimulated by the contact with water, with air and with heat and results in growth. The germinated seeds will form the stem and leaves, which will gradually fill with chlorophyll, giving rise to sprouts. Sprouts are highly nutritious foods, in whose production no fertilizer or pesticide is used.

Therefore, they are totally natural foods, which only use the reserves stored in the seeds to germinate and reach the size to be consumed. Therefore, they are good sources of minerals, vitamins, and proteins, and are low in calories. The sprouts are appreciated for their taste and for their nutritional and medicinal value (OLIVEIRA et al., 2013).

There are numerous advantages in the production of sprouts, including the use of little space, the short production time (3 to 7 days), being carried out at any time of the year and region, and without the need for soil, fertilizers, pesticides and direct sunlight. Another advantage is the high production yield (sprout/seed ratio), since normally, one kilo of seeds produces five to 12 kilos of sprouts, depending on the species used and the sprouting time (SILVA et al., 2019).

Peanut is of great economic importance, mainly in the food industry. Some varieties produce grains with a high amount of lipids (from 45 to 50% lipids) and have been used for the manufacture of cooking oil. In several regions of Africa, for example, peanuts are ground to cook various dishes of the local cuisine, making them richer in lipids and proteins. In Brazil, it is very popular as a roasted or fried aperitif (CRUZ et al., 2020).

According to Oliveira et al. (2021), peanut is a strong ally to human health, as it stands out for containing high levels of vitamins and minerals, as well as the so-called good fats, which are essential for maintaining health. This food has a high concentration of polyphenols, which act as antioxidants and reduce inflammation of the coronary arteries. In addition, peanuts contain a considerable amount of coenzyme Q10, a nutrient that strengthens the heart and protects it in conditions of reduced oxygen supply.

Lentils (*Lens culinaris*) belong to the Fabaceae family. This culture is of great importance to the global economy, standing out for its nutritional value and food security issues for millions of people around the world, especially in underdeveloped countries. The grains are nutritious, rich in proteins, carbohydrates, micronutrients, vitamins and amino acids, lysine and tryptophan (CARDOSO et al., 2021).

Pumpkin is a plant belonging to the *Cucurbitaceae* family, along with melon, cucumber and watermelon. Pumpkin seeds, although often discarded, have high potential for use because they have numerous functional and technological properties. They are considered a source of insoluble and soluble fiber, rich in lipids, proteins and amino acids, in addition to having antioxidant action due to the presence of zinc, calcium and vitamins A and E. Their consumption is associated with several benefits to human health such as bowel regulation, cholesterol, maintenance of epithelial tissue, regression of hypertension, also presenting anti-inflammatory, anticancer and vermifuge action (VIEIRA et al., 2019).

In this context, the present study aimed to germinate peanut and pumpkin seeds and lentil grains and characterize the sprouts produced in relation to their proximate composition, total phenolic compounds and water activity.

Materials and Methods

Feedstock

To carry out the present study, peanut (*Arachis hypogaea*) and pumpkin (Cucurbita) seeds and lentil grains (*Lens culinari*), acquired in the local market, were used. We present in figure 1 the main steps carried out for the elaboration of the flour

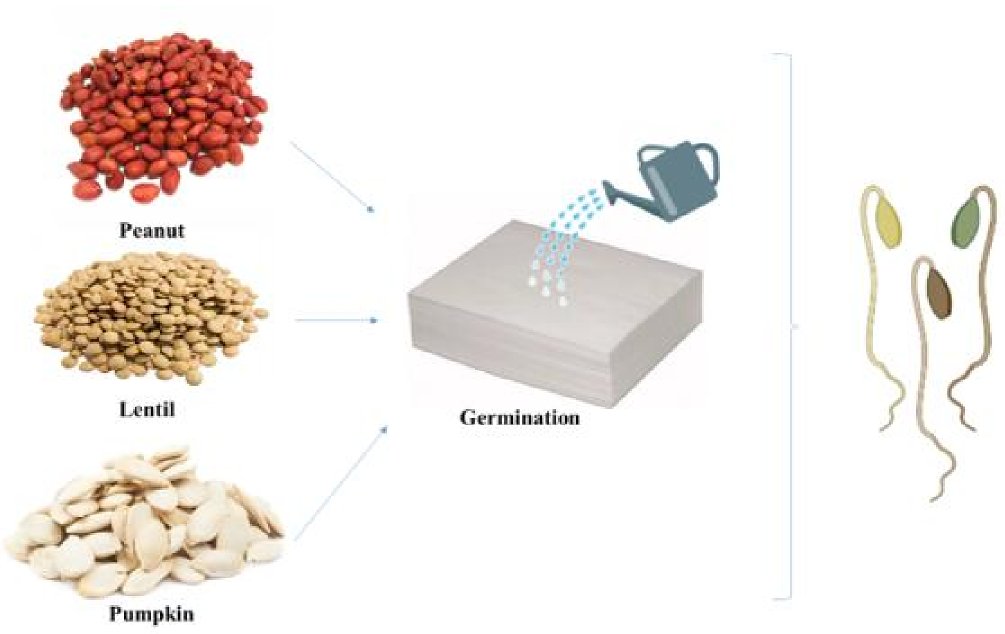

Figure 1. Main steps taken to make the flour.

Germination

To obtain the sprouts, germination was performed, in which the samples were humidified daily at room temperature, on paper with a volume of distilled water equivalent to 2.5 times the dry weight of the paper, with free passage of water, air and natural light. After 4 days of germination, samples were collected (complete shoots).

Determination of the proximate composition

The shoots obtained after the germination process were characterized in terms of the following parameters:

Moisture content was determined by drying in an oven at 105°C until constant weight (BRASIL, 2008);

Ash content was determined by muffle incineration (BRASIL, 2008).

Total protein content was quantified by the Micro-Kjeldahl method, which consisted in the determination of total nitrogen according to the methodology described by Brasil (2008);

Lipid content was quantified by the modified method of Blig and Dyer (1959);

Total carbohydrate content was calculated by difference to obtain 100% of the total composition (FAO, 2003).

Determination of total phenolic compounds

Aqueous extract was prepared at 1:10. The total phenolic content in the extracts was quantified by the spectrophotometric method with Folin-Ciocalteu (WATERHOUSE, 2006). The absorbance was measured at 750 nm in a SP-2000 UV spectrophotometer (Spectrum, Shanghai, China). The standard curve was prepared using gallic acid as standard to a concentration of 100 μg mL^{-1}.

Determination of water activity (aw)

Water activity (aw) was determined using the Decagon® Aqualab CX-2T device at 25°C.

Statistical analysis

The experimental data were analyzed in triplicate and the results were submitted to a 5% probability single-factor analysis of variance (ANOVA), and the significant qualitative responses were submitted to the Tukey test, adopting the same 5% significance level. For the development of statistical analyses, the Assistat 7.7 software was used (SILVA & AZEVEDO, 2016).

Results and Discussion

Table 1 shows the average values obtained for the water content of peanut, lentil and pumpkin sprouts after 4 days of germination.

Table 1. Water content of peanut, lentil and lentil seed sprouts

Sprout	Water content (%)
Peanut	41.16±0.13b
Lentil	39.01±0.11c
Pumpkin	44.67±0.46a

Note: Different letters in the same column differ significantly ($p \leq 0.05$) to the test applied.

The water contents of the germinated sprouts presented high values, being 39.01% (lentil), 41.16% (peanut) and 44.67% (squash), statistically, when compared to each other, they were significantly different ($p<0.05$). It is noteworthy that through the values obtained in this parameter, the application of a conservation technique is necessary so that they have a greater option of application. According to Li et al. (2010), the germination activity that occurs in the embryos promotes the increase of the metabolic activity and the supply of energy for the growth of the radicle.

Table 2 shows the average values obtained for the ash content of peanut, lentil and pumpkin sprouts after 4 days of germination. According to Oliveira et al. (2017), the ash corresponds to the inorganic residues (minerals) present in the sample after the incineration of organic matter.

Table 2. Ash content of peanut and lentil seed sprouts and lentil grains

Sprout	Ash content (%)
Peanut	0.97±0.05b
Lentil	0.72 ±0.09c
Pumpkin	1.19±0.12a

Note: Different letters in the same column differ significantly ($p \leq 0.05$) to the test applied.

The ash contents were lower than 1.5% and significantly different from each other ($p<0.05$). The highest ash content was observed for the sprouts of pumpkin seeds, which presented a value of 1.19%. Values close to those of the present study were reported by Leite et al. (2016), who obtained 1.08% ash for germinated sorghum seeds. And higher values were found by Chandrasiri et al. (2016) for raw, cooked and germinated mung bean seeds that presented values of 4.55, 4.26 and 4.71%, respectively.

Table 3 shows the average values obtained for the lipid content of peanut, lentil and pumpkin sprouts after 4 days of germination. According to Zhang et al. (2015), during germination, lipid degradation may occur due to energy supply in plant development.

Table 3.Lipid content of peanut, lentil and lentil seed sprouts

Sprout	Lipid content (%)
Peanut	30.74±1.12a
Lentil	23.66 ±0.63b
Pumpkin	20.49±0.71c

Note: Different letters in the same column differ significantly ($p \leq 0.05$) to the test applied.

As for the average values obtained for the lipid content of the shoots, statistically significant differences were observed between the varieties in the present study. For all sprouts, the lipid values were relatively high (>20%), however, peanut sprouts stand out from the others with 30.74% of lipids. According to Yu et al. (2016), the lipid content in peanut seeds is high, but they are reduced during the germination process.

Values lower than those of the present study were reported by Leite et al. (2016), for germinated sorghum seeds, in which they quantified 2.21% and by Silva (2019), who obtained 6.32% in germinated jackfruit seeds.

Table 4 shows the average values obtained for the protein content of peanut, lentil and pumpkin sprouts after 4 days of germination.

Table 4. Protein content of peanut, lentil and lentil seed sprouts

Sprout	Protein content (%)
Peanut	18.24±0.92a
Lentil	15.65 ±0.49b
Pumpkin	12.77±0.26c

Note: Different letters in the same column differ significantly ($p \leq 0.05$) to the test applied.

Regarding the protein contents, values between 12.77-18.24% were observed, with the highest percentage obtained for peanut seed sprouts. The values obtained for proteins were significantly different when compared between the sprouts produced. Values higher than those of the present study were quantified by Loures et al. (2009) for lentil sprouts (25.56%). In this way, peanut, lentil and pumpkin sprouts can be considered as good sources of protein.

Table 5 shows the average values obtained for the carbohydrate content of peanut, lentil and pumpkin sprouts after 4 days of germination. Calculated by difference, the total carbohydrate content of lentil and pumpkin sprouts were not significantly different (p>0.05) when compared to each other.

Table 5. Carbohydrate content of peanut seed sprouts, lentils and lentil grains

Sprout	Carbohydrate content (%)
Peanut	8.89 ±0.57b
Lentil	20.96 ±0.18a
Pumpkin	20.88±0.14a

Note: Different letters in the same column differ significantly (p ≤ 0.05) to the test applied.

The total carbohydrates of lentil and pumpkin sprouts showed values close to 20.96 and 20.88%, respectively. However, peanut sprouts had a low content (8.89%). This low carbohydrate content of peanut sprouts may be due to the sprouts having a high-water content and high protein and lipid content.

Table 6 shows the mean values obtained for the total phenolic compounds content of peanut, lentil and pumpkin sprouts after 4 days of germination.

Table 6. Total phenolic compounds of peanut, lentil and lentil seed sprouts

Sprout	Total phenolic compounds (mg GAE/100g)
Peanut	246.18 ±2.76a
Lentil	172.84 ±3.06c
Pumpkin	199.44±3.28b

Note: Different letters in the same column differ significantly ($p \leq 0.05$) to the test applied.

According to Rocha et al. (2011), phenolic compounds are defined as substances that have an aromatic ring with one or more hydroxyl substituents, including their functional groups. They are widely distributed in the plant kingdom, ranging from simple molecules to others with a high degree of polymerization.

The values of total phenolic compounds were statistically different when compared to each other. It can be observed in Table 6 that the peanut sprouts had the highest concentration, which was 246.18 mg GAE/100g. Values higher than those of the present study were reported by Lima et al. (2004) for mung bean sprouts (1054 mg GAE/100g).

Table 7 shows the average values obtained for the water activity of peanut, lentil and pumpkin sprouts after 4 days of germination.

Table 7. Water activity (a_w) of peanut, lentil and lentil seed sprouts

Sprout	Water activity (a_w)
Peanut	0.915 ±0.02c
Lentil	0.922 ±0.01b
Pumpkin	0.953±0.01a

Note: Different letters in the same column differ significantly ($p \leq 0.05$) to the test applied.

The water activity values of the produced shoots were higher than 0.9. The species when compared to each other showed significant statistical differences at the level of 5% probability. Pumpkin seed sprouts had the highest value (0.953). Leite (2017) reported an increase in water activity from 0.983 to 0.989 in the germination process of jackfruit seeds.

Conclusions

Through the results obtained, it can be concluded that:

The germination process is satisfactory to increase the nutritional quality of the material, making the sprouts another healthy food option;

The shoots had a high water content and water activity, which indicates the need for rapid consumption or the application of conservation techniques;

Peanut sprouts stand out for having higher levels of lipids, proteins and total phenolic compounds;

As suggestions for future work, the drying process can be applied to the shoots and the influence of the process on their nutritional and bioactive properties can be evaluated.

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PREPARATION AND CHARACTERIZATION OF REQUEIJÃO WITH ADDITION OF BIQUINHO PEPPER FLOUR (*Capsicum chinense*)

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Introduction

Requeijão is a product that belongs to the class of processed or processed cheeses. It is widely consumed by different social classes and people of all ages. The beginning of the technology of processed cheeses took place at the beginning of the 20th century, with the need to stop the microbial and enzymatic processes in Swiss and German cheeses, in order to facilitate exports to countries with hot climates (GARRUTI et al., 2003).

According to Ordinance No. 359, of September 4, 1997, which approves the Technical Regulation for Fixing the Identity and Quality of requeijão, this is defined as a product obtained by melting the curd mass, cooked or not, drained and washed, obtained by acid and/or enzymatic coagulation of milk optionally added with cream and/or butter and/or anhydrous milk fat or butter oil.

Requeijão can be classified according to the raw material and ingredients used, such as traditional requeijão which contains milk or reconstituted milk, cream and/or butter and/or anhydrous milk fat or butter oil, and light requeijão with a reduced amount of fat and may be added with condiments, spices and/or other food substances (BRASIL, 1997).

The use of condiments as food preservatives is of great interest to consumers, as they do not pose a health risk, even when used in relatively high amounts. Furthermore, the use of natural substances is preferable when compared to synthetic additives used in food processing for preservation purposes. From a food point of view, the use of condiments will always be done as a complement and integration of food, so that it is more pleasant to smell, taste and sight, stimulating appetite and digestion (SILVA, 2016).

Capsicum pepper has significant economic importance in world agribusiness, where its use is associated with seasonings used in cooking. They also constitute raw material for the extraction of dyes, flavorings and oleoresins, substances used in food products, as they impart flavor and increase the oxidative stability of lipids (DANTAS et al., 2017; JORGE et al., 2018).

The Biquinho pepper is a variety that has gained prominence in scientific research. Due to its use as an aesthetic complement to dishes in restaurants, its beneficial properties are in the background. This has drawn the attention of researchers, due to the lack of pungency, this species has pleased the palate of individuals at different ages (DANTAS et al., 2017).

In this context, the present study aims to develop different formulations of curd and seasoning with biquinho pepper flour, in addition, a second objective of the study is to characterize the formulations developed in relation to proximate, physical and microbiological parameters.

Materials and Methods

Feedstock

To carry out the present study, the following were used: milk (Molico®), liquid coagulant (Ha-La®) and biquinho pepper (*Capsicum chinense*), acquired in the local market.

Preparation of flour

Initially the peppers were sanitized and sanitized with an aqueous solution of sodium hypochlorite with a concentration of 200 mg/L of free chloride for 10 min and then rinsed with running water. The peppers were dried in an oven with air circulation

(Tecnal®) at a temperature of 60°C for 48 hours. After drying, the dried peppers were ground in a domestic food processor (Philips Walita®) and their powder was obtained. We can see in figure 1 the main steps carried out for the preparation of biquinho pepper flour are schematized.

Figure 1. Main steps taken to make the flour.

Development of curd

The curd cheese was prepared following the steps shown in the flowchart in Figure 1 and the methodology proposed by Silva (2020) and Trintim et al. (2017).

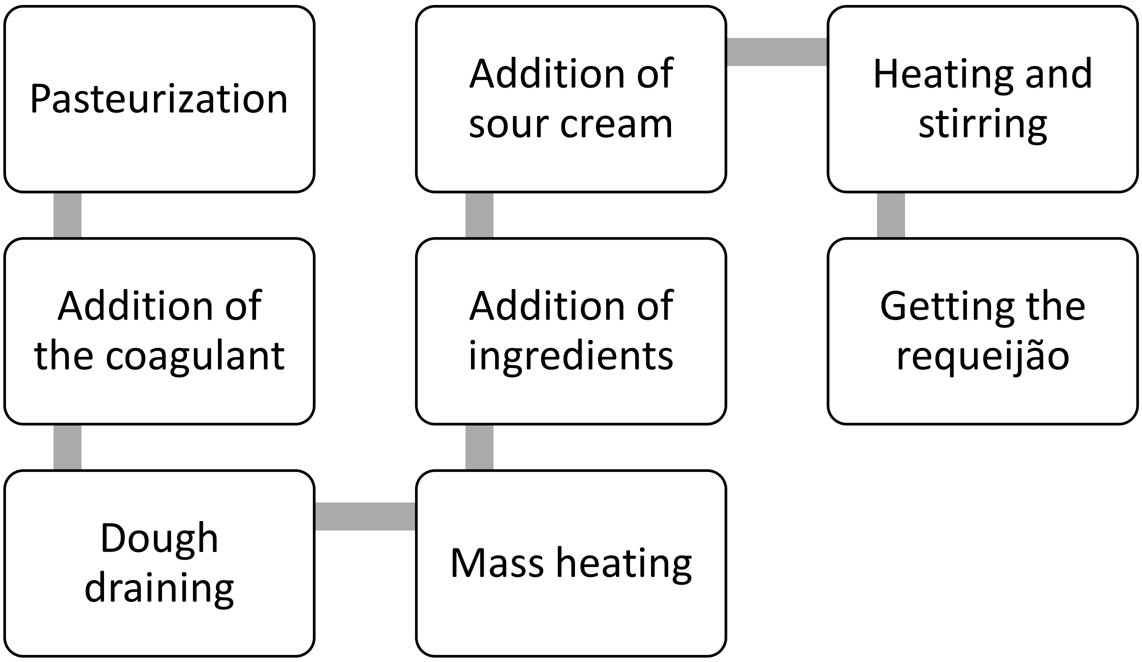

Figure 2. Flowchart of the main steps for the preparation of requeijão.

Formulation of curd with addition of flour

Four formulations were prepared, as shown in Table 1. Formulation R1 is the control formulation.

Table 1. Elaborated formulations of requeijão with addition of biquinho pepper flour

Ingredient	R1	R2	R3	R4
Cottage cheese (%)	100	95	90	85
Pepper flour pout (%)	0	5	10	15

Determination of the proximate composition

The elaborated formulations were characterized with respect to the following contents:

Moisture content was determined by drying in an oven at 105°C until constant weight (BRASIL, 2008).

Ash content was determined by muffle incineration (BRASIL, 2008);

Total protein content was quantified by the Micro-Kjeldahl method, which consisted in the determination of total nitrogen according to the methodology described by Brasil (2008).

Lipid content was quantified by the modified method of Blig and Dyer (1959);

Total carbohydrate content was calculated by difference to obtain 100% of the total composition (FAO, 2003).

Determination of water activity (aw)

Water activity (a_w) was determined for all formulations using the Decagon® Aqualab CX-2T device at 25°C.

Determination of firmness

To obtain the instrumental texture parameter of the different formulations of requeijão with the addition of biquinho pepper flour, the TPA test was used in a TAXT plus Texturometer (Stable Micro Systems), equipped with the Exponent Stable Micro Systems software, using the P/36R, pre-test speed 1.0 mm/s, test speed 2.0 mm/s, post-test speed 10.0 mm/s, and 70% compression. In the texture profile, the studied attribute was firmness.

Microbiological analysis

The microbiological analyzes of the formulations included the determination of the most probable number (MPN) of total coliforms and the detection of Salmonella spp. according to for APHA (2001).

Statistical analysis

The experimental data were analyzed in triplicate and the results were submitted to a 5% probability single-factor analysis of variance (ANOVA), and the significant qualitative responses were submitted to the Tukey test, adopting the same 5% significance level. For the development of statistical analyses, the Assistat 7.7 software was used (SILVA & AZEVEDO, 2016).

Results and Discussion

Table 2 presents the values obtained for the water content and water activity of the requeijões elaborated and added with different concentrations of biquinho pepper flour.

Table 2. Water content and water activity of the requeijão formulations prepared with the addition of biquinho pepper flour

Formulation	Water content (%)	Water activity
R1	56.14±0.21[a]	0.951±0.00[a]
R2	54.36±0.14[b]	0.932±0.002[b]
R3	52.72± 0.33[c]	0.927±0.001[c]
R4	50.06±0.09[c]	0.922±0.000[c]

Note: Different letters in the same column differ significantly by Tukey 's test.

The water content of the formulations presented values that varied between 50.06 to 56.14%, being significantly influenced by the addition of biquinha pepper flour at the level of 5% of probability. It is observed that the higher the percentage of flour addition, the lower the water content obtained, highlighting the R4 formulation which presented 50.06%. Silva et al. (2012) when evaluating the water content of light requeijão, obtained values higher than those of the present study, in which they ranged from 64.90 to 71.02%.

Still in Table 2, one can also observe the values obtained for the water activity of the samples. In general, the behavior of the water activity decreased with the increase of the addition of biquinho pepper flour, the values for all formulations were greater than 0.9, however, formulations R3 and R4 did not show significant statistical differences when compared.

Table 3 presents the values obtained for the ash and lipid contents of the requeijões elaborated and added with different concentrations of biquinho pepper flour.

Table 3. Ash and lipid contents of the requeijão formulations made with the addition of biquinho pepper flour

Formulation	Ash (%)	Lipids (%)
R1	1.75±0.09^{d}	16.01±0.58^{a}
R2	2.11± 0.16^{c}	16.54±0.25^{a}
R3	2.37±0.10^{b}	17.19±0.31^{a}
R4	2.84±0.13^{a}	17.76±0.49^{a}

Note: Different letters in the same column differ significantly by Tukey 's test.

The ash values showed statistically different means from each other ($p<0.05$). In which, an increase of up to 1.09% was observed when the concentration of biquinho pepper flour was increased by up to 15%. Values close to those of the present study were reported by Silva et al. (2012) that obtained ash contents ranging from 2.51 to 3.40% for light requeijão formulations and by Lins et al. (2009) when manufacturing cream cheese without added fat and with reduced sodium content, which obtained ash contents between 2.69 and 2.83%.

According to Gomes et al. (2010), the fat content influences the flavor, texture, creaminess, appearance and palatability, since the curd cheese is a complex system composed of proteins, fat, water, mineral salts and other ingredients.

The lipid values, presented in Table 3, did not show significant statistical differences when the percentage of biquinho pepper flour was increased ($p>0.05$). The values ranged from 16.01 to 17.6%, being higher for the formulation with 15% flour (R4). Alves et al. (2015) obtained values in the range of 10.23 to 11.19% for low-fat curds, and Bez et al. (2015) observed values between 22.3 and 22.9% for requeijão with the addition of dried tomato.

Table 4 shows the values obtained for the protein and carbohydrate contents of the requeijões elaborated and added with different concentrations of biquinho pepper flour.

Table 4. Protein and carbohydrate contents of the requeijão formulations prepared with the addition of biquinho pepper flour

Formulation	Proteins (%)	Carbohydrates (%)
R1	12.44±0.22 ^{d}	13.66±0.72 ^{to}
R2	15.01± $^{0.41c}$	11.98±0.29 ^{b}
R3	17.92±0.69 ^{b}	9.80±0.062 ^{c}
R4	18.21±0.15 ^{to}	11.13±0.50 ^{b}

Note: Different letters in the same column differ significantly by Tukey 's test.

The protein content presented values ranging from 12.44 to 18.21%, being significantly influenced by the increase in the concentration of biquinho pepper flour. Values close to those of the present study were reported by Silva (2016), who quantified values in the range of 11.29 to 12.37% of proteins in goat cream cheese with the addition of garlic seasoning, and by Bittencourt et al. (2013) who obtained a protein content of 19.51% for marajoara curd made from buffalo milk. The total carbohydrate content showed low values, ranging from 9.80 to 13.66%, being statistically different when the formulations were compared with each other.

Table 5 presents the values obtained for the instrumental parameter of texture (firmness) of the requeijões elaborated and added with different concentrations of biquinho pepper flour. According to Gomes et al. (2010), the texture characteristic of requeijão depends on the composition, physical state of the components and the type of interaction between them.

Table 5. Firmness of the requeijão formulations prepared with the addition of biquinho pepper flour

Formulation	Firmness (N)
R1	0.78±2.91^{c}
R2	1.63±1.33^{b}
R3	1.88±1.72^{ab}
R4	2.41±2.05^{a}

Note: Different letters in the same column differ significantly by Tukey 's test.

For the control formulation, the texture attribute studied presented a low value of 0.78N and may be related to the higher water content and lower protein content (R1). However, it can be observed that there was an increase in the values of this attribute when biquinho pepper flour was added. Silva et al. (2012) obtained texture values in the range of 0.02 to 2.34N for light requeijão.

Table 6 shows the results obtained from the microbiological evaluation (total coliforms and *Salmonella* spp.) of the requeijões elaborated and added with different concentrations of biquinho pepper flour.

Table 6. Microbiological analysis of requeijão prepared with the addition of biquinho pepper flour

Formulation	Total Coliforms (MPN/g)	*Salmonella* spp. (in 25g)
R1	<3.0	Absent
R2	<3.0	Absent
R3	<3.0	Absent
R4	<3.0	Absent

Note: NMP: Most Likely Number of Microorganisms.

The addition of biquinho pepper flour to the requeijão produced proved to be safe from a microbiological point of view. In all elaborated formulations, the presence of total Coliforms and *Salmonella* spp. Therefore, the elaborated requeijões are safe for consumption and acceptable in terms of hygienic-sanitary quality parameters.

Conclusions

Through the results obtained, it can be concluded that:

Requeijão with the addition of up to 15% of biquinho pepper flour is viable to be developed;

The addition of biquinho pepper flour reduced the water content and increased the ash, lipid and protein contents;

The firmness parameter was significantly improved with the addition of flour;

The requeijão presented adequate and safe microbiological conditions for consumption.

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DEVELOPMENT AND CHARACTERIZATION OF WATER SOLUBLE EXTRACT OF CASHEW NUTS FLAVORED WITH PLUM

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Introduction

Cashew (*Anacardium occidentale*) has a high economic value, due to the quality and nutritional value of its nut, which has vitamins and monounsaturated fatty acids, in addition to the richness of vitamin C and fiber in its peduncle, which corresponds to the pulpy and edible part (pseudofruit) (MORAIS et al., 2018). The mechanized processing of cashew nuts generates around 40% of broken kernels, which have a lower market value than whole kernels, being considered by-products of processing. One of the ways to value these by-products is the development of new products derived from the cashew kernel (LIMA et al., 2017).

The food industry continues to strive to offer new and innovative products aimed at satisfying consumer needs. The growing demand for healthy products has challenged the food and beverage sector (MOREIRA et al., 2010). Water-soluble extracts are beverages of vegetable origin, which have nutritional commercial appeal, in terms of health aspects, such as the absence of animal fats and high levels of minerals (CARVALHO et al., 2011). In addition, the inclusion of fruits as a flavoring in the extracts may have high acceptance by consumers (LIMA et al., 2020).

According to Alcântara et al. (2019), the use of different fruits in the elaboration of new products can be encouraged by the high nutritional value they present. Among them we can mention plums, which are generally not adapted to long periods of storage under refrigeration, due to problems of dehydration, physiological disorders and rot that make the pulp darkened and with low palatability. Therefore, the use of plums in water-soluble extracts, in addition to being a way to add value to the product, is a good way to avoid post-harvest economic losses.

In this context, the present study aimed to develop a water-soluble extract of cashew nut kernels flavored with plum pulp and to characterize them in terms of their proximate composition, total phenolic compounds and microbiological parameters.

Materials and Methods

Feedstock

To carry out the present study, the following were used: cashew nut (*Anacardium occidentale*) and plum (*Prunus subg. Prunus*) almonds, both acquired in the local market.

Getting the plum pulp

Initially, the plums were sanitized and sanitized with an aqueous solution of sodium hypochlorite with a concentration of 200 mg/L of free chloride for 10 min and then rinsed with running water. With the aid of a domestic knife the fruits were cut and their pits were removed. Then, the fraction (pulp + peel) was processed in a domestic blender until a homogeneous mixture was obtained.

Preparation of the water-soluble extract

The cashew nut kernels were already purchased without shells and for the preparation of the water-soluble extract, the experimental procedure described by Lima et al. (2017). Briefly, the chestnuts were immersed in filtered water in the proportion 1:10 (chestnuts: water), then they were ground in an industrial blender for 4 min and filtered with the aid of an organza mesh. After crushing and filtering, the extract was placed in glass bottles with a capacity of 250mL, in which they were subjected to the pasteurization process (65 °C/30min), followed by cooling in an ice bath to avoid prolonged action of heat. Finally, the bottles with extract were placed under refrigeration. We present in figure 1 the steps for the four formulations of the water-soluble extract.

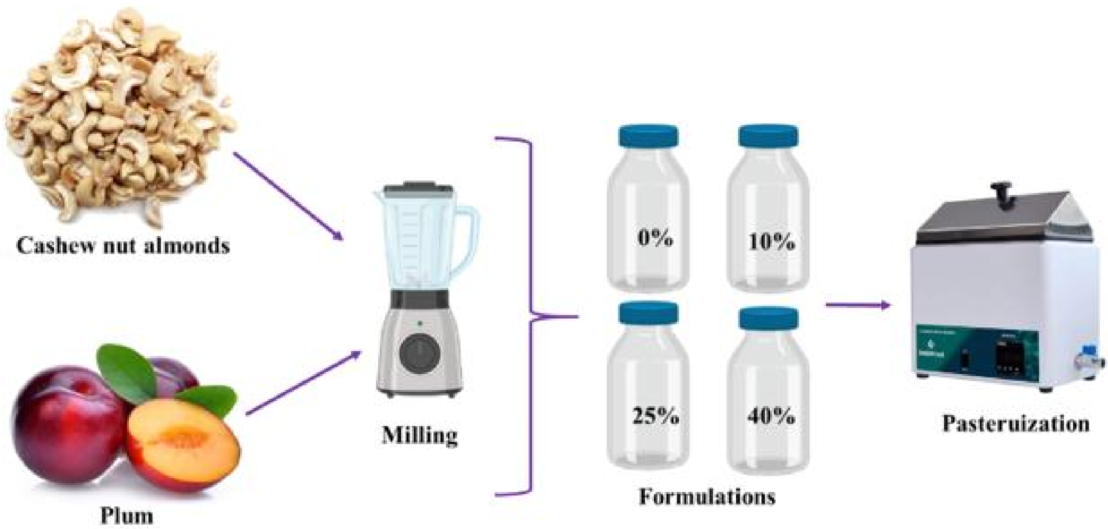

Figure 1. Main steps taken for the development of the work.

Formulations with the addition of pulp

According to Lima et al. (2017) a process variation can be carried out with the inclusion, in the crushing step, of products that add flavor to the extract. Thus, three formulations were developed by adding plum pulp, the concentrations are shown in Table 1. Each formulation followed the procedure described above.

Table 1. Concentrations of plum pulp added in the formulations of the water-soluble extract of cashew kernels

Formulation	Plum pulp (%) [1]
L1	0
L2	10
L3	25
L4	40

Note: [1] per liter of extract.

The elaborated extracts were characterized in relation to the parameters described below.

Determination of the proximate composition

Moisture content was determined by drying in an oven at 105°C until constant weight (Brasil, 2008);

Ash content was determined by muffle incineration (BRASIL, 2008);

Total protein content was quantified by the Micro-Kjeldahl method, which consisted in the determination of total nitrogen according to the methodology described by Brasil (2008);

Lipid content was quantified by the modified method of Blig and Dyer (1959);

Total carbohydrate content was calculated by difference to obtain 100% of the total composition (FAO, 2003).

Total phenolic compounds (TPC)

Aqueous extract was prepared in a 1:10. The total phenolic content in the extracts was quantified by the spectrophotometric method with Folin-Ciocalteu (WATERHOUSE, 2006). The absorbance was measured at 750 nm in a SP-2000

UV spectrophotometer (Spectrum, Shanghai, China). The standard curve was prepared using gallic acid as standard at a concentration of 100 µg mL^{-1}.

Microbiological analysis

The microbiological analyzes of the formulations included determination of the most probable number of total (35°C) and thermotolerant (45°C) coliforms, detection of Salmonella spp. and Coagulase Positive Staphylococcus forming units according to APHA (2001).

Statistical analysis

The experimental data were analyzed in triplicate and the results were submitted to a 5% probability single-factor analysis of variance (ANOVA), and the significant qualitative responses were submitted to the Tukey test, adopting the same 5% significance level. For the development of statistical analyses, the Assistat 7.7 software was used (SILVA & AZEVEDO, 2016).

Results and Discussion

Table 2 presents the results obtained for the water and lipid contents of the extracts made with cashew nut kernels and different concentrations of plum pulp.

Table 2. Water and lipid contents of the water-soluble extract of cashew nut kernels flavored with plum pulp

Formulation	Water content [1] (%)	Lipid content [1] (%)
L1	86.11 ± 0.30 [to]	2.96 ± 0.51 [to]
L2	87.06 ± 0.41 [to]	3.15 ± 0.43 [to]
L3	88.33 ± 0.16 [a]	3.60 ± 0.22 [to]
L4	89.14 ± 0.26 [to]	3.89 ± 0.19 [to]

Note: Different letters in the same column differ significantly by *Tukey* 's test; [1] wet base.

The addition of plum pulp to the extract did not statistically influence the water content of the samples. The extracts showed values ranging from 86.11 to 89.14%, with the highest value obtained for formulation L4. Values close to those of the present study were observed in the literature by Carneiro et al. (2014), who, when characterizing the water-soluble extract of babassu coconut, found values of up to 76.11% and by Lima et al. (2020) who obtained 81.65% water for macaíba almond extract with guava pulp.

Regarding the lipid contents, shown in Table 2, an increase in values from 2.96 to 3.89% is observed, when the percentage of plum pulp varied by up to 40%. Statistically, these contents were not significantly influenced by the addition of plum pulp. Vieira et al. (2020) when developing and characterizing a water-soluble extract of baru almond, obtained 5.5% of lipids. Gazola et al. (2016) when making beverages based on water-soluble soy extract with pitanga, blackberry and blueberry pulp, obtained lipid contents of 0.21, 0.22 and 0.23%, respectively.

Table 3 presents the results obtained for the ash and protein contents of the extracts made with cashew nut kernels and different concentrations of plum pulp.

Table 3. Ash and protein contents of the water-soluble extract of cashew nut kernels flavored with plum pulp

Formulation	Ash content [1] (%)	Protein content [1] (%)
L1	0.32 ± 0.10 [b]	1.51 ± 0.09 [to]
L2	0.45 ± 0.06 [b]	1.74 ± 0.10 [to]
L3	0.56 ± 0.13 [to]	1.83 ± 0.13 [a]
L4	0.61 ± 0.11 [to]	1.96 ± 0.14 [to]

Note: Different letters in the same column differ significantly by *Tukey*'s test; [1]wet base.

The ash contents of the extracts showed low values and increased when there was an increase in the percentage of plum pulp in the formulations. The control formulation (L1) presented 0.32% and the formulation with 40% pulp (L4) presented 0.61%. Statistically, when comparing formulations L1 and L2, they did not show significant differences, as well as formulations L3 and L4. Carneiro et al. (2014) quantified 0.27% of ash for extracts made with babassu seeds and Caus et al. (2018), when elaborating water-soluble soybean extract with strawberry and passion fruit pulp, obtained ash contents between 0.62 and 1.13%.

The protein content for all formulations was less than 2% and showed no statistically significant difference when compared to each other. As described in the Technical Regulation for protein products of plant origin (Resolution RDC No. 268, September 22, 2005) the minimum protein content established for water-soluble soybean extract is 3% (BRASIL, 2005). Following this same regulation, the water-soluble extract of cashew nut kernel flavored with plum pulp does not meet the minimum requirements specified for protein products of plant origin. Bicudo et al. (2012) obtained 3.15% of proteins for water-soluble fermented quinoa extract.

Table 4 shows the results obtained for the content of total carbohydrates and total phenolic compounds (TPC) of extracts made with cashew nut kernels and different concentrations of plum pulp.

Table 4. Content of total carbohydrates and total phenolic compounds (TPC) of the water-soluble extract of cashew nut kernels flavored with plum pulp

Formulation	**Total carbohydrates [1] (%)**	**TPC (mg GAE/100g)**
L1	9.10 ± 0.31a	2.36 ± 1.13 ^{d}
L2	7.6 ± 0.44 ^{b}	4.67 ± 2.04 ^{c}
L3	5.68 ± 0.45 ^{c}	6.28 ± 2.55 ^{b}
L4	4.40 ± 0.39 ^{c}	8.41 ± 1.93 ^{to}

Note: Different letters in the same column differ significantly by *Tukey*'s test; [1]wet base.

Regarding the total carbohydrate content, it was found that the extracts showed low values in the range of 9.10 to 4.40%, due to the high water content. It is also observed that the addition of plum pulp provided lower levels of carbohydrates to the extract, however, statistically the formulations L3 and L4 do not show significant differences. Bicudo et al. (2012), when elaborating a fermented water-soluble extract of quinoa, quantified 4.39% of carbohydrates.

Phenolic compounds (CF) are substances widely distributed in nature and act as antioxidants, not only because of their ability to donate hydrogen or electrons, but also because of their stable intermediate radicals, which prevent the oxidation of food ingredients, especially lipids (SILVA et al., 2010). The content of total phenolic compounds showed a significant increase in their values when there was an increase in the percentage of plum pulp. The values obtained comprise the range from 2.36 to 8.14 mg GAE/100g. Barros (2016), when preparing a mixed drink of water-soluble soy extract and grape juice, quantified values in the range of 0.37 to 0.74 mg GAE/100g.

Aiming at food safety, the microbiological characterization of the extracts was carried out.

Table 5 shows the results obtained for total (35°C) and thermotolerant (45°C) coliforms, *Salmonella* spp and *Coagulase Positive Staphylococci* from extracts made with cashew nut kernels and different concentrations of plum pulp.

Table 5. Microbiological parameters of the water-soluble extracts of cashew nut kernels flavored with plum pulp

Formulation	**Coliforms 35°C (MPN/mL)**	**Coliforms 45°C (MPN/mL)**	***Salmonella* spp. (in 25mL)**	***Coagulase Positive Staphylococci* (CFU/mL)**
L1	<3.0	<3.0	Absence	<0.1
L2	<3.0	<3.0	Absence	<0.1
L3	<3.0	<3.0	Absence	<0.1
L4	<3.0	<3.0	Absence	<0.1

Note: NMP: Most Likely Number of Microorganisms; UFC: Colony Forming Units.

Through the results of the microbiological analysis, it was noticed that all the formulations met the sanitary microbiological standards for foods established by the current legislation, reflecting good hygienic-sanitary conditions during the preparation.

Conclusions

Through the results obtained, it can be concluded that:

The elaboration of a water-soluble extract is a viable alternative to add commercial value to broken cashew nuts;

The addition of 40% of plum pulp to the extract provided the final product with higher ash, protein and lower carbohydrate contents. In addition, it also ensured a higher concentration of TPC;

The microbiological evaluation showed satisfactory results, indicating that the product was handled with good hygienic-sanitary conditions and can be consumed without risk to health.

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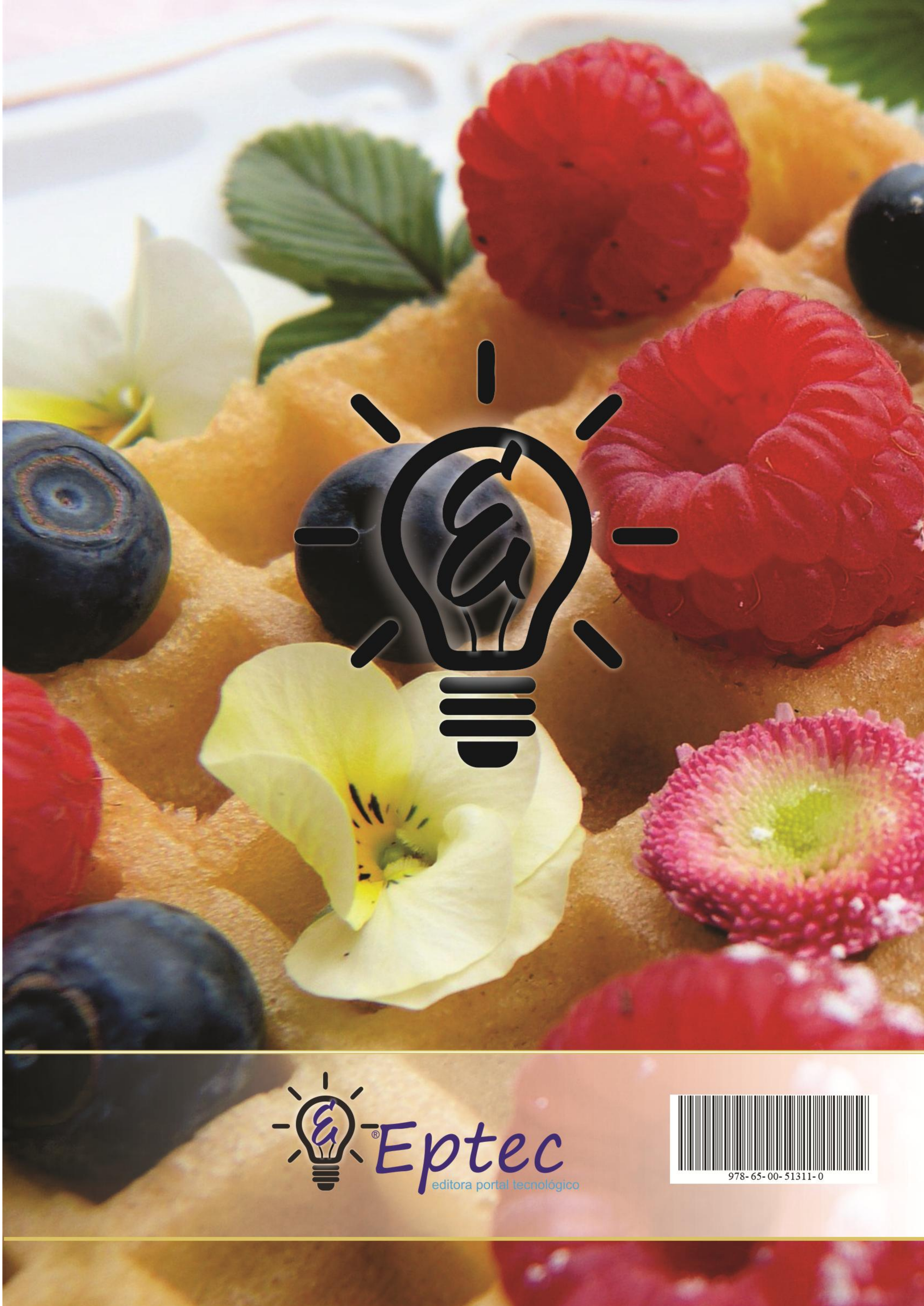

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