INTERDISCIPLINARY STUDIES IN FOOD ENGINEERING AND TECHNOLOGY

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Summary

Preface

The Interdisciplinary Studies in Food Engineering and Technology collection (Volume 1) emphasizes the importance that food science plays worldwide in the development of new foods using emerging technologies and the use of raw materials of high nutritional value, especially sweet potatoes *[Ipomoea batatas* (L.) Lam.]; beetroot [*Beta vulgaris* (L.)] ; seriguelas [*Spondias purpúrea* (L.)] pineapple [*Ananas comosus* (L.) Merril.] and cashew [*Anacardium occidentale* (L.)] residues; and dulce de leche with whey, from Cariri Paraibano.

Brazil has stood out in this sense, the development of new foods and ingredients reveals the scientific potential of its researchers, increasingly encouraging innovation and the use of local raw materials such as fruits, vegetables, grains and seeds, revealing its megabiodiversity. .

In each chapter of the collection, new product formulations were developed using new processing strategies to reduce loss and waste, creating new food structures that rely on the use of husks, stalks, leaves and seeds, in addition to milk by-products, with emphasis on the whey.

In the entire 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. Climate change and the earth's ability to regenerate its own resources is drastically decreasing and the population growth estimated for 2050 will lead to crisis in several sectors, as has happened in these last two years in food systems in the face of the COVID-19 pandemic.

Food science combined with new processing technologies is essential to ensure food safety, contributing to the transition from the current food system to a more efficient food system. In this way, food science is strongly present to ensure food safety and decisions must take into account the most technologically 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 fundamental work, deserves to be read and appreciated by all those interested in the area. I feel professionally gratified for having 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

The Interdisciplinary Studies in Food Engineering and Technology collection (Volume 1) was developed to emphasize the importance of the science of food technology in the development of food with quality and safety. It is a fascinating branch for knowledge in biology, statistics, physics, mathematics and chemistry. Since I learned from my father (Dr. Ary de Arruda Veiga) - then an employee of the Food Technology Section of the Campinas Agronomic Institute (Instituto Agronômico - IAC - APTA – SP - Brazil), the embryo of what is now the Food Technology Institute (Instituto de Tecnologia dos Alimentos - ITAL– APTA – SP - Brazil) - that food science is an essential area for agribusiness, covering the entire Brazilian production chain, from the production of matter to the consumption of the final product, in agriculture.

This text emphasizes the biochemical, physicochemical, microbiological and technological aspects focused on quality and nutrition management, under the aegis of the Hazard Analysis and Critical Control Points System (HACCP). The collection of articles contained in these presents unpublished data from scientific research with processing techniques used resources currently used and specially designed from the Northeast region of Brazil.

As emerging technologies are being used and used to develop foods, without the use of heat or chemical foods, in order to preserve their value, while at the same time the aroma, color, shape, taste and texture.

The evolution of science and technology has been increasingly generating research into knowledge in the areas of methodologies and equipment, in the various food and related areas. Even so, there is a need to structure the searches to make the chain viable, as we have a complex food production that promotes stages, from the dissemination of other stages and distribution.

Thus, the great challenge for the coming years is to improve the efficiency in agricultural production aiming at more efficient for the agri-food system, where the country must be at the forefront of sustainable agriculture and food security, since it has a high installed scientific capacity, in addition to being “the ball of the day” as the major world producer, as the agriculture that most preserves environments in the world, and still perpetuating itself as the “number one” in megadiversity.

It is known about the same consequences of the pandemic (COVID-19 and its variants of the pandemic) that also hit Brazil, the world wide indexes quickly (COVID-19), although at a lower rate than in the countries, since another population – up to 811 million people – was undernourished (The State of Food Insecurity and Nutrition in the World – SOFI-2021).

To reverse this, with all certainty, what is possible the development of chains, with new products developed locally, productive and with production of food and nutrition in all seasons of the year, in addition to continuing and increasing the preservation of the environment.

Thus, the development of this timely work was demonstrated to several people emerging from food processing and conservation, using strategies and raw materials of high phytogenetic value, such as Sat. Royen] ; sweet potato [Ipomoea batatas (L.) Lam.] ; beetroot [Beta vulgaris (L.)] ; seriguelas [Spondias purpúrea (L.)] residues of pineapple [Ananas comosus (L.) Merril.] and cashew apple [Anacardium occidentale (L.)]; and dulce de leche with whey, from Cariri Paraibano.

It is observed that several technologies were used in each chapter for processing, including value-added by-products, which are easily integrated into current production, such as those that can create or extra bioactive foods with pharmaceutical value.

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

Chapter I - presents the elaboration and characterization of the sapodilla pulp foam, highlighting the foam aspects. The foam drying technique is made for heat fruit foods which are indicated as high in fruit and sugar. It is one of the best drying methods, as the dry powder features high quality and, as nutrients, greater solubility (SOUZA, 2011).

Chapter II - deals with the physical-chemical analysis of pineapple residue meal and cashew penduncle. Flours obtained from fruit residues present greater preservation of nutrients, shorter drying time, and different physical and chemical properties. In addition, the use of by-products from fruit processing is an alternative to reduce losses in agribusinesses (MENEZES FILHO & CASTRO, 2020).

Chapter III - aimed to evaluate the effect of temperatures used on the physicochemical properties of sweet potato flour through spouted bed drying. The spouted bed is an equipment with specific fluid dynamic characteristics such as granulation, catalytic polymerization, among others (MATHUR & EPSTEIN, 1974).

Chapter IV – evaluated the influence of thickness on drying kinetics of beet slices by applying mathematical models (empirical and diffusive) to experimental data. The use of mathematical models is extremely necessary for the simulation of the drying process, time and temperature definitions, in addition to the optimization and improvement of the equipment used in drying and storage (ALMEIDA et al., 2020).

Chapter V – evaluated the influence of the application of three drying techniques on the powdered seriguela pulp, evaluating its physical properties of the powder and the anthocyanin content. Anthocyanins have antioxidant action and act in the prevention of chronic-degenerative diseases (OKOMURA F. et al., 1984).

Chapter VI – evaluated the physicochemical properties of dulce de leche added with whey. Whey proteins are considered excellent quality proteins due to their high digestibility and ability to provide a large amount of bioavailable essential amino acids for use by the human body . The use of whey for the development of new functional products is essential to establish and expand the use of functional dairy products (MATHAI et al., 2017).

Chapter VII – evaluated the instrumental texture profile and microbiological quality of coalho cheese, verifying the parameters required by current legislation. The microbiological analysis of dairy products becomes an important parameter for determining the quality of the product (PINTO et al., 2016).

Finally, in presenting this collection, I feel able to read and enjoy it in advance. This volume contains unpublished texts and data that increasingly contribute to the application of science and the country's technological and productive evolution in the definitive implementation of a clean system and model of food production for the world.

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Our recognition and dedication to Prof. Vania Moda Cirino for encouraging the creation of this 2022 collection and publication of this work.

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

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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 global alignment of food safety standards that provides the improvement in cost efficiency throughout the entire supply chain supply. For it is imperative that we need to transform our food systems so that they provide better health and we need to do so in a sustainable way.

Furthermore, it represents our contribution to the World Food Safety Day established by the United Nations in 2018, as everyone has the right to have access to safe and nutritious food and the DTAS are avoidable. According to FAO/WHO Foodborne diseases are responsible for 420,000 preventable deaths every year.

Therefore, this Collection represents the continuous effort of our group in the production of different formulations of new products using strategic raw materials for the development of safe, nutritious and functional foods. In addition, we use efficient mathematical models in processing these emerging techniques.

Our inspiration for the creation of this Collection was the reading of the book: “Noé Arca das Frutas Nativas Brasileiras” published by the Brazilian Agricultural Research Corporation (EMBRAPA) in November 2021, with support from the Brazilian Society of Genetic Resources (SBRG) and the Rede of Plant Genetic Resources of the Northeast (RGVNE). He mainly highlights the conservation of genetic resources and the improvement of native fruit species, the huge and competitive real and potential market that presents itself, with several niches for fresh and dried fruits, as well as for their products and by-products.

Thinking about these aspects and the importance of the techniques used to obtain functional products, this work presents, in each chapter, research in a comprehensive way, exemplifying most unit operations, conservation techniques and their models.

We thank everyone who contributed to the realization of this work and we hope that it can increasingly contribute to the technological and productive development of the country in the definitive implementation of an efficient and clean model of safe food production for the world.

The authors

PREPARATION AND PHYSICAL CHARACTERIZATION OF SAPOTI PULP FOAM WITH MILK AND EMULSIFIERS

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Introduction

The sapodilla (*Manilkara zapota* L.) originates from hot and humid regions of Tropical America, with potential for economic exploitation in Brazil, with greater emphasis on research in the Northeast region, with the state of Pernambuco being the largest national producer, other states such as Bahia, Pará, Ceará, Paraíba, Sergipe and Rio Grande do Norte also stand out in fruit production (LUZ et al., 2019).

The search for diversification of sapodilla crops provided an increase in the interest in cultivation and consumption, and its commercialization was driven by the search for diversified products, where the aroma, flavor and nutritional value are valued. The use of this fruit species considered exotic reflects in the offer of new alternatives of fresh fruits for consumption and also as raw material for agribusiness (SOUSA et al., 2012).

The evidence that the fruit is ripe is not linked to color, but rather to consistency, soft without being too soft. When ripe, the fruit has a slightly brownish, thin, but rough, inedible skin. The edible part is a pulp that varies in color from yellow to brown. If the fruit is not quite ripe, ingesting the pulp may result in a small aftertaste in the mouth, due to the presence of traces of latex (SANTOS et al., 2020).

Due to the biochemical deterioration reactions responsible for the loss of fruit quality, its post-harvest shelf life is reduced. In this way, its processing contributes to increasing the shelf life, in addition to facilitating transport and adding value to the product (COELHO et al., 2019). And one of these forms of processing is the transformation of the pulp into a powdery material, which can be carried out by drying the material (KAMALI et al., 2022).

Foam layer drying is a simple process used for the dehydration of fruit pulps, liquids and semi-liquids, and requires simple equipment and shorter processing times compared to lyophilization, for example. It consists of transforming a liquid or semi-solid food into a stable foam, which increases the surface area of the food material to be dried, leading to greater heat and mass transfer (SANTOS et al., 2022).

In order to achieve superior performance, proper knowledge of foam physical properties is important and parameters such as foam stability and foamability influence foam drying efficiency (WATHARKAR et al., 2021).

Several works in the advanced literature on the characterization of the foam mat drying process, foam dynamics, modeling and approach to hybrid drying (KUMAR et al., 2022), fruits such as blueberries (GAO et al., 2022); bacaba (DE CÓL et al., 2022) green banana powder (KAMALI et al., 2022); papaya (QUADRI et al., 2020) and other foods orange drink powder (NEMATI et al., 2022).

In this context, the present study aims to make foam from sapodilla pulp with different concentrations of powdered milk, Emustab® and neutral alloy to evaluate the best condition in relation to its physical parameters.

Methodology

Feedstock

They were used with sapoti raw materials (*Manilkara zapota*) purchased at the Agricultural Products Supply Center (CEASA), whole powdered bed (Itambé®) and the additives: emustab (Selecta®) and neutral alloy (Du Porto®), the powdered milk and the additives were purchased at local market.

Figure 1. Sapoti (*Manilkara zapota* L.). Source: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/11929/2/00076300.pdf.

Fruit cleaning

Initially the sapodillas went through the steps of cleaning, sanitizing, sanitizing in sodium hypochlorite solution (200 mg L^{-1} of free chlorine) for 15 min and washing in running water. Then, by manual pulping, its fractions were divided into pulp, husks and seeds.

Pulp pasteurization

The pulp was placed in a metal container and subjected to the pasteurization process (60°C/30 min) followed by cooling in an ice bath to avoid the prolonged action of heat (SANTOS et al., 2020b).

Experimental planning for foam preparation

To analyze the different individual and combined effects of the independent variables: emustab (2, 3 and 4g), neutral alloy (0.5, 1.0 and 1.5g) and powdered milk (10, 15 and 20g) an experimental design was carried out 2^3 with 3 central points (Table 1), totaling 11 experiments.

Table 1. Experimental design with coded variables for foaming sapodilla pulp with milk and emulsifiers

Experiments	Emustab (g)	Neutral alloy (g)	Milk (g)
1	2 (-1)	0.5 (-1)	10 (-1)
2	4 (+1)	0.5 (-1)	10 (-1)
3	2 (-1)	1.5 (+1)	10 (-1)
4	4 (+1)	1.5 (+1)	10 (-1)
5	2 (-1)	0.5 (-1)	20 (+1)
6	4 (+1)	0.5 (-1)	20 (+1)
7	2 (-1)	1.5 (+1)	20 (+1)
8	4 (+1)	1.5 (+1)	20 (+1)
9 (C)	3 (0)	1 (0)	15 (0)
10 (C)	3 (0)	1 (0)	15 (0)
11 (C)	3 (0)	1 (0)	15 (0)

Note: C is the center point.

In order to define the best condition for foam preparation, the following answers were obtained: specific mass (Equation 1) and expandability (Equation 2), calculated according to the equations described by Oguntunde and Adeojo (1993).

$$\rho = \frac{m}{V} \quad \text{(Eq.1)}$$

Where: ρ is the specific mass (g cm^{-3}), m is the foam mass (g) and V is the volume (cm$^{3)}$.

$$Exp(\%) = \frac{\frac{1}{\rho_e} - \frac{1}{\rho_p}}{\frac{1}{\rho_p}} x100 \, \text{(Eq.2)}$$

Where: ρ_e is the foam density (g cm^{-3}) and ρ_p is the pulp density (g cm$^{-3)}$.

The factorial design was analyzed using Statistica software (Version 7.0, from Statsoft , Inc).

Preparation of the foam

The foam was prepared keeping the mass of the sapodilla pulp (74.5g) and the mixing time of the mixture (20 min) fixed. The mixture was carried out and the foam obtained, using a domestic mixer (Britânia$^{®}$ 340W) using its maximum speed. In Figure 2, it is possible to visualize a summarized scheme that was used to make the sapodilla foam.

Figure 2. Reduced diagram for the preparation of sapodilla pulp foam.

Results

The results of the physical properties (specified mass and expandability) are presented in Table 2.

Table 2. Response variables (specific mass and expansibility) of the experimental design for the elaboration of sapodilla pulp foam with milk and emulsifiers

Experiments	Specific mass (g cm^{-3})	Expandability (%)
1	0.657	57.333
2	0,500	107.017
3	0.578	78.787
4	0.438	136.000
5	0.736	40.476
6	0.587	76.119
7	0.692	49.367
8	0.508	103.448
9 (C)	0.605	71.014
10 (C)	0.561	84.375
11 (C)	0.587	76.119

Analyzing the specific mass values presented in Table 2, a low value of 0.438 g cm^{-3} is observed in experiment 4 (4.0g of emustab, 1.5g of neutral alloy and 10g of milk) and a high value of 0.736 g cm^{-3} in experiment 5 (2.0g of Emustab, 0.5g of neutral alloy and 20g of milk). The increase in density was observed when analyzing the low concentrations of emustab and neutral alloy combined with the high concentration of milk in the foam composition.

These results agree with previous publications, such as the work carried out by Benković et al. (2019), where the optimization of the foam layer drying process for the production of cocoa powder enriched with peppermint extract was studied, and Shaari et al. (2018) when studying the production of pineapple powder (*Ananas comosus*) with foam layer drying, which concluded that high density values were observed when using low concentrations of foaming agents.

The structure of food foam usually consists of the air and liquid phase, while the gas is dispersed and thermodynamically unstable (VARHAN et al., 2019). The foam expansion depends on the incorporation of air and the foaming properties of the agents and the concentration used in the formulation (NG and SULAIMAN, 2018).

From the results presented in Table 2, the minimum expansion value of 40,476% was obtained in experiment 5 (2.0g of Emustab, 0.5g of neutral alloy and 20g of milk) and the maximum of 136% in experiment 4 (4.0g of Emustab, 1.5g of neutral alloy and 10g of milk). The increase in foam expansion occurred with the increase in the concentrations of emustab and neutral alloy combined with the decrease in the concentration of milk, the inverse of what was observed for the specific mass.

The increase in expansion and reduction in density as a function of increasing concentration of the foaming agent was reported by Ayetigbo et al. (2019) in the preparation, optimization and characterization of white and yellow pulp cassava foam (*Manihot esculenta*) for powder production, and in the work carried out by Ng and Sulaiman (2018), where they developed a powdered beet product (*Beta vulgaris*) using foam layer drying.

In Table 3, it is possible to observe the result of the analysis of variance (ANOVA) for each response variable of the process of elaboration of the sapodilla pulp foam.

Table 3. Analysis of variance (ANOVA) of the experimental design for foaming sapodilla pulp with milk and emulsifiers

ANOVA	**Specify mass ($g\ cm^{-3}$)**	**Expandability (%)**
MSRegression	0.074	7276.162
MSResidual	0.002	285.359
$F_{calculated}$ ($F_{Tabulated}$)	109,976 (4.35)	59.496 (4.35)
p- value	< 0.0004	< 0.002
MSLack of Fit	$5{,}930 \times 10^{-4}$	194.453
MS Pure error	$9{,}750 \times 10^{-4}$	90.906
R^2	0.97922	0.962
Adj R^2	0.97032	0.946

The complete experimental design 2^3, with 3 central points, was used to evaluate the effects of independent variables on foam properties. The high value of F calculated for the specific mass (109.976) and expandability (59.496) indicated that the model obtained was statistically significant. The high value of F calculated for the specific mass (109.976) and expandability (59.496) indicated that the model obtained was statistically significant.

The coefficient of determination (R^2) for the physical properties of the foam was greater than 0.932, which indicates the good accuracy of the model (MONTGOMERY, 2017), as well as the values obtained for the adjusted coefficients of determination (Adj R^2), suggesting a high degree of correlation between the experimental and predicted values. Furthermore, the p- value for the lack of fit was non-significant in all cases ($p>0.9$), which means that the dispersion of the experimental data was an independent measure of the pure error model. These data are presented in Table 2.

The models obtained satisfactorily predicted the foam properties (specific mass and expandability) and are instrumental in selecting the optimal conditions required for foaming. The significant terms of the model obtained were the linear terms of the independent variables, as given in Equations 3 and 4, for the specific mass and expandability, respectively.

$$\text{Especific mass} = 0,7580 - 0.0789 \times \text{E} - 0.0658 \times \text{NA} + 0.0088 \times \text{M} \quad \text{(Eq3)}$$

$$\text{Expandability} = 25.75629 + 24.5776 \times \text{E} + 21.6642 \times \text{NA} - 2,7432 \times \text{M} \quad \text{(Eq4)}$$

Where: E is the concentration of emustab (g), NA is the concentration of neutral alloy (g) and M is the concentration of milk (g).

Figure 2 shows the response surfaces to the effects of the independent variables under the dependent variables: specific mass (Figures 1A and 1B) and expansibility (Figures 1C and 1D).

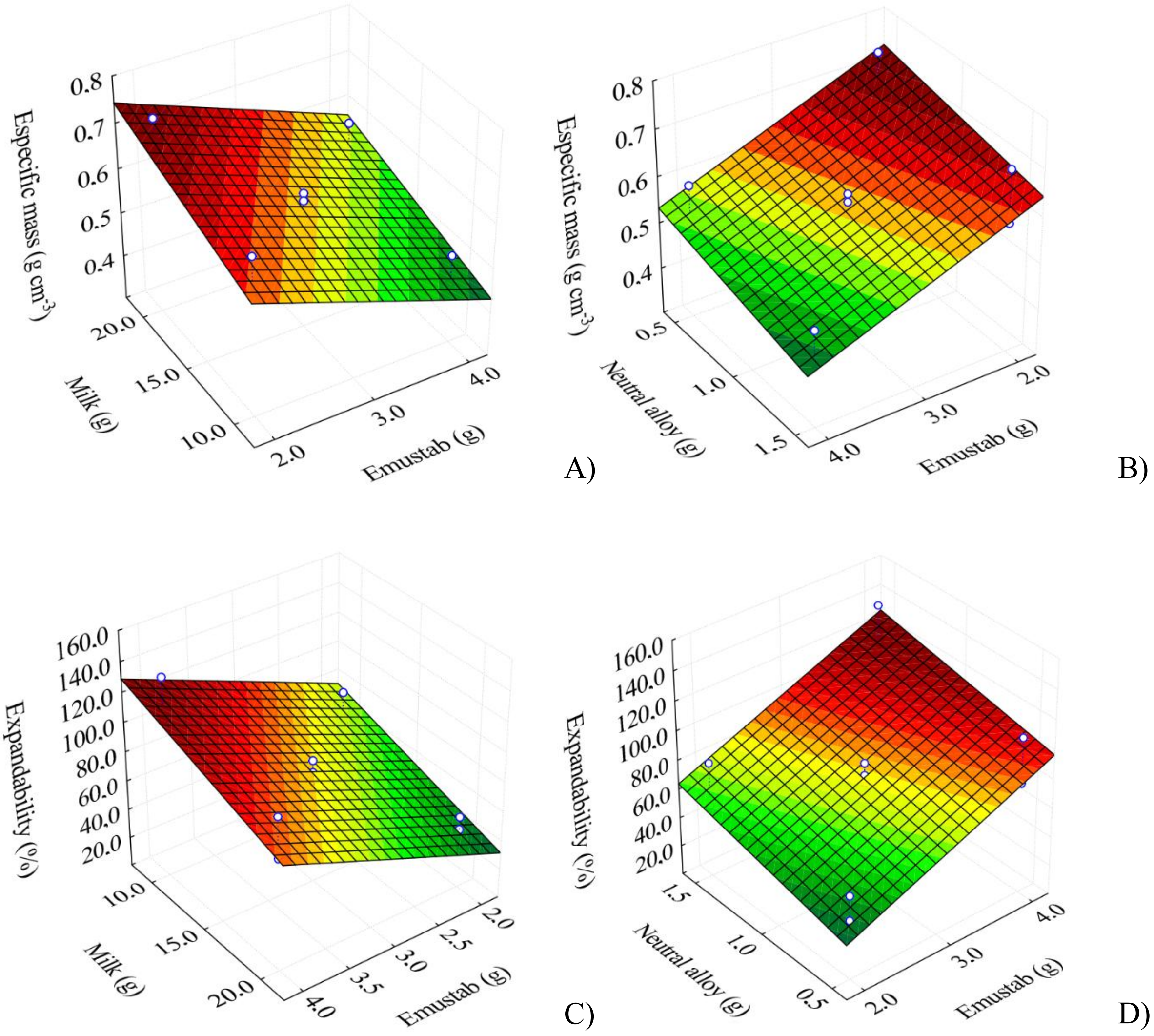

Figure 2. Response surfaces for the specification mass : A) Milk as a function of Emustab ; B) Neutral alloy as a function of Emustab ; and for expandability : C) Milk as a function of Emustab ; D) Neutral alloy as a function of Emustab.

These figures show the profile of physical properties with the concentrations of foaming agents, where it was observed that the most suitable condition for the production of foam from sapodilla pulp was obtained in experiment 4 (4.0g of emustab, 1.5g of neutral alloy and 10g of milk) in which the foam had a low specific mass and high expandability, desirable characteristics to obtain greater efficiency in the drying process.

Conclusion

From our results it can be concluded that:

Specific mass values ranged from 0.438 to 0.657 g cm^{-3} and expandability values ranged from 40.476 to 136%.

The composition optimized for foam production of sapodilla pulp was for levels (+1) of emustab and neutral alloy and (-1) for milk.

On ANOVA the lack of fit was non-significant in all cases.

And the dispersion of the experimental data was an independent measure of the pure error model.

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PHYSICO-CHEMICAL CHARACTERIZATION OF FLOUR FROM PINEAPPLE AND CASHEW STAND WASTE

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Introduction

Fruits are foods consumed all over the World, as they have essential nutrients for the human diet, as they contain vitamins, minerals, dietary fiber, carbohydrates, among others. In world fruit production, Brazil ranks third, second only to China and India. The varieties produced in Brazil total around 500 species, of which 220 are plants native to the Amazon (TREICHEL et al., 2016). Although this growth in productivity provides positive consequences, on the other hand, it contributes to the worsening of an increasingly common environmental problem in world society, the generation of waste.

It is estimated that the processing of fruits for the production of juices and pulp generates between 30 and 40% of agro-industrial residues. The production of these by-products generates thousands of tons, and it is interesting to add value and economic interest to these wastes, which require scientific and technological research to enable their use since they are rich in bioactive compounds (FILHO & FRANCO, 2015).

Fruit peel residues, which account for up to 50% of the total fruit weight, are simply discarded in the trash or incinerated, so further use of these by-products can help reduce waste and environmental problems. This material has great potential to be applied in bakery products, as it contains a considerable amount of bioactive compounds, sugars, minerals, fibers and phenols, which enables significant nutritional, antimicrobial and antiviral activities (HANANI et al., 2018).

According to Miranda et al. (2015), pineapple is presented as a perishable fruit and vulnerable to crushing in conditions that end up causing post-harvest losses. Being one of the most popular fruits in the world, where Brazil is one of the biggest producers. Its consumption is based only on juice or *in natura* fruit. Residues such as bark and stalk are wasted causing a large accumulation when discarded in the environment.

Cashew, *Anacardium occidentale* L., is one of the crops of great economic and social importance for the Northeast region of Brazil, which is globally recognized as one of the major cashew producers (SERRANO, 2016). Annually, in the Northeast, about 2.5 million tons of cashew peduncle are produced, with more than 1.5 million tons of peduncle being wasted, representing about 75% of production, thus generating large amounts of waste. However, cashew residue has a great potential for use in the food industry, thus enabling the supply of new foods. It can give functional properties to foods, as there is a constant search for good quality foods that provide, in addition to the energy needed for the body's functions, health benefits (SIQUEIRA & BRITO, 2013).

Flours obtained from fruit residues have advantages over cereal flours such as greater preservation of nutritional values, shorter drying time, different physical and chemical properties. These allow a wide range of 20 applications and different possibilities of using the whole fruit as raw material for different products. It is important to note that this is a natural product, as the only ingredients in the flour are the residues. Fruit flours can be applied in bakery products, such as cakes, breads, cookies, among others (MORENO, 2016).

As fruit and vegetable flours also have important technological features, they can be used as thickeners, gelling agents, fillers, and water-retaining agents, as well as producing edible films (FOSTE et al., 2020). Several research were carried out to produce flour: banana peel, plantain, and apple banana (SÁ et al., 2021); jackfruit peel (DE SOUSA et al., 2020); jabuticaba peel flour (RESENDE et al., 2020) and buriti (RESENDE et al., 2019).

Therefore, the use of residues from fruit processing is an alternative to reduce losses in agro-industries, generally, only residue dehydration technologies are used to dry the product and crush it to transform it into flour (ALVES et al., 2011).

Considering the importance of the use of fruit residues, sustainability and nutritional support, this work aimed to obtain a flour from pineapple and cashew peduncle residues, as well as to characterize it in terms of its physicochemical properties.

Methodology

Feedstock

Pineapples (*Ananas comosus*) and cashew (*Anacardium occidentale*) stalks used were purchased at the local market in the city of Campina Grande, Paraíba, Brazil. Pineapples and cashew apples were selected according to size and maturity stage, then washed in running water and sanitized in sodium hypochlorite solution at 200 ppm for 15 minutes.

Figure 1. Pineapple peel (A) and cashew peduncle (B) used in the samples.

Obtaining and drying waste

The fruits were cut with the aid of a stainless-steel knife and processed in a domestic blender, after which the juice and the residue were separated through sieves. The residues obtained were placed separately in stainless steel trays forming a thin layer and subjected to a temperature of 60°C for 24 hours with an air velocity of 1.5 $m.s^{-1}$. After drying, the product was subjected to a unitary grinding operation, using a knife mill (Manufacturer BOTINI).

After milling, three flours were prepared: Pineapple residue flour, Cashew peduncle residue flour and Flour made from the pineapple and cashew peduncle blend (1:1 ratio). After drying and milling, the flours were packed in airtight packages and kept at room temperature.

Physicochemical characterizations of flours

Physico-chemical characterizations were carried out in the dehydrated residues and in the mixed flour: moisture, total solids, ash, proteins according to the methodology proposed by the Instituto Adolfo Luttz (BRASIL, 2008); the lipid content was determined according to the methodology of Bligh and Dyer (1959); water activity (A_w) was determined using the Decagon® Aqualab CX-2T device at 25°C; the total carbohydrate content was calculated by difference to obtain 100% of the total composition (FAO, 2003).

The other determinations of pH, titratable acidity, and the results expressed in citric acid, determined according to the methodology proposed by the Instituto Adolfo Lutz (BRASIL, 2008).

Statistical analysis

Statistical analysis was performed for experimental data in triplicate and the results were submitted to single-factor analysis of variance (ANOVA) of 5% probability and significant qualitative responses were submitted to *Tukey's* test, adopting the same level of significance. For the development of statistical analysis, the ASSITAT software version 7.0 was used (SILVA & AZEVEDO, 2016).

Results

Table 1 shows the means and standard deviations referring to the physicochemical characterization of dehydrated pineapple and cashew residues.

Table 1. Physical-chemical characterization of dehydrated pineapple and cashew residues and mixed flour

Parameters (%)	**Pineapple waste**	**Cashew waste**	**Mixed flour**
Moisture	8.05 ± 0.03a	6.18 ± 0.01c	7.51 ± 0.05b
Total solids	91.95 ± 0.03a	93.82± 0.01c	92.49±0.05b
Ash	2.15 ± 0.13a	1.62 ± 0.23c	1.84 ± 0.02b
Proteins	3.18 ± 0.15a	1.55± 0.01c	2.61 ± 0.01b
Lipids	0.72 ± 0.21b	1.53 ± 0.02a	1.12 ± 0.03ab
Carbohydrates	85.90 ± 0.24c	89.12 ± 0.18a	87.36 ± 0.12b

Note: Equal letters on the same line do not differ statistically from each other by *Tukey's test* at the 5% probability level.

Through Table 1, it is observed that the evaluated samples present low values in relation to the moisture content. Lower values of moisture content were observed in the flour made with cashew residue (6.18%), which presented a statistically significant difference when compared to the other treatments.

Soares et al. (2017) obtained slightly lower moisture content (5.95%) in guava residue flour. Silva and Souza (2017) obtained a moisture content of (10.06%) for jamelão residue flour obtained by drying at 60°C. All samples are adequate to the quality standard established by legislation through resolution number 263, which limits the moisture content of flours up to 15% (BRASIL, 2005).

It can be seen that the amount of total solids is greater when a lower moisture content is obtained, thus, the dehydrated cashew residues, when presenting 6.18%

of moisture, consequently obtained a high total solids content (93.82%). Such growth is caused by the reduction in the water content, however, all the two residues evaluated and the mixed flour present a significant difference between them.

Regarding the ash content, the pineapple residue flour showed higher values when compared to the others (2.15%). Nunes et al. (2017) when drying pineapple residues at temperatures of 50, 60 and 70°C, found 2.82 to 2.87% ash content. Silva et al. (2019) when dehydrated beets at 60°C obtained an ash content of 2.37%.

Vasconcelos et al. (2019) when obtaining and analyzing the guava residue flour (dehydrated at 60°C for 16 h), obtained an ash content of 1.68%. Statistically, the dehydrated residues and the mixed flour, when compared to each other, presented significant differences at the level of 5% of probability.

Regarding the protein content, the pineapple residue flour showed higher values (3.18%), similar to what was reported by Aranha et al. (2017) in fruit waste flour (3.87%). A value close to that obtained for mixed flour was observed by Garmus et al. (2009) in potato peel flour (2.5%). However, there were statistically significant differences between the dehydrated residues and the mixed flour.

The flour obtained from cashew residue had the highest lipid content (1.53%) and the flour from pineapple residue had the lowest content (0.72%), when compared to the other samples, only the mixed flour with 1.12% of lipids showed no statistically significant difference. Stork et al. (2015) observed a lipid content similar to that obtained in the present study, when drying apple residue (1.24 to 3.10%). Scorsatto et al. (2017) when making eggplant flours obtained 1.85%.

According to Almeida et al. (2018) and Santos et al. (2019a), the determination of lipids becomes important, as lipids play an important role in food quality, contributing attributes such as texture, flavor and caloric value.

The results obtained in relation to the total carbohydrate content were relatively high, ranging from 85.90 to 87.12%, in which the analysis of total carbohydrates is including the total fiber content, showing that the residues of pineapple, cashew and mixed flour, are a powder with high fiber content, with a statistically significant difference between them at a 5% probability level ($p < 0.05$). According to Santos et al. (2019b) carbohydrates when determined by difference from the other constituents, the reduction of moisture automatically provided an increase in this content.

Table 2 shows the results obtained for the determinations of water activity (Aw), pH and total titratable acidity (ATT).

Table 2 determines water activity (Aw), pH and total titratable acidity (ATT).

Parameters	Pineapple waste	Cashew waste	Mixed flour
Water activity (A_w)	0.580± 0.01a	0.530 ± 0.11a	0.569 ± 0.01a
pH	3.66± 0.01c	4.52 ± 0.02a	4.02 ± 0.03b
ATT (% citric acid)	2.98 ± 0.05a	1.38 ± 0.01c	2.13 ± 0.01b

Note: Equal letters on the same line do not differ statistically from each other by *Tukey's test* at the 5% probability level.

No significant statistical difference was observed between the samples in relation to water activity, which varied from 0.530 to 0.580. According to Barros et al. (2019), moisture content and water activity are parameters that directly influence the quality and stability of food products, and products with a water content of less than 0.60 can be classified as foods with low water content. Based on this assumption, it can be said that all flours have low water activity and are not susceptible to degradation.

Regarding the titratable total acidity (TTA) parameter, a higher value was observed in the pineapple residue flour (2.98% citric acid), which presented a statistically significant difference when compared to the cashew residue flour and the mixed flour. Santos et al. (2019c) when making kiwi peel flour obtained 0.196% citric acid, which is lower than the values obtained in the present work.

For the pH values there was a variation from 3.66 (pineapple residue) to 4.52 (cashew residue) showing statistically significant differences to the Tukey test with 5% probability. Alcantara et al. (2012) when performing the drying of the cashew pendulum, obtained a pH of 4.15. Lima et al. (2015) when dehydrating the watermelon rind to obtain flour also obtained values close to the present study.

Conclusions

Based on the results obtained, it can be concluded that:

The three flours presented values adequate to the quality standard established by the legislation, being the cashew residue flour, the one that presented the lowest value for moisture and consequently the highest concentration of total solids.

The pineapple residue flour had the highest titratable acidity and the lowest lipid concentration, with a significant difference between the three flours in terms of ash and protein content.

The three flours had a high concentration of carbohydrates and a low water activity, factors that evidence the high fiber content and low susceptibility to degradation, respectively.

Elaborated flours can be used as a food ingredient in the development of new products.

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PHYSICAL PROPERTIES AND ANTHOCYANIN CONTENT OF SERIGUELA POWDER OBTAINED BY LYOPHILIZATION, SPRAY DRYER AND FOAM-MAT DRYING

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Introduction

The seriguela, one of the most cultivated species of the genus *Spondias*, is a very perishable tropical fruit that stands out for its exotic flavor and excellent market acceptance. The growing demand for processed tropical fruits has led many agro-industries to operate in the Northeast of Brazil, with a market demand for quality fruits. There has been a growing interest from fruit growers and agro-industries in the cultivation of *Spondias* species, which confirms the agro-socioeconomic potential of these species (ALBUQUERQUE et al., 2016).

The seriguela is a tropical fruit that presents high perishability during post-harvest handling, susceptible to softening and consequently quickly reaching senescence, in order to change its flavor. For this reason, industries have been increasingly investing in new conservation techniques that aim to prolong the shelf life of seasonal fruits such as seriguela (NERIS et al., 2017).

Among numerous conservation methods, lyophilization, spray dryer and foam-mat drying stand out. Lyophilization is a drying technique, which basically consists of removing water through sublimation at low temperatures and under vacuum. This method was developed in order to preserve sensory and nutritional characteristics of the product, usually lost in conventional drying due to high temperatures. Its performance is intrinsically linked to adequate operating conditions and the quality of the product that will be subjected to the process (COSTA et al., 2021).

Spray drying is a technology in which a liquid product is atomized in hot air to obtain a powder. simple, continuous and low cost compared to other techniques, in addition to the ease of operation, high production rates and the ability to handle labile products due to the short exposure of the product to high temperatures (PEREIRA et al., 2018).

Drying in a foam layer is a process widely used in the dehydration of heat-sensitive foods, such as fruit pulp, providing retention of the nutritional and sensory properties of fresh fruit. It is a simple process with considerable advantages, which requires little equipment and involves shorter processing times compared to lyophilization, for example (ALEXANDRE et al., 2014).

It consists of transforming a liquid or pasty food into a stable foam by incorporating air and subsequent formation of bubbles in the food. This procedure increases the contact area between the drying air and the food, improving mass transfer as well as heat transfer due to the increase in surface heat exchange area (ARAÚJO et al., 2020).

In this context, the present study aims to obtain powder from seriguela pulp through the application of three different drying techniques and to evaluate the influence of the technique in relation to the physical properties of the powder and the anthocyanin content.

Methodology

Cleaning the fruits and obtaining the pulp

The seriguelas in the mature stage went through the steps of cleaning, sanitizing, sanitizing in sodium hypochlorite solution (200 mg L^{-1} of free chlorine) for 15 min and washing in running water. Then, by manual pulping, its fractions were divided into pulp + husks and seeds. The pulp and peel mix was processed in a domestic blender to obtain a homogeneous sample. After processing, the pulp was filtered in bags made of organza (mesh opening close to 100 mesh).

Figure 1. seriguelas (*Spondias purpúrea* (L.)).
Fonte: https://diariodonordeste.verdesmares.com.br/ser-saude/seriguela-veja-origem-e-beneficios-da-fruta-1.3129521

Obtaining seriguela powder

To obtain the powder from the seriguela pulp, three different drying techniques were applied.

Lyophilization

For lyophilization, the lyophilization procedure, initially the pulp was subjected to slow freezing in a freezer for 48 hours at a temperature of -18°C. After freezing, the pulp was transferred to a bench lyophilizer and subjected to a temperature of -50°C for 48 h.

Spray dryer

For drying the pulp using the spray dryer, it was necessary to use a carrier agent, for this, 10% maltodextrin (DE20) was used. The drying process took place under the following conditions: mixture feed flow (0.5 L/h), hot air flow (3.5 L/h), inlet temperature (150ºC) with the speed of the air (30 L/min) and atomizing pressure (100 psi).

Foam mat drying

In this drying technique, the foam was initially made with seriguela pulp and 4% Emustab®. The foam prepared was subjected to convective drying (thickness 5mm) at a temperature of 60°C, until mass equilibrium was reached.

Characterization of the powders obtained

The powders obtained were characterized in triplicates regarding the following parameters, described below:

Water content

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

Water Activity Methodology

Cleaning the fruits and obtaining the pulp

The seriguelas in the mature stage went through the steps of cleaning, sanitizing, sanitizing in sodium hypochlorite solution (200 mg L^{-1} of free chlorine) for 15 min and washing in running water. Then, by manual pulping, its fractions were divided into pulp + husks and seeds. The pulp and peel mix was processed in a domestic blender to obtain a homogeneous sample. After processing, the pulp was filtered in bags made of organza (mesh opening close to 100 mesh). Obtaining seriguela powder

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Characterization of the powders obtained

The powders obtained were characterized in triplicates regarding the following parameters, described below:

Water content

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

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

Apparently density

The apparent density was determined with the aid of a 10 mL beaker previously weighed and then filled with flour, and determined using Equation 1 (TONON et al., 2009).

$$\rho_{ap} = \frac{m}{V} \qquad \text{(Eq.1)}$$

Where: $\rho_c$is the tapped density (g cm^{-3}), m is the mass and Vc is the volume occupied after compaction.

Compacted density

The compacted density was determined from the assembly used in the apparent density, by beating the beaker filled with the sample for 50 times on the bench, from a pre-established height of 2.5 cm, calculating the ratio through from Equation 2 (TONON et al., 2009).

$$\rho_c = \frac{m}{V_c} \qquad \text{(Eq.2)}$$

Where: $\rho_c$is the tapped density (g cm^{-3}), m is the mass and V_c is the volume occupied after compaction.

Absorption capacity in water

The water absorption capacity was determined according to Beuchat (1977), in which about 10 mL of (distilled) water was added to 1 g of the sample in centrifuge tubes. The suspension was homogenized for 30 seconds and then left to rest for 30 minutes. Subsequently, the tubes were closed and centrifuged for 15 minutes at 1000 rpm. The outer walls of the tubes were dried and then weighed. The mass of water absorbed was expressed as a percentage (%).

Solubility

Solubility was determined by the method of Eastman and Moore (1984), where 1g of powder sample was diluted in 100 mL of distilled water and centrifuged (2600 rpm/5 min) the supernatant was dried at 105°C/24 hours.

Total anthocyanins

The method used for reading total anthocyanins was the single pH method described by Francis (1982). The method consists of making a quantitative transfer of an aliquot of the concentrated extract to a container and then this aliquot is diluted with an amount of Ethanol - HCl solution at 1.5 $mol.L^{-1}$, thus having a volume of diluted extract

Statistical analysis

The results were subjected to statistical treatment through a completely randomized design with a comparison of means test, using the software Assistat version 7.7 beta (SILVA & AZEVEDO, 2009).

Results

In Table 1, it is possible to observe the average values of water content and water activity of the seriguela powders obtained by lyophilization, spray dryer and foam-mat drying.

Table 1. Water content and water activity of powdered seriguela obtained by different drying methods

Method	Water content (%)	Water activity
Lyophilization	4.57 ± 0.09 ^{C}	0.216±0.00 ^{A}
Spray dryer	9.16 ± 0.04 ^{A}	0.289±0.01 ^{A}
Foam mat	6.12 ± 0.05 ^{B}	0.231±0.00 ^{A}

Note: Equal letters in the same column do not differ significantly from each other by Tukey's test at the 5% level.

Regarding the water content, the three drying techniques applied presented values lower than 10%, however, the lowest water content (4.57%) was obtained for the lyophilization method. Statistically, when comparing the results between the applied techniques, the water content values were significantly different from each other. Coelho et al. (2021) when drying the acerola pulp in spray dryer at temperatures of 150, 160 and 170°C, obtained water content with values close to 5%.

The water activity values were low and below 0.3 ($a_w<0.3$), however, there were no statistically significant differences ($p>0.05$). Silva et al. (2021) when determining the water activity of a freeze-dried mix composed of blackberry and blueberry pulp, obtained values ranging from 0.228 to 0.291.

According to Staudt et al. (2013), water activity is one of the most important parameters in the study of food, as it is related to the amount of water available for physical, chemical and biochemical reactions and microbiological growth. It is a factor that directly influences the characteristics of foods and their stability, indicating whether there is a possibility of microbial growth.

In Table 2, the average values of the apparent and compacted densities of the seriguela powders obtained by lyophilization, spray dryer and foam-mat drying are presented.

Table 2. Bulk density and compacted density of powdered seriguela obtained by different drying methods

Method	**Apparently density ($g\ cm^{-3}$)**	**Compacted density ($g\ cm^{-3}$)**
Lyophilization	0.310 ± 0.01^{C}	0.388 ± 0.01^{C}
Spray dryer	0.380 ± 0.01^{A}	0.422 ± 0.02^{A}
Foam mat	0.356 ± 0.00^{B}	0.401 ± 0.01^{B}

Note: Equal letters in the same column do not differ significantly from each other by Tukey's test at the 5% level.

The apparent density values were significantly influenced ($p>0.05$) by the applied drying technique. The highest value was 0.380 $g\ cm^{-3}$ for powders obtained in spray dryer and the lowest value was 0.310 $g\ cm^{-3}$ for powders obtained by lyophilization. Silva et al. (2021) obtained apparent density values ranging from 0.336 to 0.451 $g\ cm^{-3}$ for powders from a blend with blackberry and blueberry pulp, obtained by lyophilization.

The compacted density showed higher values than those obtained for apparent density, due to the smaller volume occupied by the powder. However, it followed the same behavior as the apparent density, that is, it reduced its values as the water content of the powder increased (as shown in Table 1).

The tapped density values ranged from 0.388 to 0.422 g cm^{-3}, statistically, they were significantly different ($p<0.05$). Martins et al. (2019) when preparing freeze-dried blends with banana pulp and peel, they obtained compacted density ranging from 0.77 to 0.80 g cm^{-3}.

In Table 3, the average values of water absorption capacity and solubility of the seriguela powders obtained by lyophilization, spray dryer and foam-mat drying are presented.

Table 3. Water absorption capacity and solubility of seriguela powders obtained by different drying methods

Method	**Water absorption (%)**	**Solubility (%)**
Lyophilization	81.03 ± 0.14	92.33 ±0.11 ^{A}
Spray dryer	69.47 ± 0.09	76.19 ±0.13 ^{C}
Foam mat	75.86 ± 0.20	84.06 ± 0.16 ^{B}

Note: Equal letters in the same column do not differ significantly from each other by Tukey's test at the 5% level.

The values of water absorption capacity were significantly influenced by the applied drying technique ($p<0.05$). The seriguela powders showed high values in the range of 69.47-81.03%, highlighting the powders obtained by lyophilization that presented the highest percentage and the lowest water content. The ability to absorb water from powders is a relevant property desirable for application in meat products, breads and cakes. It is necessary to determine the water absorption capacity to know the availability of hydrophilic groups to bind water molecules (FERREIRA et al., 2020).

According to Fernandes et al. (2014) solubility is the last step of particle dissolution and is considered a decisive factor for the quality of these products (JAYASUNDERA et al., 2011). The solubility values were 76.16, 84.06 and 92.33% for powders obtained by spray drying, foam-mat drying and lyophilization, respectively. The highest solubility value was obtained for the powder that presented the highest water absorption capacity (Spray dryer), statistically the values were significantly different ($p<0.05$). According to Beltran et al. (2021), fruit powders with high solubility values can be used in foods that require low temperatures to be prepared (instants) or as ingredients for the formulation of soups, desserts and sauces, which require ingredients with greater water solubility.

Table 4 shows the total anthocyanins values of fresh seriguela pulp and powders obtained by lyophilization, spray dryer and foam-mat drying.

Table 4. Total anthocyanins content of powdered seriguela obtained by different drying methods

Method	Total anthocyanins (mg/100g)
Fresh pulp	3.91 ± 0.02
Lyophilization	3.10 ± 0.10 ^{A}
Spray dryer	1.04 ± 0.04 ^{C}
Foam mat	2.31 ± 0.02 ^{B}

Note: Equal letters in the same column do not differ significantly from each other by Tukey's test at the 5% level.

The fresh seriguela pulp presented 3.91 mg/100g of anthocyanins, however, the drying process promoted degradation of these in up to 73.40%. It is observed that the powders obtained by lyophilization ensured a greater preservation compared to the other applied techniques and those obtained by spray dryer showed lower values as a function of the higher drying temperature. The values obtained for the powders ranged from 1.04 to 3.10 g/100g and were significantly different from each other ($p<0.05$).

The color of a food is an important factor in consumer choice. In the case of fruit pulp powders, the stability of anthocyanins as natural dyes associated with their antioxidant properties has been studied, resulting in a final product with added value to its image, in addition to its functional properties presenting beneficial characteristics for the health of the consumer. As they have a protective capacity against oxidative stress, acting in the prevention and/or reduction of the risk of developing heart diseases, some types of carcinomas and other diseases, and also, in addition to their ability to inactivate free radicals (BRAMONT et al., 2018).

Conclusion

From our results it can be concluded that:

The three drying techniques applied were effective in reducing water content and water activity to safe levels for longer product shelf life.

The apparent density values were lower than those of the compacted density and showed a strong correlation with the water content of the seriguela powder.

The water absorption capacity and the water solubility indicated that the powdered seriguela obtained can be a desirable ingredient for the elaboration of new products.

Finally, the lyophilization method ensured lower degradation of total anthocyanins content.

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INFLUENCE OF DRYING TEMPERATURE ON THE PHYSICAL-CHEMICAL PROPERTIES OF SWEET POTATO POWDER OBTAINED BY DRYING IN A SPOUT BED

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Introduction

The sweet potato (*Ipomoea batatas* L.) is one of the most popular and important vegetables in the world. It has a relatively low production cost and high return, being the raw material for obtaining alcohol, starch, breads, sweets, flours, flakes and starches (SANTOS et al., 2009; FERREIRA et al., 2019).

Sweet potato has medicinal benefits such as balancing the body's acid-base balance, preventing cancer, and reducing how it maintains blood (RASHID et al., 2022). This type of tuber has become the focus of research due to a diverse claim of nutritional and health-promoting values, suitable for the human diet and animal feed. Furthermore, the accessibility, abundance, good source of carbohydrates and the significant use of their by-products in food processing and industrial applications place them as an important product in the food industry supply chain (SANCHEZ et al., 2020). As it is a seasonal crop that must be used within a specific period after harvest, it has a short storage period with high moisture content that stimulates microbial activity, leading to spoilage (RASHID et al., 2022).

Due to the high perishability of this type of tuber, some type of processing must be used so that it has a longer shelf life. One of the ways to minimize the loss of perishable foods is through drying them (SILVA et al., 2019). Drying is the most common and widely applied preservation method to produce dried fruits and vegetables. This is because it slows down its deterioration due to microbial activity, removing water from it without causing significant physical, nutritional and sensory loss if drying is carried out under appropriate operating conditions (VELOSO et al., 2020).

And spouted bed drying with inert particles is considered a flexible alternative drying technique for the production of powders from liquid and pasty foods, due to its lower costs and lower temperature requirements when compared to the popular dryer. of spray (DANTAS et al., 2017).

However, according to Brito et al. (2018), the spouted bed also provides high heat and mass transfer rates, due to the high degree of mixing between the phases and the high solid recirculation rate.

In this context, the present work aims to obtain sweet potato flour through the process of spray drying, in a spouted bed and to evaluate the effect of the temperatures used on its physicochemical properties.

Methodology

Raw material and hygiene

The sweet potato (*Ipomoea batatas* L.) was purchased at the open-air market in the city of Campina Grande-PB. In the laboratory, they were selected manually, in order to eliminate roots at an advanced stage of maturation and physical damage; then they were washed in running water and then sanitized by immersing them in a container containing a sodium hypochlorite solution with a concentration of 200 ppm for 15 min, and finally rinsed in running water to remove the excess of the hypochlorite solution.

Figure 1. Sweet Potato (Ipomoea batatas (L.) Lam.). Fonte: https://revistacampoenegocios.com.br/batata-doce-cultivo- produtividade-e-rentabilidade/.

Bleaching

After sanitizing the sweet potatoes with skins, they were cut into undefined geometries with the aid of a domestic knife and were subjected to the steam blanching process, followed by cooling to avoid excess heat.

Obtaining the extract

To obtain the extract, the sweet potatoes already cut and blanched were crushed in a domestic blender®, the separation of solid residues from the liquid was done using a domestic sieve and then passing the mixture through an organza mesh.

Spouted bed drying

To dry the extract, a spouted bed was used with a temperature varying between 60, 70 and 80°C, air flow in the atomizer nozzle of 3.0 m^3/min and pump feed flow of 2.7 ml/min.

Physicochemical characterization

The *in natura* sweet potato and the flours obtained were characterized in terms of the following physicochemical parameters:

Moisture by oven drying at 105°C to constant weight; total solids by difference (100- moisture) (BRASIL, 2008);

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

Ash by incineration in a muffle furnace at 550°C (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);

pH with direct reading on the digital pH meter (BRASIL, 2008);

Total titratable acidity (TTA) determined by titration, total soluble solids (SST) by direct reading in a refractometer and ratio (SST/ATT) according to Brasil (2008);

Lipids by the modified method of Blig and Dyer (1959);

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

Statistical analysis

Statistical analyzes were performed for the experimental data in triplicate and the results were submitted to single-factor analysis of variance (ANOVA) of 5% probability and the significant qualitative responses were submitted to the Tukey test adopting the same level of 5% of significance. For the development of statistical analyses, the ASSISTAT software version 7.0 was used.

Results

Table 1 shows the data obtained for the physicochemical characterization of fresh sweet potato and flour obtained at temperatures of 60, 70 and 80°C.

Table 1. Physicochemical characterization of *in natura* sweet potato and flours obtained

Parameters	**Treatments**				**CV (%)**
	in natura	**60°C**	**70°C**	**80°C**	
Moisture (%)	69.48a	6.34b	5.68b	4.48c	2.12
Total solids (%)	30.52c	93.66b	94.32b	95.52a	0.58
Water activity (a_w)	0.995a	0.181b	0.153c	0.140d	0.85
Ash (%)	0.98d	1.23c	1.44b	1.78a	2.92
Lipids (%)	0.26a	0.40a	0.38a	0.45a	3.62
Proteins (%)	1.17a	0.98b	0.83bc	0.68c	6.61
Carbohydrates (%)	28.11c	91.05b	91.67ab	92.61a	0.60
pH	6.17b	6.25b	6.48a	6.54a	1.27
ATT	1.18a	0.98b	0.85c	0.78c	3.82
OSH	10d	21c	24b	27th	2.42
Ratio (SST/ATT)	8.47d	21.43c	28.23b	34.61a	4.16

Note : Equal lowercase letters superscripted in the same column do not differ significantly in the storage time studied when Tukey 's is applied at the 5% probability level; ATT- total titratable acidity; TSS – total soluble solids; CV – coefficient of variation. Source: Own (2020).

In natura sweet potato had a high moisture content of 69.48%. However, the value found for both flours is within the maximum value stipulated by legislation (BRASIL, 2005) for flour, which is 15%.

Statistically, the flours obtained at 60 and 70°C did not differ significantly from each other, in which there was a reduction in the moisture content of 65% between the in natura sample and the flour obtained at 80°C. Silva et al. (2017), when applying the convective drying process to peeled beet slices at temperatures of 50, 60 and 70°C, obtained moisture values of 11.1, 9.87 and 8.42%, respectively.

It was found that the amount of total solids was higher when higher temperatures were used, with 95.52% at 80°C. Such growth is caused by the reduction in the water content, however, statistically, the flours obtained at 60 and 70°C did not differ significantly from each other.

In relation to water activity (a_w) the sweet potato in natura showed a high value (0.995). According to Almeida et al. (2020) high values of moisture content associated with high levels of water activity (aw) directly affect the stability of the product, allowing the occurrence of contamination processes.

The flours obtained showed reduced values of this parameter, being less than 0.2 and statistically differing between the temperatures applied. Castro et al. (2017) when determining the water activity (aw) in taro flour obtained in a spouted bed at temperatures of 70, 80 and 90°C, obtained values of 0.16, 0.15 and 0.10, respectively.

An increase in ash content was observed when the drying temperature was increased, with the highest value of 1.78% for a temperature of 80°C. However, statistically the flours obtained showed significant differences between the temperatures applied with a coefficient of variation of 2.92%. Values higher than those of the present study were obtained by Basetto et al. (2011) when using a temperature of 100°C to obtain beet flour, which had an ash content of 6.71%.

For the lipid content, no statistically significant difference was observed, with the highest value being 0.45% obtained at a temperature of 80°C. Sá et al. (2018) when determining the lipid content in yam and taro flours obtained by convective drying at a temperature of 60°C, obtained values of 0.08 and 0.10%, respectively.

According to Santos et al. (2020) the determination of lipids becomes important, as lipids play an important role in food quality, contributing attributes such as texture, flavor and caloric value.

There was a degradation in the protein content with increasing drying temperature. The protein content of the flour obtained at 70°C showed no statistically significant difference in relation to the flours obtained at 60 and 80°C. Higher values of this parameter were observed by Garmun et al. (2009) when analyzing flours obtained from potato skins (2.5%).

The results obtained in relation to the total carbohydrate content were 91.05, 91.67 and 92.61% for temperatures of 60, 70 and 80°C, respectively. Presenting a statistically significant difference between temperatures of 60 and 80°C. These high values obtained according to Santos et al. (2020) are related to the total fiber content, as the fiber content is included in the analysis of total carbohydrates, showing that sweet potato flour is a powder with a high fiber content.

It can also be seen in Table 1 the values obtained for the parameters of pH and total titratable acidity (TTA), in which there was an increase in pH (6.0 < pH < 7.0) and a reduction in acidity values of the flours obtained. For these two parameters, the temperatures of 70 and 80°C did not show significant statistical differences. Sá et al. (2018) observed pH values of 5.59 for yam flour and 6.06 for taro flour. Araújo et al. (2015), when characterizing sweet potato flour, observed acidity values ranging between 0.64 and 0.52%.

The total soluble solids (TSS) content showed statistically significant differences between the applied temperatures. There is an increase in the values of this parameter with the increase of the drying temperature. The flour obtained at 80°C had the highest content (27 °Brix). According to Lins et al. (2016), this increase occurs due to the decrease in the water content in the medium, caused by an increase in the precipitation of compounds that were originally in solution.

According to Chaves et al. (2004) and Araújo et al. (2017) the quality of the final product in the agroindustry is related to the content of total soluble solids (TSS), since products with high concentration imply less addition of sugar to obtain the final product.

The ratio of total soluble solids and total titratable acidity (SST/ATT) also showed an increase in their values with increasing drying temperature. This increase was due to the increase in the levels of total soluble solids and the reduction in the values of total titratable acidity. Statistically, the values showed significant differences between them.

Conclusion

From our results, it can be concluded that:

Drying made it possible to reduce the moisture content and water activity of fresh sweet potato, ensuring a longer shelf life of the product. In addition to presenting ease of handling and storage, since the shelf life of the powdered product is longer compared to the in natura product.

There were statistically significant differences between the temperatures used in relation to the physicochemical parameters.

The temperature of 80°C allowed the highest value of total soluble solids, ratio (SST/ATT) and total carbohydrates, evidencing the technological potential of the powdered product.

As suggestions for future work, fiber and starch analysis can be performed as well as all parameters analyzed during storage for 180 days. As well as applying the flour obtained in the development of a bakery product.

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DRYING BEET SLICES: INFLUENCE OF SLICE THICKNESS ON KINETICS AND ADJUSTMENT OF EMPIRICAL AND DIFFUSION MATHEMATICAL MODELS

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Introduction

One of the most frequently cultivated plants used in the sugar industry is the sugar beet. Sugar production from beetroot is the second largest in the world after sugarcane production. The Food and Agriculture Organization of the United Nations (FAO) reported that world beet production exceeded 2772 million tonnes in 2016 (FAOSTAT, 2019). The largest amount of beet is produced in Europe, then in Asia and North America (PATHAK et al., 2014; BORYSIUK et al., 2019).

As a by-product of the sugar refining industry, beet pulp is generally used for feed formulation, with little commercial value. Meanwhile, the process often generates an environmental problem; therefore, several attempts were used to make the best use of these by-products (CHEN, FU & LUO, 2015; HUANG, LI & WANG, 2017).

Drying is one of the most common and ancient ways of preserving food. The main objective of this technique is to remove water from the solids to a certain level, at which the chemical reactions of spoilage and microbial spoilage are greatly minimized. Other important goals of food dehydration are weight and volume reduction, aimed at lowering transportation and storage costs.

The wide variety of dehydrated foods currently available to the consumer, and the interesting concern to meet quality and energy conservation specifications, emphasize the need for a detailed understanding of the drying process (KROKIDA et al., 2003; VEJA et al., 2007).

Recently, vegetable drying is of particular interest because it is added to various ready-to-eat meals in order to improve their nutritional quality due to the health-beneficial compounds present in vegetables (vitamins, phytochemicals, dietary fiber) (KUNZEK & VETTER, 1999). Usually, vegetables are convectively dried using hot air as a means to heat and remove the evaporated water in this complex phenomenon of heat transfer and coupled mass (LÓPEZ, De ITA & VACA, 2009).

The most important aspect of drying technology is the mathematical modeling of drying processes and equipment. Its objective is to allow engineers to choose the most suitable operating condition and dimension the drying equipment and drying chamber according to the desired operating conditions (KALETA & GÓRNICKI, 2010). Drying rates must be related for a given product and for a given operation (process and equipment), and can be established through heat and mass transfer studies, in addition to possible mechanisms of internal moisture migration. However, heat and mass transfer equations demand considerable knowledge of numerical calculus for their analytical solution (VILHALVA et al., 2012).

Therefore, the present work aims to evaluate the influence of thickness on the drying kinetics of beet slices and to adjust mathematical models (empirical and diffusive) to the experimental data.

Methodology

The beetroot slices were purchased at the open-air market in the city of Campina Grande-PB. In the laboratory, they were manually selected in order to eliminate samples at an advanced stage of maturation and physical damage; then, they were washed in running water and sanitized by immersion in a container containing sodium hypochlorite solution at a concentration of 200 ppm for 15 min, and finally rinsed in running water to remove excess hypochlorite solution.

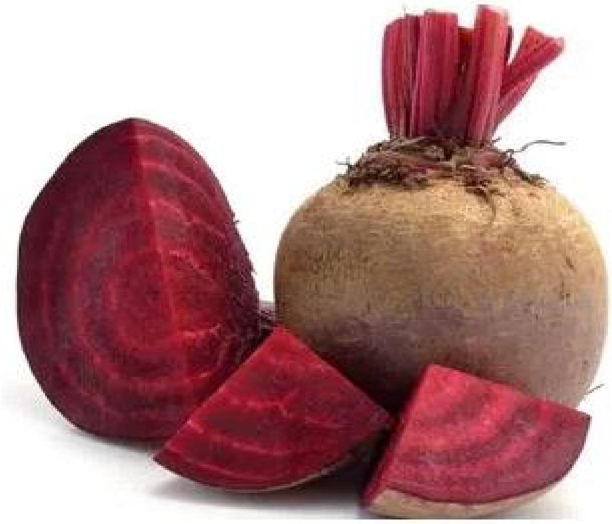

Figure 1. Beet (*Beta vulgaris* L.). Fonte: https://www.clubeorganico.com/.

Drying kinetics

The drying kinetics was carried out in an air circulation oven with an air speed of 1.5 ms^{-1} , at a temperature of 60ºC, in which the beet slices with different thicknesses (4, 6 and 8mm) were uniformly distributed in trays. The experimental data were expressed in terms of water content ratio (X^*), given by the relationship between differences in water content over time, t, and equilibrium water content (X(t) – X_{eq}) and initial and balance ($X_i - X_{eq}$). As described in Equation (1).

$$X^*(t) = \frac{X(t) - X_{eq}}{X_i - X_{eq}} \qquad \text{(Eq.1)}$$

Where: X^*= water content ratio (dimensionless); X_{eq}= equilibrium water content (dry basis); X(t) = water content (dry basis); X_i= initial water content (dry basis).

Empirical models

The three empirical functions *f* (t,a,b) presented in Table 1, were fitted to the experimental data sets, using nonlinear regression through the Curve Fitting Software LAB Fit (SILVA & SILVA, 2008). The results of the empirical models were evaluated using the chi-square χ^2 statistical indicators (Equation 5) and the coefficient of determination, R^2.

Table 1. Empirical models fitted to experimental data of drying kinetics of beet slices

Models	**Equation**	
Lewis	$X^* = e^{-at}$	(2)
Page	$X^* = e^{-at^b}$	(3)
Handerson and Pabis	$X^* = ae^{-bt}$	(4)

$$\chi^2 = \frac{\sum_{i=1}^{N} \left(X^*_{\exp,i} - X^*_{pre,i}\right)^2}{N - n} \qquad \text{(Eq.5)}$$

Where, χ^2: is the chi-square function; $X^*_{exp,i}$: is the experimental humidity ratio; $X^*_{pre,i}$: is the moisture ratio predicted by the model; N: is the number of experimental data; en: is the number of coefficients and constants in the model.

Diffusion model

Analytical solution of the diffusion equation

The average moisture content of the solid with infinite wall geometry at time t is given by (LUIVOK, 1968), disregarding the volumetric shrinkage.

$$X^*(t) = \sum_{n=1}^{16} B_n \exp\left(-\mu_n^2 \frac{Def}{(L/2)^2} t\right) \qquad \text{(Eq.5)}$$

Where: $X^*(t)$is the moisture ratio at time t; L is the thickness; *Def* is the diffusivity; t is the time.

The parameters of Equation 6 were obtained through Equations 6, 7 and 8.

$$B_n = \frac{2Bi^2}{\mu_n^2\left(Bi^2 + Bi + \mu_n^2\right)} \qquad \text{(Eq.6)}$$

$$Bi = \frac{h(L/2)}{Def} \qquad \text{(Eq.7)}$$

Where: h is the convective heat transfer coefficient; Bi is the Biot number.

$$\cot\mu = \frac{\mu}{Bi} \qquad \text{(Eq.8)}$$

Where, Equation 8 is characteristic for the infinite wall. To obtain the analytical solution of the diffusion equation, the process optimization was performed according to the methodologies proposed by Silva et al. (2010).

Results

In Table 2, it is possible to observe the values obtained for the parameters of the mathematical equations of Lewis, Page and Handerson and Pabis adjusted to the experimental data, as well as the values of the statistical parameters, coefficient of determination (R^2) and chi-square function (χ^2).

It was observed that the parameter “*a*” of the empirical equations of Lewis and Page showed a tendency to decrease with increasing thickness of the slices, however, this same behavior was not observed for the model of Handerson and Pabis.

The parameter "*b*" of the Page model showed a tendency to increase with the increase in the thickness of the slices. In the Handerson and Pabis model, this same parameter showed an inverse behavior, that is, it reduced with increasing slice thickness. According to Moreira et al. (2018) parameter "*b*" is a proportionality constant between the drying rate and the moisture ratio.

Table 2. Parameters obtained by fitting the models to the experimental data of drying kinetics of beet slices at different thicknesses at a temperature of 60°C

Model	**Thickness (mm)**	**parameters**		**R^2**	χ^2
		The	***B***		
Lewis	4	1.355×10^{-2}	-	0.9949	0.003010
	6	0.826×10^{-2}	-	0.9962	0.025709
	8	0.723×10^{-2}	-	0.9952	0.043990
Page	4	1.076×10^{-2}	1.056	0.9994	0.001525
	6	0.301×10^{-2}	1.219	0.9991	0.001704
	8	0.169×10^{-2}	1.307	0.9995	0.002353
Handerson and Pabis	4	1.012	1.383×10^{-2}	0.9991	0.002485
	6	1.042	0.882×10^{-2}	0.9959	0.017690
	8	1.065	0.800×10^{-2}	0.9959	0.022691

It can be seen in Table 2 that the three empirical mathematical models showed a coefficient of determination (R^2) greater than 0.99 for the three thicknesses. But the evaluation of only a single statistical parameter is not a good criterion for selecting nonlinear models.

Therefore, it is necessary to analyze other parameters such as the chi-square function, which presented low values for the three adjusted models, however, for the three thicknesses, Page's model was the one that presented the lowest observer values ranging from 0.001525 a 0.002353 being considered as the best fit model. Because, in addition to presenting $R^2 > 0.99$ and low values of the chi-square function, it also presents simplicity in its equation.

Moreira et al. (2018) when performing the drying kinetics of kiwi slices at different thicknesses (5, 10 and 15mm) at temperatures of 50, 60, 70 and 80°C, also determined that the mathematical model of Page was the one that best performed. fitted to the experimental data.

As the Page model was considered the best fit in Figure 1, there are graphs for each thickness of the beet slices, observing that longer processing times (990 min) were required for the thickest slices (8mm) and consequently, shorter times (570 min) for the thinner slices (4mm).

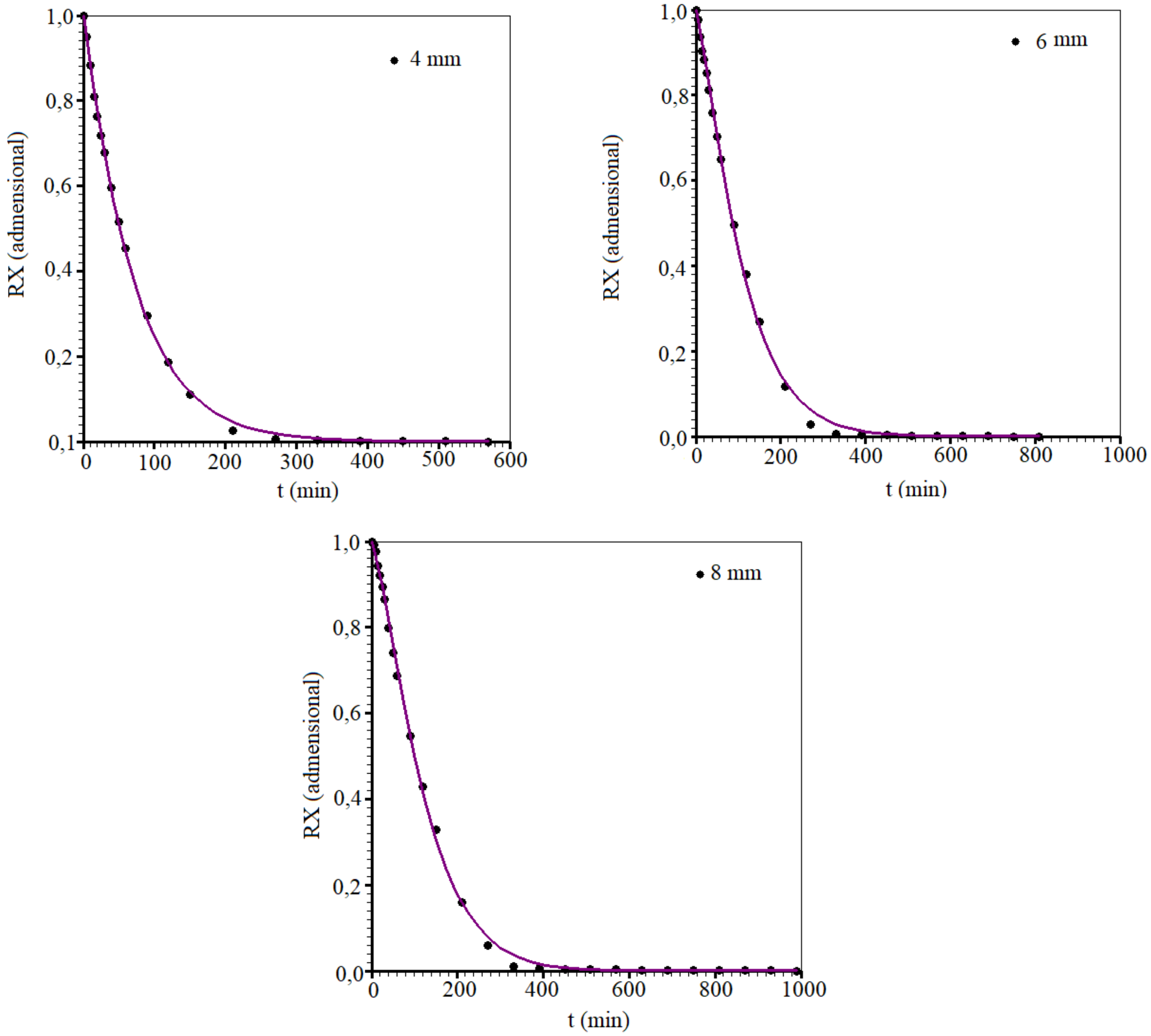

Figure 1. Adjustment of Page's mathematical model to experimental data of drying kinetics of beet slices at different thicknesses at a temperature of 60°C.

It can be seen from Figure 1 that the greater slopes of the curves during the initial moments of the drying process indicate greater temperature gradients between the drying air and the product. Therefore, according to Santos et al. (2020) it can be observed that the greatest moisture losses are verified in the initial moments of the process, which tends to decrease until the product presents equilibrium moisture.

In Table 3, it is possible to observe the values obtained by the analytical solution of the diffusion equation with infinite wall geometry and boundary condition of the third type for the drying kinetics of beet slices in different thicknesses at a temperature of 60°C.

Table 3. Parameters obtained by the analytical solution of the diffusion equation

Thickness (mm)	**Def x 10^{-5} ($m^2.min^{-1}$)**	**hx 10^{-5} ($m.min^{-1}$)**	***Bi* x 10^{-3}**	**R^2**	χ^2
4	3.31	2.74	1.75	0.9991	0.002450
6	5.48	2.89	1.50	0.9965	0.015746
8	8.51	3.19	1.50	0.9974	0.022927

Source: Own (2020).

An increase in the diffusivity values was observed when the slice thickness was increased, ranging from 3.31 to 8.51 x 10^{-5} $m^2.min^{-1}$. Values close to those of the present study were obtained by Santos et al. (2019a) who obtained diffusivity values ranging from 3.28 to 5.53 x 10^{-11} ($m^2.s^{-1}$) for drying acuri slices with a thickness of approximately 4.07mm at temperatures of 60, 70, 80 and 90°C. According to Sousa et al. (2017) there is a trend of increasing effective diffusivity with increasing thickness, directly influencing the removal of water from the product.

Regarding the convective heat transfer coefficient (*h*) there was also an increase in its values when the slice thickness was increased, ranging from 2.74 to 3.19 x 10^{-5} ($m.min^{-1}$). Santos et al. (2019b) when performing the drying kinetics of peach slices at temperatures of 50, 60 and 70°C obtained values ranging from 1.51 to 1.79 x 10^{-6} ($m.min^{-1}$).

Low values were obtained for the Biot number, not showing a direct relationship with the increase in thickness. Low values of the Biot number were also observed by Moreira et al. (2018) ranging from 1.25 to 1.75 x 10^{-3} for drying kiwi slices in different thicknesses (5; 10 and 15mm). According to Silva et al. (2012), for such a low Biot number, the infinite series representing the solution of the diffusion equation can be represented only by its first term, with insignificant truncation error.

In Figure 2, one can observe the moisture distribution inside the beet slices in their different thicknesses (4, 6 and 8mm) at a temperature of 60°C and a time of 200 minutes.

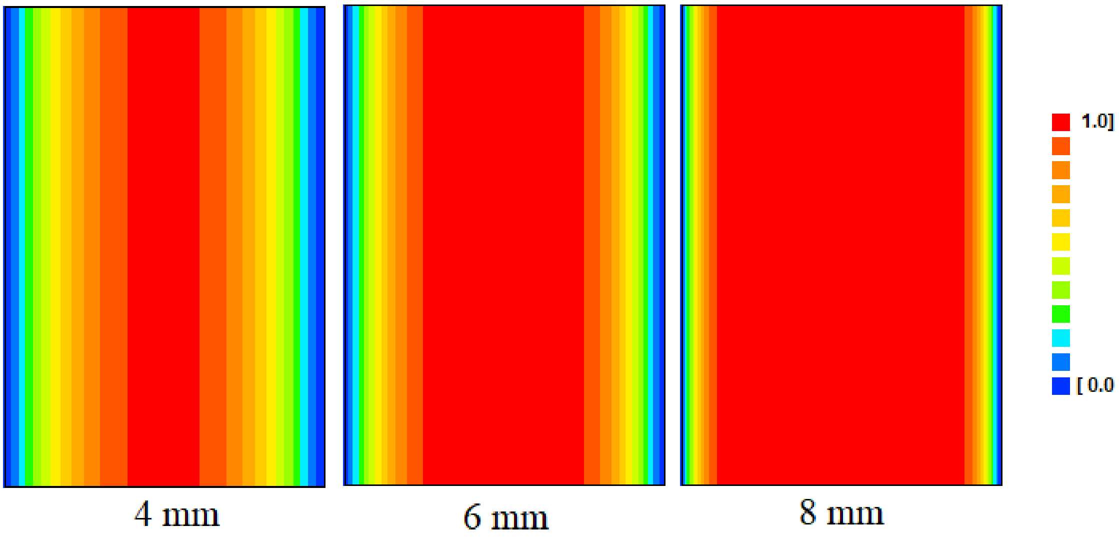

Figure 2. Moisture distribution inside the beet slices at a temperature of 60°C in their different thicknesses in a time of 200 min.

Figure 2 shows the existing moisture gradients inside the beet slices during the drying process, in which the moisture loss of the product occurs mainly from the outside to the inside of the product. And that for the same time interval analyzed (200 min) when there was an increase in the thickness of the smaller slices, there were variations in the humidity gradients inside.

Conclusion

Based on our results, it can be concluded that:

All mathematical models analyzed showed satisfactory adjustment to the experimental data obtained.

Page's model presented a superior fit when compared to the others, as it presents higher values of R^2 and lower values of the chi - square function.

The analytical solution of the diffusion equation with infinite wall geometry showed an increase in the diffusivity and in the convective heat transfer coefficient, with an increase in the thickness of the slices and the low values of the number of biot.

The boundary condition used (third type) satisfactorily described the process.

The increase in the thickness of the slices promoted smaller variations of humidity inside the slices over time.

As suggestions for future work, new drying kinetics of beetroot slices can be performed at different temperatures, as well as the evaluation of the influence of drying on the instrumental texture profile of the slices.

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DETERMINATION OF TEXTURE AND MICROBIOLOGICAL EVALUATION OF COALHO CHEESES SOLD AT THE OPEN FAIR

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Introduction

Coalho cheese is one of the best known traditional Brazilian cheeses. It was introduced by countries in Europe, and is produced in the Northeast region, especially in the states of Ceará, Pernambuco, Rio Grande do Norte and Paraíba, for over 150 years. It is one of many traditional cheese varieties that have socioeconomic and nutritional importance for the region due to its commercialization and consumption (FONTENELE et al., 2017).

Its production and commercialization are the main source of income for many local families, and although coalho cheese has been produced for over 100 years, the manufacturing process is not standardized, leading to changes in physical-chemical, technological and property aspects sensory. Presenting a high humidity which enables the development of microorganisms (SOARES et al., 2017).

The main raw material used for the production of cheese is raw milk, most of which are produced on the dairy farms themselves and are generally very manipulated products, for these reasons, they are susceptible to contamination, especially of microbiological origin (PINTO et al., 2009; KIM et al., 2018).

The presence of pathogens in dairy products has become a major public health concern. The consumption of contaminated cheese can cause various diseases, from zoonoses (brucellosis, tuberculosis) to food poisoning. Cheeses made from raw milk, or produced under unsatisfactory hygienic conditions, can become unfit for consumption (COSTA SOBRINHO et al., 2012; LEITE, 2012).

The texture of cheeses is influenced by the initial chemical composition of the cheese and the processing conditions used during manufacture. However, it is important to have an adequate control of the parameters that affect the texture, because in addition to directly influencing the quality and consumer satisfaction, it becomes capable of producing from softer to harder cheeses with different types of consumption and consumer markets (REN et al., 2013; SILVA et al., 2019).

The determination of the texture profile 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 the food together with appearance and taste (ALCÂNTARA et al., 2019).

In view of the above and taking into account the food risks and aspects of consumer acceptance, the present work aims to evaluate the instrumental texture profile and microbiological quality of coalho cheeses marketed in the city of Garanhuns-PE, thus verifying if the products comply with the parameters required by current legislation.

Methodology

Six samples (1, 2, 3, 4, 5 and 6) of coalho cheese purchased from different retailers at the open-air market in the municipality of Garanhuns located in the Pernambuco country side were analyzed. The samples were collected as a consumer and, immediately after acquisition, were identified, packed in a thermal box and refrigerated for the performance of texture and microbiological analyses.

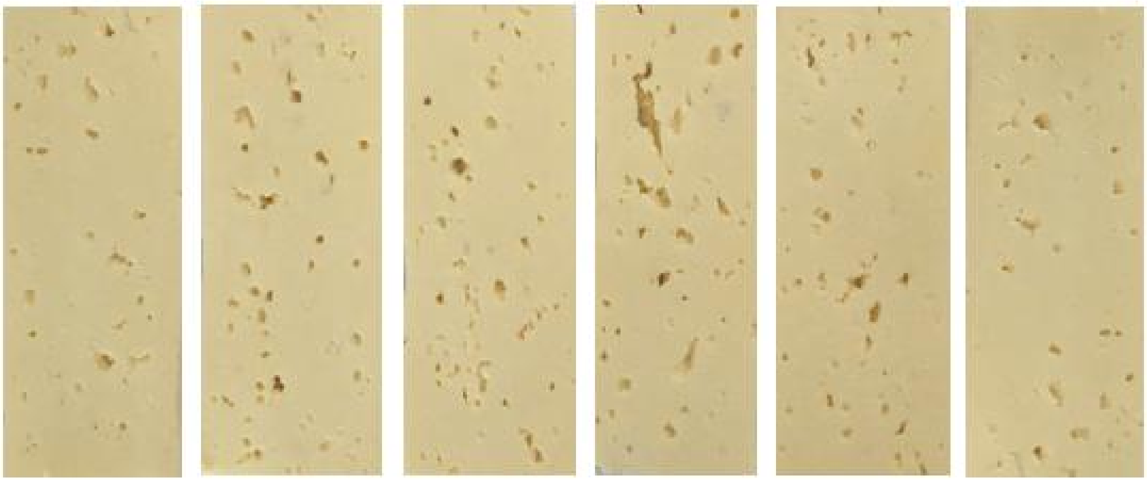


Figure 1. Coalho used in the samples.

Texture instrumental profile

To obtain the parameters of the instrumental texture profiles of the different cheese curds, 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 probe, pre-test 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 attributes studied were firmness, cohesiveness, adhesiveness and gumminess.

Microbiological analysis

For microbiological evaluation, a 25 g portion of each hot dog was homogenized in 225 g of saline solution. From this initial dilution, serial dilutions were prepared using the same diluent. The determination of coliforms at 35°C (total) was performed by determining the most probable number (MPN) of coliforms, using the culture medium lactosado broth green bile bright 2% through the multiple tube technique. For the confirmation of E. coli, the culture medium Agar BEM was used, the plates were inoculated from the positive tubes of EC broth in an oven at 35ºC for 24 hours.

For *Staphylococcus* analysis, 0.1 mL aliquots were transferred to Petri dishes containing Mannitol agar for surface seeding. After sowing, the plates were incubated at 36 ± 1°C for 48 h.

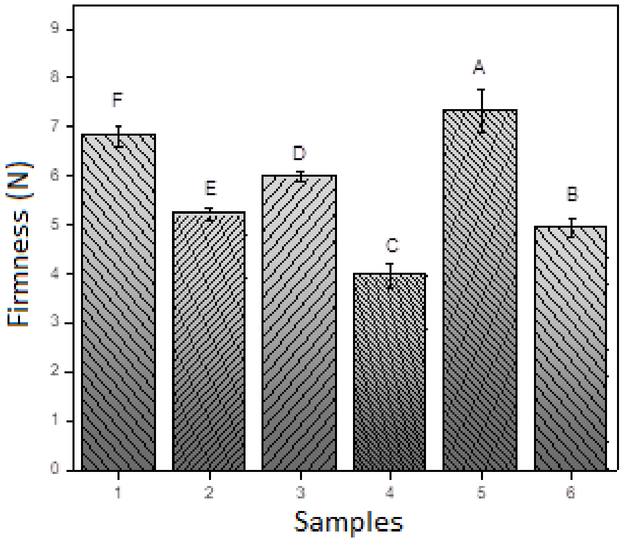
In the verification of *salmonella spp*, a portion of 25g of the sample was contained in the saline peptone water and incubated at 35°C for 24 hours. After incubation, 0.1 mL aliquots of the samples in saline solution were transferred to a Petri dish and incubated at 35°C for a period of 24 hours.

Statistical analysis

Statistical analysis was performed for experimental data in triplicate and the results were submitted to single-factor analysis of variance (ANOVA) of 5% probability and significant qualitative responses were submitted to Tukey's test adopting the same level of 5% of significance. For the development of statistical analyses, the STATISTICA software version 7.0 was used.

Results

In Figure 1, the results obtained for the firmness of the different curt cheeses sold in open markets are presented.

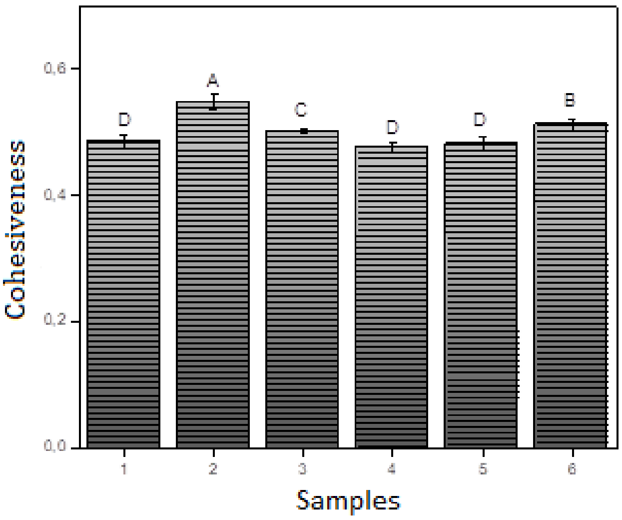


Note: Equal letters do not differ significantly from each other at the 5% probability level.

Figure 1. Firmness of the different coalho cheese sold in open markets.

Regarding the firmness parameter, it is observed that all analyzed samples presented statistically significant differences. In sample 5, it was necessary to apply a greater force of 7.34N. Shabbir et al. (2019) when making goat's milk cheese with different concentrations of commercial yogurt as a starter culture, they obtained firmness values ranging from 2.10 to 3.00 N. For Almeida et al. (2020) firmness is the force required to achieve a given deformation in the food. Texture analysis is an important issue in the food industry in controlling the manufacturing process, raw materials, final product and research for the development of new products (CARNEIRO et al., 2011).

Figure 2 shows the results obtained for the cohesiveness of the different coalho cheeses sold at the open-air market.



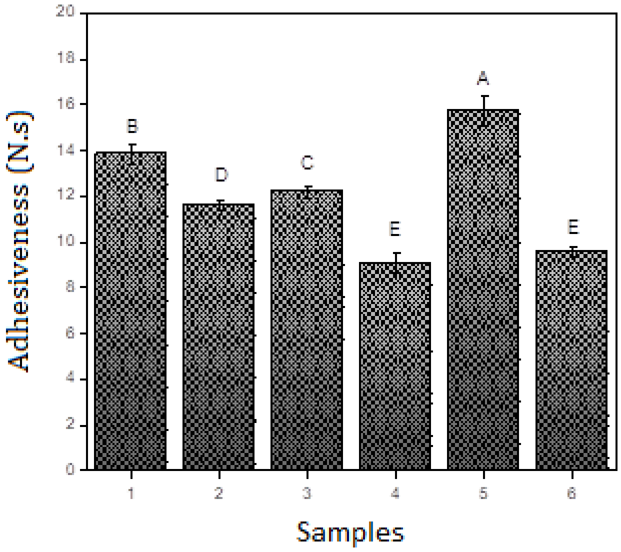
Note: Equal letters do not differ significantly from each other at the 5% probability level.

Figure 2. Cohesiveness of the different coalho cheese sold at an open-air market.

Cohesiveness values ranged from 0.481 to 0.547. However, the highest value was obtained for sample 2. Statistically, samples 1, 4 and 5 did not present significant differences at the 5% probability level. Maruyama et al. (2006), when evaluating the instrumental texture profile of potentially probiotic cheese petit-suisse, obtained cohesiveness values ranging from 0.340 to 0.593 between the formulations prepared.

According to Atallah and Morsy (2017) and Barros et al. (2020), this parameter is often discussed in terms of adhesion forces and is responsible for the deformation that occurs in the material before failure, indicating its structural integrity. For Mantovani et al. (2012) cohesiveness allows evaluating the product's resistance to dissolving during the tasting of the taster.

In Figure 3, the results obtained for the adhesiveness of the different coalho cheeses sold in open markets are presented.

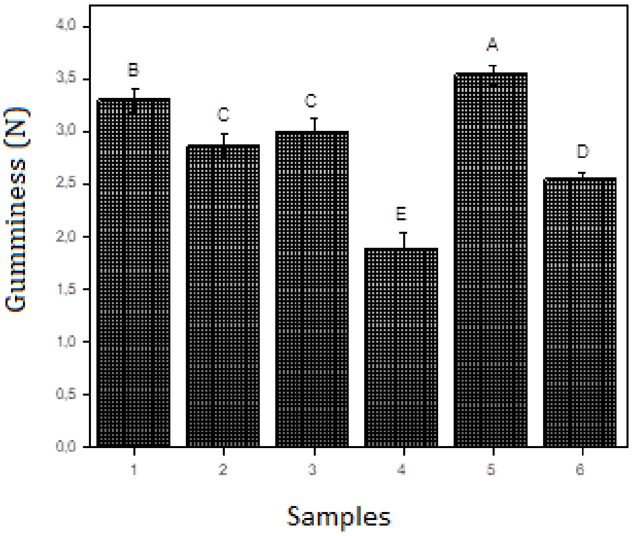


Note: Equal letters do not differ significantly from each other at the 5% probability level.

Figure 3. Adhesiveness of the different coalho cheese sold in open markets.

The adhesiveness of the coalho cheese samples was higher for sample 5, which presented a value of 15.75 N.s. Buriti et al. (2008) when developing and evaluating the instrumental texture profile of a fresh cream cheese, obtained adhesiveness values ranging from 10.23 to 21.16 N.s during 21 storage for the symbiotic formulation.

In Figure 4, the results obtained for the gumminess of the different coalho cheeses sold in the open market are presented.



Note: Equal letters do not differ significantly from each other at the 5% probability level.

Figure 4. Gumminess of the different coalho cheese sold in open markets.

The gumminess ranged from 1.88 to 3.53 (N), however, samples 2 and 3 did not differ statistically from each other at the 5% probability level. According to Bolzan and Pereira (2017) and Alcântara et al. (2020), gumminess is a secondary parameter, associated with firmness and cohesiveness and its variation is a reflection of these

The result of the microbiological evaluation of the coalho cheeses (Table 1) were analyzed based on RDC n. 12, of January 2, 2001, which provides for acceptable levels of microorganisms for confectionery, snack bars, bakeries and similar products, sweet and savory – ready for consumption, from the National Health Surveillance Agency (ANVISA).

Table 1**.** Microbiological evaluation of coalho cheese sold in open markets

Microorganisms	**Samples**					
	1	**2**	**3**	**4**	**5**	**6**
Total Coliforms (MPN/g)	28	1.5×10^2	$>1.1 \times 10^3$	$>1.1 \times 10^3$	4.6×10^2	2.4×10^2
Thermotolerant Coliforms (MPN/g)	7.4	28	35	11	36	2.4×10^2
E. *coli*	Absence	Absence	Absence	Presence	Absence	Absence
staphylococcus (CFU/g)	2.0×10^2	3.2×10^3	6.9×10^4	4.5×10^5	5.6×10^2	4.8×10^2
Salmonella sp.	Absence	Absence	Absence	Presence	Presence	Absence

NMP- Most Likely Number; UFC – Colony Forming Units.

As shown in Table 2, all samples showed growth for total coliforms, with sample "E" as the highest Most Probable Number of this microorganism, but the current legislation does not indicate tolerant limits for cheeses. However, for the group of thermotolerant coliforms, the legislation establishes a maximum value of 5 x 103 NMP/g, therefore, all analyzed samples are in accordance with the legislation regarding this parameter.

According to Santos et al. (2018), the high number of coliforms may not mean direct contamination with fecal material, but rather inadequate handling, such as handler hygiene, inadequate transport and packaging.

According to Tronco (2003), *Escherichia coli* belongs to the coliform group and with rare exceptions, this bacterium is destroyed by the pasteurization of milk. Its presence in the final product can cause a series of technological problems such as undesirable fermentation, acidification and stewing.

The tests for confirmation of E. coli, only the sample (4) showed the presence of this contaminant of fecal origin, which is in disagreement with the current legislation that establishes its absence. Silva et al. (2008), who analyzed the sanitary quality of Prato cheese sold in the city of Recife, observed that of the 16 samples analyzed, 18.75% were positive for E. coli, and 56.25% of the samples were outside the standards legal toilets.

Borges et al. (2003), when evaluating the microbiological quality of curt cheeses sold in the state of Ceará, observed that among the 43 samples analyzed, all of them presented total coliforms and fecal coliforms, and the presence of E. coli was confirmed in 93% of the samples. Regarding fecal coliforms, they observed that 74.4% of the samples contained levels above the standards established by current legislation.

Alves et al. (2009) in their studies with coalho cheeses commercialized informally in the city of São Luíz - MA, found that among 30 samples analyzed, 20 are in disagreement with the microbiological standards in relation to the coliform parameter at 45°C and only 7 in disagreement for the Staphylococcus parameter.

In the quantification of Staphylococcus, RDC No. 12 of January 2, 2001 establishes a tolerance of 1 x 103 CFU/g among the analyzed samples, only samples 2, 3 and 4 presented higher values, thus not being in accordance with the standards established by the current legislation. Sousa et al. (2014), when quantifying *Stapylococus* in artisanal coalho cheeses sold in the northeast, found values from 2.5 to 25x105 CFU/g. In which 98.15% of the samples were outside the established standard.

In the determination of *Salmonella sp*. we obtained presence in 20% of the analyzed samples, being them 4 and 5. The current legislation establishes that the samples must present the absence of this microorganism. Food poisoning is usually caused by the consumption of contaminated food or water containing different bacteria, viruses, parasites or toxins of a biochemical or chemical nature, Salmonella sp. One of the main causes of food poisoning (PENTEADO & CASTRO, 2016).

Oliveira et al. (2010) when determining the presence of *Salmonella sp*. in curt cheeses sold in the municipality of Cabo de Santo Agostinho-PE, among the 42 samples analyzed, 4 of them showed the presence of this microorganism. Therefore, it was concluded that Most of the coalho cheeses sold in the Municipality of Cabo de Santo Agostinho, State of Pernambuco, Brazil, are in disagreement with the microbiological standards in force in Brazilian legislation, being considered unfit for human consumption.

Conclusion

Through the results, it can be achieved that:

In the commercialized coalho cheeses, only sample 5 presented the highest values of firmness, adhesiveness and gumminess, in addition, it also presented the highest growth for total coliforms. However, with regard to the group of coliforms, all thermotolerants are in accordance with the limit established for this parameter. With the presence of bacteria, sample (4) indicated the presence of E. coli and sample ratio 4 and 5 indicated the presence of Salmonella sp. Regarding the quantification of

Staphylococci, observed, observed, which samples 2 3 and 4 are not in accordance with the standard established by legislation. Thus, among them, only the 16 can be established according to the definition established in relation to the microbiological quality standards performed.

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PREPARATION OF SWEET MILK ADDED FROM WHEY

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Introduction

Brazil has great prominence in the production of dairy products, being considered as the sixth largest producer of cheese in the world. In the cheese production process, a large volume of effluents is generated, it is estimated that for the production of 1 kg of cheese, 10 L of milk are needed, resulting in the disposal of 8 to 9 L of whey (TEIXEIRA et al., 2019).

Whey, which is a dairy co-product extracted from the coagulation of milk in the cheese manufacturing process, has high nutritional value and therefore can be used as a raw material in the production process of other foods. However, several studies show that about 40% of the whey produced in Brazil is improperly disposed of, especially by small and medium-sized companies.

Resulting in an industrial waste toxic to nature and causing a high environmental impact, due to the damage to fauna and flora, due to its high biochemical oxygen decomposition (BOD) which is ten to 100 times greater than that of domestic sewage (NUNES et al., 2018).

Whey is composed of 93 to 94% water, 4.4 to 5.0% lactose, 0.7 to 0.9% soluble proteins and 0.6 to 1.0% mineral salts. In addition to having high nutritional value, whey has functional properties such as gel formation capacity, viscosity, emulsifying power, water retention capacity, and can then be used in the elaboration of various products such as dairy drinks, milk jams, mousses, breads, cakes etc. (MANTOVANI et al., 2015; SANTOS et al., 2017).

Dulce de leche is defined by the Regulation for fixing the identity and quality of dulce de leche, as the product is obtained through the concentration of milk or reconstituted milk subjected to heat, with or without the addition of other food substances, with or without addition of milk solids and/or sucrose added cream (BRASIL, 1997).

From non-enzymatic browning reactions, dulce de leche acquires characteristic color, consistency and flavor, having great acceptance among consumers. They are traditionally made in Latin America, where they are also consumed directly, as an accompaniment to bread, toast, or as an ingredient in the preparation of foods such as confectionery, cakes, cookies and ice cream (SANTOS et al., 2017).

In this context, the present study aimed to develop dulce de leche with the addition of whey from the manufacture of coalho cheese in the Cariri region of Paraíba, studying its feasibility and evaluating the influence of the percentage of whey used on the physical properties. final product chemicals.

In this context, the present study aimed to develop dulce de leche with the addition of whey from the manufacture of coalho cheese from the Cariri region of Paraíba, studying its feasibility and evaluating the influence of the percentage of whey used on the physicochemical properties of the final product.

Methodology

Feedstock

As raw materials were used crystal sugar, sodium bicarbonate acquired in the retail market in the city of Campina Grande-PB; milk and whey from the processing of coalho cheese were purchased from a small producer in the city of Lagoa Seca - PB.

Figure 1. Dulce de leche used in the samples.

Preparation of the candy

Four formulations of sweets were prepared varying the percentage of whey according to Table 1.

Table 1. Percentage of whey used in the formulations of elaborated sweets

Formulations	Serum percentage (%)
F1*	0
F2	20
F3	30
F4	40

Note: *Standard formulation

The percentages of sugar (1:1) and starch (2%) were calculated in relation to the mixture (milk + whey). Sodium bicarbonate (0.1%) was used to regulate the acidity of the mixture, which was placed in an open pan and kept under heating on a domestic stove until a soluble solids content of 52 °Brix was reached.

The mixture, after reaching the point, was cooled in a water bath to 70°C, then they were packaged and still warm in glass pots, previously sterilized in boiling water, being kept at room temperature.

Physicochemical characterization of sweets

The four different sweet formulations (F1, F2, F3 and F4) were submitted, in triplicate, to the following analyses: moisture content in a vacuum oven at 70°C until constant mass; ash in a muffle furnace at 55°C and lactose according to the methodologies described by the Instituto Adolfo Lutz (IAL, 2008). The lipid content was determined by the method of Bligh and Dyer (1959) and the protein content by the Kjeldahl method (AOAC, 2011).

Statistical analysis

Data were statistically evaluated using a completely randomized design, using analysis of variance and Tukey's test at 5% probability, using the statistical program ASSISTAT version 7.7 beta (SILVA, 2008).

Results

Table 2 shows the results obtained for the water content of the four dulce de leche formulations.

Table 2. Moisture content of the different dulce de leche formulations

Formulations	**Moisture content (%)**
F1	24.88±0.138d
F2	26.09±0.04c
F3	29.13±0.142b
F4	33.11±0.053a

Note: Mean ± standard deviation. Equal lowercase letters on the same line did not differ significantly between the formulations developed (P>0.05).

Regarding the moisture content of the samples, there was a variation from 24.88 to 33.11%, in which the sample containing the highest percentage of whey presented higher values in relation to this parameter. Carvalho et al. (2017) when evaluating dulce de leche with the addition of pequi pulp, obtained values similar to those observed in the present study (31.97 to 33.70%).

Only the F4 sample is inadequate for the legislation, with a moisture content higher than the established (30%), which may represent less stability of the final product.

Table 3 shows the results obtained for the ash content of the four dulce de leche formulations.

Table 3. Ash content of the different dulce de leche formulations

Formulations	**Ash content (%)**
F1	1.4±0.029c
F2	1.53±0.011c
F3	1.80±0.013b
F4	2.00±0.001a

Note: Mean ± standard deviation. Equal lowercase letters on the same line did not differ significantly between the formulations developed (P>0.05).

The ash content of the samples presented a variation from 1.4 to 2.086%, however the samples F1 and F2 did not present a statistically significant difference when compared to each other. Gaze et al. (2015) in their studies with dulce de leche obtained values similar to those of the present study, ranging from 1.31 to 2.05%.

There was a tendency to increase the ash content in relation to the increase in the percentage of whey used in the formulations. All samples comply with the quality standard established by Brazilian legislation for dulce de leche through Ordinance No. 354 of September 4, 1997, which limits the maximum ash content to 2.0%.

Table 4 shows the results obtained for the lipid content of the four dulce de leche formulations.

Table 4. Lipid content of the different dulce de leche formulations

Formulations	**Lipid content (%)**
F1	7.55±0.296a
F2	7.16±0.290b
F3	6.88±0.201c
F4	6.65±0.614d

Note: Mean ± standard deviation. Equal lowercase letters on the same line did not differ significantly between the formulations developed (P>0.05).

Lipid content was found to be inversely proportional to the percentage of whey used in the formulations. Thus, lower values of lipids were observed in high percentages of whey, ranging from 7.55 to 6.65%. Similar behavior was observed by Santos et al. (2017) in dulce de leche formulations using whey obtained from the processing of Minas Frescal cheese. All samples evaluated are in accordance with Brazilian legislation regarding this parameter, which establishes that dulce de leche must have 6 to 9% fat.

Table 5 shows the results obtained for the protein content of the four dulce de leche formulations.

Table 5. Protein content of the different dulce de leche formulations

Formulations	**Protein content (%)**
F1	6.81±0.018a
F2	6.21±0.02b
F3	5.83±0.062c
F4	5.69±0.058d

Note: Mean ± standard deviation. Equal lowercase letters on the same line did not differ significantly between the formulations developed (P>0.05).

The protein content ranged from 6.81 to 5.69%, all samples evaluated differed statistically when compared to each other. A decrease in the protein content was observed with the increase in the percentage of whey used. All samples present values higher than the minimum value established by legislation in relation to this parameter (BRASIL, 1997).

Cohene et al. (2016) found a similar behavior in dulce de leche with the addition of whey, obtaining higher values in relation to this parameter in samples containing a lower percentage of whey, observing a variation from 5.36 to 6.25%. Table 6 shows the results obtained for the lactose content of the four dulce de leche formulations.

Table 6. Lactose content of the different dulce de leche formulations

Formulations	**Lactose content (%)**
F1	9.88±0.067a
F2	9.85±0.074a
F3	9.81±0.081a
F4	9.76±0.101a

Note: Mean ± standard deviation. Equal lowercase letters on the same line did not differ significantly between the formulations developed (P>0.05).

There was no significant difference between the studied samples regarding the lactose content, which ranged from 9.76 to 9.88%. Brazilian legislation does not define the appropriate values for this parameter in dulce de leche.

Conclusion

Through the results obtained, it can be concluded that:

The use of whey in dulce de leche formulations is an excellent alternative for the use of this raw material, reducing an environmental problem and providing the development of a quality product at a reduced cost.

All samples are adequate in terms of the physical-chemical parameters evaluated, with the exception of formulation F4, which has a moisture content higher than that established by legislation.

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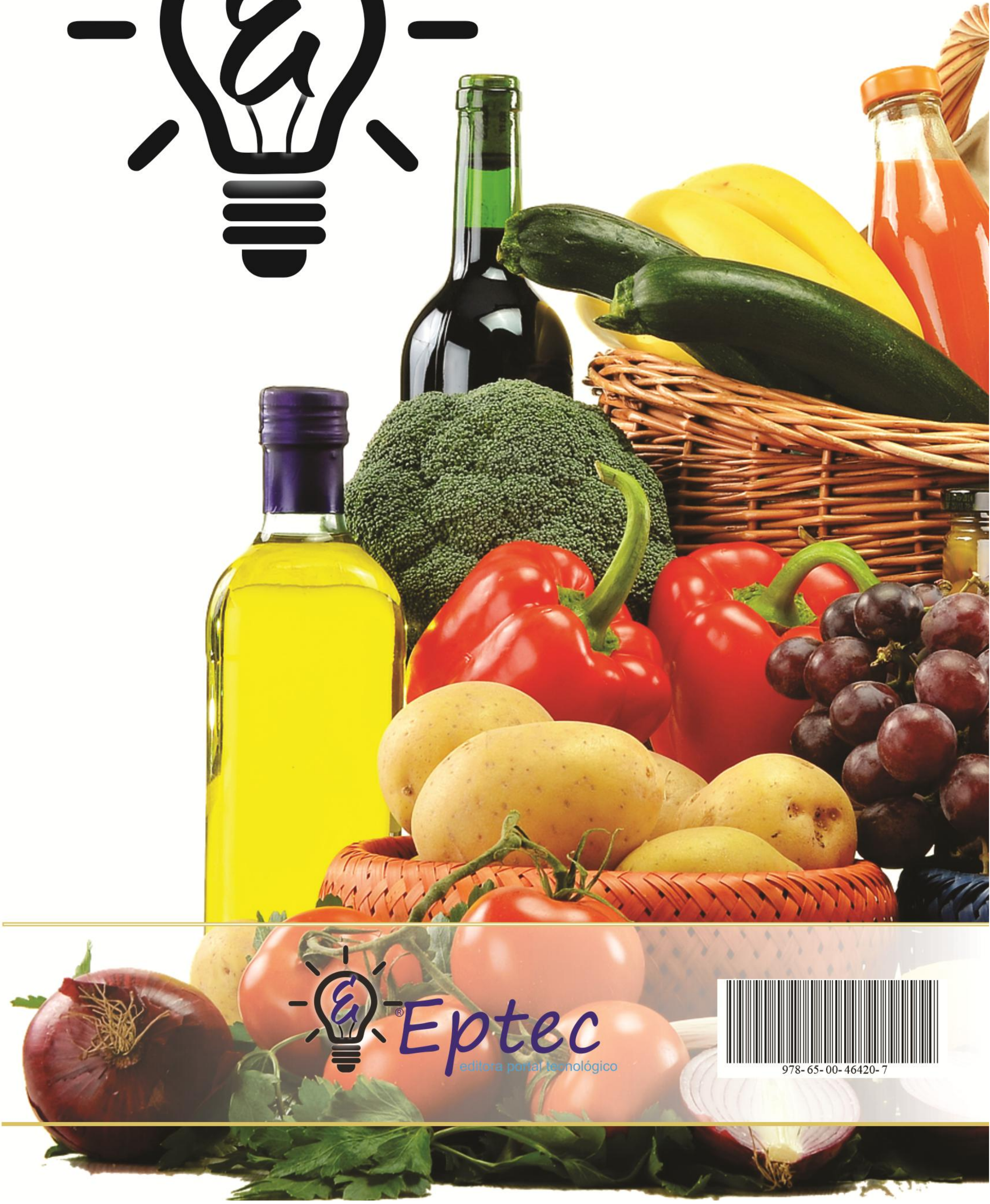

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