DRYING AVOCADO SEEDS TO OBTAIN GLUTEN-FREE FOOD FLOUR

10.56238/edimpacto2025.012-001

Priscylla Palmeira Diniz Rozendo[1], Ana Paula Trindade Rocha[2],Flávio Luiz Honorato da Silva[3], Newton Carlos Santos[4], Anna Emanuelle Soares Tome[5], Jéssica Gonçalves Matias[6] and Yasmin Diniz de Morais[7]

ABSTRACT

Currently we can see a significant increase in the problem of hunger. Given this reality, it is important to consider the complete nutritional value of foods, including bark, leaves, and roots, in order to maximize their use. An illustrative case is that of avocado, which has residues rich in nutrients, but which are little used. In view of this, the objective of this research was to obtain data on the use of avocado seeds for their use in the form of flour in the most diverse industrial purposes. The study of the drying kinetics of avocado seeds at temperatures of 40, 50, 60 and 70 ºC was carried out, with the evaluation of mathematical models. The flours obtained from the drying were evaluated for physical and physicochemical parameters (water activity, pH, ash, proteins, lipids, total titratable acidity, soluble solids and starch). Significant adjustments were observed to the mathematical models applied to the data of the drying kinetics of avocado seeds, with a maximum drying time of 690 min for the process at 40 and 390 ºC for drying at 70 ºC. The physicochemical characterization revealed flours with low water activity and lipid content, but rich in starch. Thus, the data reported in this study serve as a basis for the use of avocado seeds in the form of flours for partial or full replacement of flours commonly used in the industry.

Keywords: Drying kinetics, Vegetable flour, *Persea americana*, Vegetable residues.

---

[1] PhD Student
Complete Master's Degree
UFCG
[2] Postdoctoral fellow
UFCG
[3] Doctorate
UFPB and UFCG
[4] Postdoctoral Student
Complete Doctorate
UFCG
[5] Masters
UFCG
[6] Master's Student
Complete Graduation
UFCG
[7] Undergraduate Student
Full technician
UFCG

INTRODUCTION

Avocado is the most important and unique edible fruit of the *Lauraceae family,* having high commercial and nutritional value. According to Knight (2002), the avocado (*Persea americana)* is defined as a large drupe that has the highest oil content of all fruits, and its status as a food may vary according to the region where it is consumed. Nutritionally, avocado contains high amounts of fiber, proteins, carbohydrates, pigments, tannins, vitamins, minerals, and polyphenols, making it an acceptable and essential food for consumption, as it is beneficial in supporting cardiovascular health, weight control, and healthy aging (Araújo et al., 2018).

As it is an irrigated crop, avocado has become one of the most imported and commercialized tropical fruits in the world due to its high concentration of vitamins and use by the pharmaceutical, food and cosmetic industries. The avocado trade has experienced a significant and steady increase at the global level, rising from around 0.4 Mt in 2000 to around 1.9 Mt in 2016, with an overall increase of around 435% (Caro et al., 2021).

Brazil is considered the third largest fruit producer in the world. However, with such high volumes it has caused some problems, since much of this food is wasted, whether due to treatment, processing, storage, among others, generating organic waste. The avocado, in this context, has a medium fruit that weighs approximately 150 – 400 g, and is composed of exocarp (peel), mesocarp (pulp), endocarp and seed. The husk and seed are little used in the food industry, generating an excessive amount of waste. These by-products usually represent between 21 and 30% of the avocado mass (Peixoto, 2018; Mora-Sandí et al., 2021).

The demand for food and the growth of the world's population are important challenges that we will face in the coming decades. It found that 60% of hungry people in the world are women and almost 5 million children under the age of five die from causes related to malnutrition every year. Thus, the task of feeding the world in a sustainable way is one of the great challenges of our society, since the exponential growth of the population has resulted in an increase in the demand for food. And it is estimated that by 2050, there will be 9.7 billion people, and about 70% more food available for human consumption will be needed than is currently consumed (Cole et al., 2018; Mc Carthy et al., 2018).

Due to the increased consumption and processing of avocados, by-products such as peel and seeds are often discarded as waste. However, these materials can be a rich source of bioactive compounds, which can be developed as functional food ingredients. Avocado seeds are a good natural source of biologically active ingredients for the food sectors, as they do not contain harmful or dangerous compounds, making its exploitation as a promising source capable of developing new value-added products and a safe alternative with high anticancer, antidiabetic, antioxidant, anti-neurogenerative, and anti-inflammatory activity (Bangar et al., 2022; Ong et al., 2022).

Updated food applications of avocado seeds usually come in the form of flour and extract, and these two by-products are applied in other segments. Avocado flour is the object of study of the present research, some of its applications include yellow-orange pigment, food supplement, source of fiber in breads, cakes and cookies, as well as starch extracted from flour, among others. When included in diets, the flour under study has satisfactory partial effects, such as reduced cholesterol levels, extinction of high blood glucose, hepatic glycogen storage, modulation of lipid and carbohydrate metabolism, in addition to ensuring low toxicity (ARAÚJO et al, 2018; Bangar et al., 2022).

Based on the information presented, the objective of the present work is to obtain the flour from the avocado seed in order to process a nutritionally rich residue, thus reducing its waste.

AVOCADO

The avocado tree is a fruit tree native to the American continent. The first mention of it was made by navigators, still in the early days of the discovery of America, between 1526 and 1554, in reports that describe plants found in the ancient city of Mexico in what is currently Colombia. In these accounts, avocados were given various names, such as nahuatl and ahuacatl, possibly of indigenous origin. Archaeological research shows that avocado trees have been exploited in the area for more than 10,000 years. (Koller, 1984).

It is a subtropical/tropical fruit widely produced and consumed around the world, with about six million tons of avocado produced annually, 62% of which are harvested in five main countries: Mexico (33%), Dominican Republic (10.5%), Peru (7.8%), Indonesia (5.7%) and Colombia (5.1%). According to the Institute of Agricultural Economics published by Baptistella and Coelho (2019), in Brazil, the largest avocado-producing areas are in the states of São Paulo, Minas Gerais and Paraná, which account for 85.7% of Brazilian production.

Avocados of Brazil (2019) mentions that there are more than 500 known species of avocados. The seasonality of each avocado variety depends on weather conditions and other factors that affect late or early production. In Brazil, the main types are avocado (Hass), Breda, Fortuna, Geada, Margarida, Ouro Verde and Quintal.

The high concentrations of MUFAs (Monounsaturated Fatty Acid) in avocados indicate that the avocado-rich diet has beneficial effects on blood lipids (Mahmassani et al., 2018).

Figure 1 - Fortuna Avocado (Persea Americana)

Source: Author (2023)

In the case of avocado, from a nutritional point of view, this fruit stands out for the presence of large amounts of monounsaturated fatty acids in its composition, especially oleic acid (Omega 9). Although its caloric value is higher than that of other fruits, its pulp contains several vitamins and minerals, mainly potassium and vitamin E, which makes its consumption in human food interesting (Ferrari, 2015). Table 1 shows the nutritional composition of avocado according to TACO data (2011).

Table 1 - Nutritional table of avocado.

NUTRIENT	QUANTITY	%DV*
Energy value	96.2 kcal	5%
Carbohydrate	6.0g	2%
Protein	1.2g	2%
Saturated fats	2.3g	10%
Monounsaturated fats	4.3g	-
Polyunsaturated fats	1.4g	-
Dietary fibers	6.3g	25%
Calcium	7.9mg	1%
Vitamin C	8.7mg	19%
Phosphorus	22.0mg	3%
Manganese	0.2mg	9%
Magnesium	14.7mg	6%
Lipids	8.4g	-
Iron	0.2mg	1%
Potassium	206.3mg	-
Copper	0.2ug	0%
Zinc	0.2mg	3%

Riboflavin B2	0.0mg	0%

Source: TACO (2011)

Avocado is a bright green fruit with a large seed. They are known in the United States as alligator pears or butter fruits. Avocados are many people's favorite produce section fruits. This fruit is the main ingredient for the preparation of guacamole (Booth, 2020). Figure 2 depicts the avocado fruit.

Figure 2 - Fortuna avocado (*Persea Americana*)

Source: Author (2023)

To identify the avocado varieties, the identity table of the Companhia de Entreposto e Armazéns Gerais de São Paulo (CEAGESP, 2015) described in Table 2 and the bulletin published by EMBRAPA described in Mouco and Lima (2014) are used to ensure identification regarding the maturation period.

Table 2 - Avocado identification

Cultivate	Format	Peel coloration	Peel texture	Shell thickness	Pulp color	Pulp texture
Breda	elliptical	green	Lisa	thin	yellow	fiber-free
Fortune	Piriformis	green	Average roughness	average	yellow	fiber-free
Fucks	Piriformis	green	Lisa	thin	yellow	with fibers
Frost	Piriformis	green	Lisa	thin	yellow	Few fibers
Hass	Piriformis	green	Very rough	Thick	yellow	fiber-free
Daisy	spheroid	green	Rough	Thick	Light green	fiber-free

Green gold	elliptical	dark green	slightly rough	average	yellow	fiber-free
Backyard	Piriformis	green	Average roughness	average	yellow	fiber-free

Source: Mouco and Lima (2014)

Avocado seeds are rich in extractable bioactive compounds, such as condensed tannins, phenolic acids, and flavonoids. These extracts have been shown to have great biological activities related to their composition, namely antioxidant, anticancer, antibacterial, anti-inflammatory and antihypertensive properties, with a wide range of uses (Figueroa et al., 2018).

While there are some reports on the chemical composition of avocado seeds, few describe the volatile or lipophilic chemical composition. Vieira and Moraes (2019) studied the composition of avocado flour and stated that the moisture content of avocado seed flour was 7.14%, and the values of ash, protein, and lipids were 2.63, 5.46, and 3.36%, respectively. The crude fiber content was 3.37% and the carbohydrate content was 79.19%. Regarding the concentrations of micronutrients, values of 49.02 mg/100 g of calcium and 165.96 mg/100 g of phosphorus were obtained.

Nascimento et al. (2016) emphasized the use of avocado seed meal in human nutrition because it is rich in fiber, protein, and minerals that add nutritional value to preparations. In addition, it was possible to verify, based on the centesimal composition of dehydrated avocado seed flour, that it contains 15.12% dietary fiber, being predominantly insoluble dietary fiber with 11.55% of the total fiber, in addition to containing a large amount of trace elements, mainly potassium 11.27 mg/100g, zinc 11.56 mg/100g and especially iron 20.26 mg/100g, thus providing the minimum diet recommended by RDC No. 265 for adults.

Among avocado by-products, the seeds represent 13-18% of the whole fruit and are practically unused in most countries, are thrown into landfills, and cause some ecological problems or harm to humans (Ezeagu et al., 2018).

According to research conducted by Daihan et al. (2016), avocado seeds are used in traditional medicine to treat various diseases, they have antibacterial, antifungal, antiviral and healing properties. They reported that the antioxidant potential of plant extracts was evaluated by the content of total phenolic compounds, total flavonoids, and DPPH radical scavenging activity. The highest concentrations of phenolic compounds and flavonoids were observed in the methanolic extract, while the lowest concentrations were obtained in the aqueous extract. At a concentration of 500 µg/mL, the scavenging activity of the DPPH radical was higher in the methanol-based extract (70%) and lower in the aqueous extract (51%). The antibacterial activity of different extracts was evaluated by the disk diffusion method. The highest antibacterial activity was observed with the methanol extract against *Streptococcus pyogenes*, while minimal activity was observed with the aqueous extract against *Etamoeba. coli*.

Avocado oil and guacamole are the main products of industrialized avocado, the loss of its seeds, peel and pulp results in waste generated during this production. Currently, this waste does not have significant use value compared to the large quantities produced daily, which indicates a serious environmental problem (Figueroa et al., 2018).

DRYING

Food drying is an important and valuable process, since it allows the preservation and obtaining of products with reduced water content, with the advantage of increasing the shelf life of the product and the low cost of requiring only a tray and protective nets against insects (Leonardi; Azevedo, 2018).

Drying is one of the oldest forms of food preservation. This process can be done in different ways, but the choice directly affects the quality of the product, being influenced by the temperature, time and/or degree of the vacuum drying chamber. Loss of quality, such as shrinkage, crystallization, reduced rehydration capacity, as well as loss of flavor, aroma, color and nutritional value are the main problems encountered, which can be solved through drying processes. (Fijalkowska et al., 2016; Zhang et al., 2016).

Drying, when compared to other methods of food preservation, such as chemical treatments, irradiation, among others, is a simple and lower cost operation (Moura, 2016).

Although there are many benefits associated with drying food, the process results in some changes in the product, mainly observed in relation to texture, flavor, aroma, color and quality, nutrients, as some substances decompose when subjected to high temperatures. Therefore, it is essential to carry out studies on drying processes and systems to verify the conditions that allow the development of a better quality product (Santos et al., 2019a).

Drying is defined as the application of heat under controlled conditions to remove, by evaporation, the greatest amount of water present in a material. Moisture removal always involves mass transfer, which corresponds to the water acquired by transferring heat to the product (Fellows, 2006).

DRYING KINETICS

Drying kinetics includes obtaining the initial and final water content in the material, applying theories and formulas capable of understanding the phenomena and predicting the drying rate of the food (Barbosa; Lobato, 2016; Defraeye, 2017). Silva et al. (2015), stated that drying kinetics consists of the speed with which a material loses moisture, and this factor is dependent on its specific properties, temperature, drying air velocity and relative humidity.

Considering the diversity of biological structures and differences in the behavior of materials during processing, experimental and semi-empirical mathematical models are adjusted to the experimental data obtained to observe the rate of water loss of the product over time until equilibrium is reached. The semi-empirical models are based on the analogy with Newton's Law for cooling, applied to mass transfer, while the empirical models present a relationship between water content and drying time, considering diffusion as the main mechanism, based on Fick's second Law (Zanoelo et al., 2007).

The resulting water content, essential parameters for equipment sizing and process optimization, allows for reduced drying times and, consequently, lower costs and better preservation of product nutrients. (Santos et al., 2019b).

With the data of drying kinetics, it is possible to obtain predictive models that describe the process of various agricultural products and residues, given the great diversity of structure and composition of biological materials and the influence that these characteristics exert on the phenomena of heat and mass transfer (Mendonça et al., 2015).

For years, the models developed were used in calculations that involved the design and construction of new systems, optimization of the process and the description of all their behavior. Therefore, mathematical models are used to represent the kinetics of drying under these conditions, being fundamental for mathematical simulations of the drying process (Goneli et al., 2014; Onwude et al., 2016).

FLOUR

One of the alternatives that the food industry has been advancing in the treatment of food waste since the mid-1970s is the use of this waste as raw material for the manufacture of other products, which are mainly included in human and animal food. One of these products is flour, considered a low-cost product that pleases most of the Brazilian population (Gomes et al. 2016).

Flours made from fruit and vegetable waste have been widely used to replace and/or fortify foods, such as breads, cookies, and cakes due to their better nutritional quality, in addition to improving the palatability of some foods, being considered a powdered form of grains (Silva, 2019).

The application of flour in product development and food formulations is guided by its end-use properties, such as composition, physicochemical, and functional properties. In addition, to increase its commercial use, the mixture of high-protein flours derived from other botanical sources is widely used, with the aim of intensifying the nutritional quality of the final product (Chisenga et al., 2019).

STATE OF THE ART

A study carried out by Nascimento et al. (2016) on the centesimal and mineral composition of avocado seed flour, showed that avocado seed flour can be used in human food, adding nutrition, thanks to its preparations rich in fiber, protein and minerals, especially iron. This research provides new perspectives for work aimed at the development of new food products to which flour can be added, increasing nutritional value and reducing environmental pollution by industrial waste. The authors also found that avocado seed flour has 11.55% insoluble fiber, 3.57% soluble fiber, and 4.57% crude protein.

Research also indicates different possibilities of use with avocado seeds. Nascimento et al. (2017) studying the fatty acid profile in oil extracted from this seed, pointed out that avocado seed oil had higher concentrations of saturated fatty acids than oils produced from jackfruit and seriguela seeds. They also highlighted that linoleic acid is present in large quantities. The properties of seed oil can be used as ingredients in the manufacture of products, adding value to this normally discarded material. Avocado seeds predominated saturated fatty acids with 65%.

Amado et al. (2019) performed an analysis of antioxidant and antibacterial activities in avocado varieties and found that the highest antioxidant and microbial activity was observed in the ethanolic extract of the peel, followed by avocado seeds of the Quintal, Hass, Fortuna and Margarida varieties. The extract of the bark of Quintal showed better performance in all tests and can be used as a natural antioxidant or to help prevent contamination of food during handling, especially against *Staphylococcus aureus* on human skin. Toxicity tests of this extract also showed that it exhibited no toxicological effects in *Artemia* salts or hemolytic activity tests so this ingredient appears to be a promising alternative in food applications to prevent spoilage and thus extend shelf life.

According to the results obtained by Tomé (2020), avocado seed flour becomes efficient with the combination of other ingredients for the composition of vegan food. This author verified in his study on the technological analysis of Persea americana seed flour, that the greater the amount of this ingredient, the higher the water absorption and the lower the consistency of gluten, which makes it difficult to homogenize and grow the dough without leaving it pasty.

Silva et al. (2019) performed a sensory analysis of a cookie made from avocado seed flour and observed that the physicochemical properties (moisture, ash, lipids, proteins, total carbohydrates, energy value) of avocado seed flour favor its application in food formulations and facilitate the development of new products. They also observed that cookies made with 5% avocado seed bran instead of wheat flour have good sensory acceptance and above-average purchase intention, indicating that the addition of avocado seed bran helps to develop a commercial market potential and increases the nutritional value of new products.

Alissa et al. (2020) studying the effect of avocado seed powder spray drying technology, concluded that spray dryer technology is a viable method for developing avocado seed powder. Based on the results, it was observed that the formulation with the lowest concentration of avocado extract (10g) was the most stable, as it was free of solute particles and showed the least color change after 24 hours of storage at room temperature. For future experiments, it is recommended to measure the pH of the solution to more clearly explain the stability of the mixture. In addition, the concentration of maltodextrin is recommended as an independent variable, since the concentration of the carrier agent also affects the properties of the spray-dried powder.

Lobato et al. (2021) reviewed the potential of avocado seed flour in the development of food products and stated that avocado seed flour showed very promising potential due to the observed presence of nutrients, such as type A and B procyanidins, phenolic compounds, fatty acids, fiber, potassium, zinc, and iron, They also recognized its conservation potential, as well as its role as an antioxidant due to the carotenoids in its composition, in addition to its desirable physical and organoleptic properties, such as the presence of unconventional starches, which allow its use in various food formulations.

Marques (2022) in his experimental study with avocado seed flour in the addition of mouse diets with the objective of reducing fats, stated that it was possible to notice positive effects in preventing weight gain, reducing visceral adiposity. It also established that despite the rich macronutrient composition found in seed meal, as well as an excellent fatty acid profile and high fiber concentrations, more studies are needed.

INTRODUCTION

Brazil is the third largest fruit producer in the world. However, because it has large production, some problems are presented by a large part of this food being wasted, for various reasons, generating organic waste (Peixoto, 2018).

Persea americana, better known as avocado, is a fruit of tropical origin, widely recognized and accessible, it comes in different forms due to the wide variety of species, but for the most part, it has a dark green skin with a wrinkled texture, a juicy pulp of olive green color and buttery flavor. It has a seed commonly discarded by the industry, since the greatest commercial interest is in its pulp (Carvalho, 2015).

The acceptance of avocado as a food varies depending on the region where it is consumed and the level of familiarity and cultural importance with which it is considered by the local population. Among avocado by-products, seeds account for about 13-18% of the whole fruit and are virtually unused in most countries, are wasted and thrown into landfills, thus contributing to ecological problems and environmental pollution (Ezeagu et al., 2018).

Despite current advances in scientific research, the biological activities of avocados and their seeds are little explored. According to Freitas et al. (2021), the avocado seed has some nutritional properties, such as water content around 6.75% and ideal macronutrient amounts to be used as a flour. However, there are still few studies exploring the potential of this ideal seed for food production or for its use as an anti-inflammatory, antidiabetic or antihypertensive agent.

While there are some reports on the chemical composition of avocado seeds, few describe the volatile or lipophilic chemical composition. According to Vieira and Moraes (2019), the composition of avocado seed flour had a moisture content of 7.14%, and the values of ash, protein, and lipids were 2.63%, 5.46%, and 3.36%, respectively. The crude fiber content was 3.37%, while the carbohydrate content reached 79.19%. Regarding the concentrations of micronutrients, values of 49.02 mg/100 g of calcium and 165.96 mg/100 g of phosphorus were obtained.

It is known that the drying method consists of eliminating water through evaporation, which concentrates nutrients, improves nutritional value, and helps control microbial growth. In addition, the low moisture content is a determining factor for the stability of the flour, which must comply with the standards established by Brazil (2005) which establishes a value of a maximum of 15%.

With the data of the drying kinetics, it is possible to obtain predictive models that describe the process of various agricultural products and residues, given the great diversity of structure and composition of biological materials and the influence that these characteristics exert on the phenomena of heat and mass transfer (Mendonça et al., 2015).

In order for drying and storage operations to be carried out properly, it is necessary to know the relationship between the product and the air that surrounds it. The equilibrium water content of an agricultural product is reached when the partial water vapor pressure of this product equals that of the surrounding air (DINCER; ZAMFIRESCU, 2016). This characteristic is prescribed by mathematical models that correlate temperature, relative humidity and plant water activity, and has been studied by several authors in the literature (Ferreira Junior et al., 2018; Moussaoui et al., 2019; Silva et al., 2019).

In this sense, it is necessary to obtain theoretical information about the behavior of each product during drying. This information can be obtained through drying simulations, using mathematical models to describe the process of water loss (GOMES et al., 2020).

Due to the scarcity of data in the literature and studies that discuss the use of avocado seeds in the academic environment, regarding the processing of drying, this work aimed to study the kinetics of drying avocado seeds, as well as to apply mathematical models, thus observing their behavior.

RESULTS AND DISCUSSION

The data in Table 2 show the means of drying times and final water contents. It was verified that the drying time was shorter as there was an increase in temperature. This is due to the fact that higher temperatures have a greater capacity to remove the water present in the product.

The same behavior was observed by Nascimento et al. (2016) in their analysis of avocado seed flour. They stated that this flour can be used in human food, adding nutritional values to preparations due to its nutritional richness and low water content. After drying, they stated that the drying times of the avocado seeds were shorter as the drying air temperature increased. According to this study, the moisture content of flour is within the limit, according to the legislation that recommends the maximum value for flours, of up to 15.0% moisture.

With the increase in the drying temperature, it is observed that the higher the heat (in ºC) used in the process, the faster the constant weight of the seed was reached.

Table 2 - Drying times and moisture content of avocado seed samples obtained at different temperatures

Temperature (ºC)	Drying Time (min)	Initial moisture content (%b.u.)	Final moisture content (%b.s.)
40	690	58.42nd ± 0.34	10.87th ± 0.10
50	570	60.21st ± 0.25	10.38th ± 0.07
60	450	61.28th ± 0.31	10.25th ± 0.06
70	390	61.06th ± 1.87	10.40th ± 0.26

Means with different letters in the same column differ significantly ($p \leq 0.05$). Mean ± standard deviation.

After obtaining the experimental data found through drying and calculating the humidity ratio over time at the temperatures used, these data were adjusted to the mathematical models. It was observed that the temperature of the drying air, used in the process, had a lot of influence on the drying curves, considering that the higher the temperature, the faster the equilibrium humidity is obtained, since the stability of the product is achieved according to the equilibrium water content (Silva et al., 2014).

The parameters obtained from the adjustments of the mathematical models to the experimental data of the drying kinetics of the avocado seed are described in Table 3, as well as the coefficient of determination (R^2), mean square deviation (DQM) and chi-square (χ^2), obtained for drying at temperatures of 40, 50, 60 and 70 ºC.

According to Moscon et al. (2017), the best adjusted model for drying has an R^2 value ranging from 0 to 1, indicating the proximity between the obtained and estimated data and a DQM value closer to zero. The use of mathematical models is essential to represent the drying process, since the information generated is valuable for the development of equipment and the prediction of drying times (Silva et al., 2009). The application of reliable mathematical models allows for accurate prediction of the behavior of various phenomena that occur during the drying process, which means a reduction in operating costs (Dionello et al., 2009). Araújo et al. (2017) stated that R2 values higher than 98.0% indicate that the mathematical models satisfactorily represent the drying behavior.

Table 3 - Parameters of the mathematical models adjusted to the drying data of avocado seeds with coefficients of determination (R^2), mean square deviations (DQM) and chi-square (χ2)

Model	T(°C)	Parameters					
		the	k	n	R²	DQM	χ2
Page Modified	40	0.97691	0.00109	1.2688	0,9838	0,3620	0,0066
	50	0.99106	0.00645	1.1917	0,9975	0,0030	0,0006
	60	0.99173	0.00300	1.3012	0,9930	0,0054	0,0019
	70	0.97645	0.00226	1.4497	0,9965	0,0039	0,0009
	T(°C)	K			R²	DQM	χ2
Lewis	40	0.004650			0,9897	0,4781	0,0173
	50	0.014383			0,9952	0,0041	0,0012
	60	0.011185			0,9870	0,0073	0,0035
	70	0.014839			0,9869	0,0076	0,0035
	T(°C)	The	k	b	R²	DQM	χ2
Diffusion approach	40	-6.72497	0.00863	0.91692	0,9837	0,4624	0,0167
	50	-8.71599	0.02532	0.93906	0,9975	0,0030	0,0006

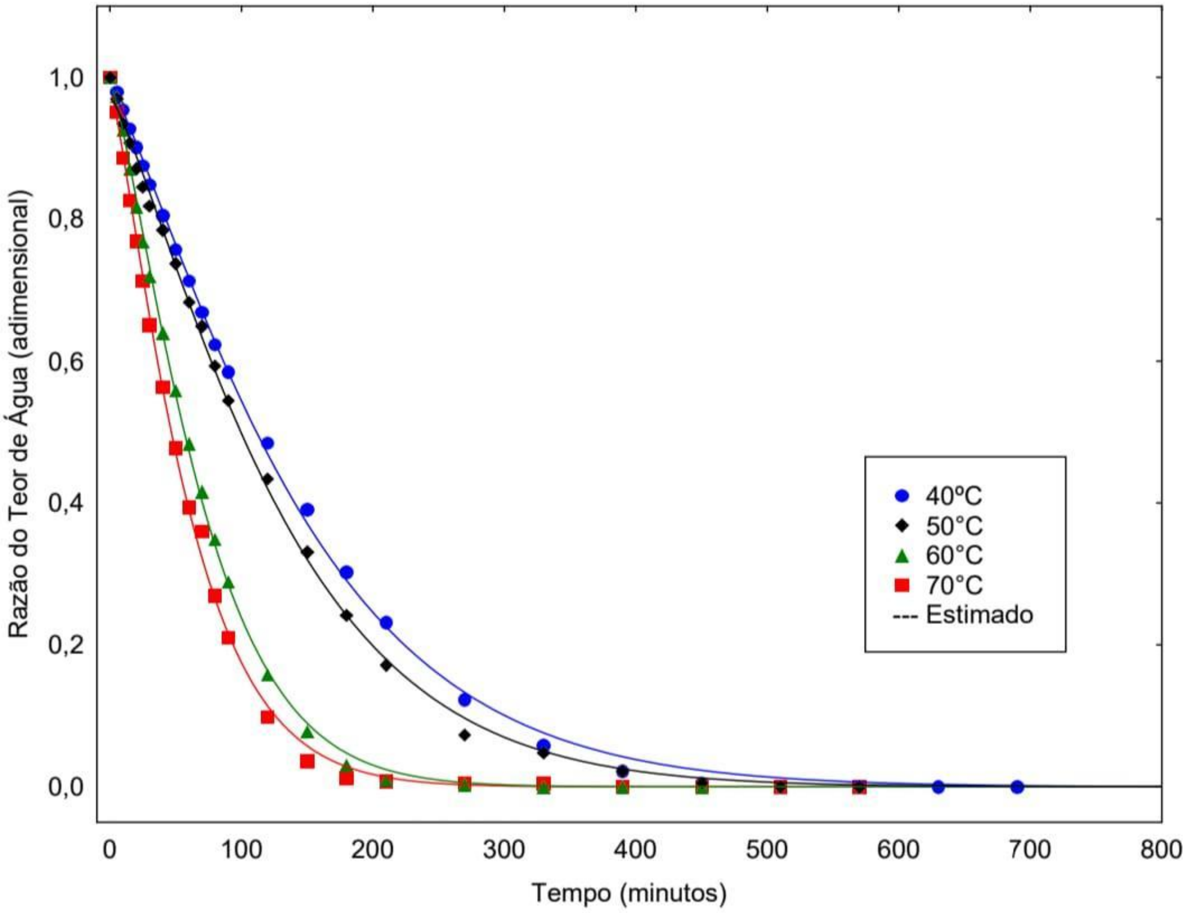
	60	-7.31671	0.02266	0.91074	0,9929	0,0054	0,0019
	70	-12.2167	0.0310	0.9378	0,9960	0,0042	0,0011
Exponential Two-Term	**T(°C)**	**The**	**k**		**R²**	**DQM**	**χ2**
	40	0.001437	3.219898		0,9896	0,4785	0,0176
	50	0.002085	6.857945		0,9951	0,0042	0,0012
	60	0.001470	7.588037		0,9740	0,0074	0,0036
	70	0.001340	11.03032		0,9738	0,0010	0,2119
Henderson and Pabis	**T(°C)**	**The**	**k**		**R²**	**DQM**	**χ2**
	40	1.033632	0.004898		0,9809	0,4738	0,0173
	50	1.040268	0.015189		0,9961	0,0037	0,0010
	60	1.061345	0.012174		0,9896	0,0066	0,0028
	70	1.074539	0.016295		0,9903	0,0065	0,0026
Page	**T(°C)**	**K**	**n**		**R²**	**DQM**	**χ2**
	40	0.001636	1.200462		0,9835	0,0017	0,0165
	50	0.007117	1.171065		0,9974	0,0030	0,0006
	60	0.003367	1.278276		0,9929	0,0054	0,0019
	70	0.003183	1.375906		0,9963	0,0040	0,0010
Peleg	**T(°C)**	**the**	**b**		**R²**	**DQM**	**χ2**
	40	220.8773	0.6190		0,9817	0,4702	0,0170
	50	54.51228	0.83002		0,9857	0,0072	0,0036
	60	80.27902	0.73246		0,9819	0,0873	0,0049
	70	59.40866	0.74447		0,9792	0,0096	0,0057
Wang & Singh	**T(°C)**	**the**	**b**		**R²**	**DQM**	**χ2**
	40	-0.003508	0.00003		0,9834	0,4638	0,0165
	50	-0.007048	0.000010		0,9109	0,5599	0,0222
	60	-0.007431	0.000012		0,9787	0,0094	0,0058
	70	-0.009244	0.000018		0,9712	0,0112	0,0079
Logarithm	**T(°C)**	**K**	**the**	**c**	**R²**	**DQM**	**χ2**
	40	0.003898	1.125016	-0.10995	0,9834	0,4636	0,0168
	50	0.014660	1.052338	-0.01596	0,9964	0,0036	0,0009
	60	0.011145	1.094593	-0.04237	0,9907	0,0062	0,0025
	70	0.014808	1.111927	-0.04724	0,9920	0,0059	0,0022
Newton	**T(°C)**	**k**			**R²**	**DQM**	**χ2**
	40	0.004650			0,9897	0,4781	0,0173
	50	0.014383			0,9952	0,0041	0,0012
	60	0.011185			0,9870	0,0073	0,0035
	70	0.014839			0,9869	0,0076	0,0035

Table 3 shows a favorable fit when compared with the other adjusted models, with R2 values higher than 98% and low values of mean square deviation (DQM) and chi-square deviation (χ^2). The greatest highlight was observed for the Modified Page model (R2 ≥ 0.9838, DQM ≤ 0.003620 and χ^2 ≤ 0.0066).

Thus, considering the experimental conditions of this study, the R^2 values were very close, with the difference from the mean being only 0.000138, indicating the Modified Page model the best result. As for the DQM, the difference in the mean was 0.003568, and the modified Page was also the closest to 0. In addition, the difference in x^2 was 0.003839 with the average of Page Modified being the closest to 0. Therefore, based on these criteria, the mathematical equation was selected, and the Modified Page equation was the most appropriate. Similarly, Silva et al. (2021) also found satisfactory adjustments in two mathematical models, with Page and Midilli being the experimental data on hazelnut seed drying.

Figure 2 shows the adjustment of the Modified Page model to the experimental data.

Figure 2 - Representation of the adjustments of the Modified Page model to the avocado seed drying data



These curves represent the relationship between the ratio of water content (dimensionless) to drying time (minutes). It can be observed that the temperature had an influence on the drying of the samples, with the curves presenting positions far from each other, although there were differences in the final drying time, until the equilibrium was reached.

CONCLUSIONS

Satisfactory mathematical fit of the models to the experimental data of the drying kinetics of avocado seeds was verified, and the Modified Page model was the most suitable to represent the phenomenon, presenting the best values of R2, DQM and χ 2, indicating that the data have low dispersion and divergence.

The behavior of the drying curves was similar, with a gradual decrease in the water content over time, until it reached a constant state. In addition, it can be seen through the drying curves that the ideal temperature and time for this process are, respectively, 50 ºC and 570 min. By using these conditions, the process time was reduced in relation to the other temperatures used, and the final sample did not have its structure compromised.

ARTICLE II

RESULTS AND DISCUSSION

Characterization of avocado seed flour

The data obtained in the characterization of avocado seeds are shown in Table 1, with their mean values, standard deviations and statistics.

Table 1 - Characterization of avocado seed flour

Parameters	Drying temperature of avocado seed flours			
	40 °C	**50 °C**	**60 °C**	**70 °C**
Water activity (a_w)	0.55th ± 0.005	0.47th ± 0.003	0.30b ± 0.001	0.29b ± 0.008
ph	5.18th ± 0.005	5.14th ± 0.01	5.19th ± 0.005	5.17th ± 0.01
Crude protein (%)	5.90ab ± 0.71	6.85th ± 0.04	5.55b ± 0.21	6.99th ± 0.28
Lipids (%)	1.32d ± 1.69	2.19c ± 0.52	2.58b ± 0.39	3.05th ± 0.11
Carbohydrate (%)	86.30th ± 2.15	86.34th ± 0.66	87.95th ± 0.75	85.68th ± 1.07
Acidity (%)	5.95c ± 0.89	7.15b ± 0.89	5.92c ± 0.89	8.29th ± 0.89
Soluble solids (°Brix)	2.2nd ± 0.00	2.23rd ± 0.11	2.2nd ± 0.00	2.5th ± 0.00
Water content (%)	4.66th ± 0.57	2.66b ± 1.15	1.66c ± 0.57	2.0bc ± 1.0
Ash (%)	0.098b ± 0.01	0.112ab ± 0.007	0.117ab ± 0.009	0.126th ± 0.008

Means with different letters in the same line differ significantly ($p \leq 0.05$). Mean ± standard deviation.

Based on the data obtained, it is observed that the flours presented a moderately acidic pH, with values ranging from 5.19 to 5.14, denoting a slightly acidic sample. However, flours with a higher pH than usual (6.0 - 6.8) are preferable to ensure good performance in baking processes and to preserve the shelf life of the product. Melo et al. (2012) conducted a study on avocado seeds and found an average pH of approximately 5.50, a value similar to those obtained in this study, and this occurrence was attributed to the presence of organic acids, resulting in an average acidity of 8.84%.

The water activity of the samples showed values higher than 0.29, indicating that they are favorable for the conservation of flour, because low values of water activity inhibit the development of unwanted microorganisms, which is an objective when producing flours for certain products.

It is possible to observe that as the temperature decreases during the drying process, the rate of water evaporation is progressively decreased, which promotes a smoother and more gradual removal of the water present. Consequently, as the water content gradually decreases, a corresponding decrease in water activity is observed. This phenomenon occurs due to the slower removal of water and the reduction of the kinetic energy of the water molecules, making it difficult for them to be released from the material's matrix. From these results, it is possible to verify that the availability of free water is reduced, resulting in a lower water activity. Water activity is a factor of great importance for the stability and quality of food and other materials, as it influences microbial activity, chemical reactions, and the texture of products. The application of low-temperature drying, when appropriate for the material in question, can preserve the quality and properties of the product by reducing water activity to desirable levels.

The mineral content of the samples is close to the values obtained by Freitas (2021), with a result of 2.33%. Coinciding with the research of Nascimento (2016), who found the ash content of 2.22% in his study of avocado seed flour, characterizing a sample with the presence of minerals in its composition.

It is verified that the protein content of avocado seed flour is relatively low when compared to wheat flour, which prevents its classification as a protein flour, being a flour considered protein when it has a protein content higher than 12-14%. The protein composition of avocado seeds has an approximate concentration of 5.5 to 6.9%, while wheat flour exhibits a variation of 10 to 14% of protein, this result is valid for other applications that do not include the replacement of wheat flour or flours with high protein contents.

It is found that the avocado seed has a lower protein quantification compared to wheat flour, whose values can fluctuate within this more extensive amplitude, and this parameter can be influenced by external factors, such as the stage of fruit maturation, seed storage, exposure to light and oxygen, drying temperatures used, among others. However, it is important to note that the avocado seed has more expressive amounts of other nutritional parameters evaluated, such as minerals, carbohydrates, fats and fibers.

The flour showed an average lipid content of 2.29, indicating the presence of oil that can be extracted and used in the production of edible vegetable oils or in the manufacture of cosmetics. This parameter brings values similar to the results obtained by Oliveira et al. (2009) who found 2.55% of lipids when conducting a study on the Fortuna avocado.

The flour also demonstrated low moisture, which contributes to its conservation, transport, product quality, convenient handling and effectiveness in the application processes. Therefore, it is desirable that the flour has a low and controlled moisture.

The analysis of total carbohydrates (by difference) reveals that the avocado seed is an important source of energy. The value found in this study was 86.57% on average, and this value was higher than some reference values present in the literature, due to the inclusion of starch content. For example, Rodrigues et al. (2007) found a value of 53.04% for the Fortuna variety, while Bora et al. (2001) identified a value of 75.45% for the Fuerte variety. However, Tango et al. (2004) concluded that the carbohydrate content in the seeds of 24 avocado varieties ranged from 14.87% to 45.05% for the Fortuna variety. In all of these studies, the carbohydrate content in the seed was higher than that of the pulp.

The starch content of the avocado seed was quantified with an average value of 58.18%, which was higher than the study conducted by Silva (2021), which presented a value of 74.47%. It is relevant to highlight that the method of determination and the type of drying used for starches can cause changes in their components and impact their application in the food industry (Castro et al., 2018).

The acidity value found was 6.83%, indicating a pleasant balance of acidity for the palate, considering that it is close to neutrality. Sousa and Costa (2012) conducted a study on the avocado seed and stated that the acidity content was 8.84%. The acidity found in flours is associated with several factors, including the presence of organic acids, microbial activity, and lipid oxidation. It is important to note that a high acidity can have negative effects on the quality of baked goods, such as breads, cakes, and cookies, affecting their texture, flavor, and shelf life. Figure 6 shows the data regarding the acidity content of the samples.

The data regarding the content of soluble solids ranged from 2.1% to 2.5%. These soluble solids can include sugars, acids, phenolic compounds, and other soluble components. However, it is important to note that the highest concentration of soluble solids is typically found in the pulp of the avocado, while the seed is mainly composed of fiber and other water-insoluble substances.

Comparing the results obtained by Oliveira (2019) with other avocado seeds, such as Margarida (10.21%), Geada (8.14%) and Breda (10.56%), it is possible to observe that the Fortuna species has a lower content of soluble solids.

In general terms, it is possible to observe that the drying temperature of 60 °C presented greater relevance in relation to the other temperatures studied, because it offers better characteristics regarding nutritional composition and because it has percentages of ideal parameters for use in food production. The water activity range of 0.29 ± 0.008 is the lowest, which can be beneficial for the stability and durability of the product. In addition, the pH values are similar in all the options provided; therefore, they do not provide a significant differential in the choice. Flour with crude protein content of 6.99 ± 0.28% has the highest value, which may be relevant if protein is an important factor for the final product. Flours with higher lipid contents (2.19 ± 0.52% and 2.58 ± 0.39%) can provide a texture and flavor of greater acceptance. Avocado seed flour dried at 60 °C has the highest percentage of carbohydrates (87.95 ± 0.75%), the lowest acidity (5.92 ± 0.89%), soluble solids of 2.2 ± 0.00 brix° and a water content of 1.66 ± 0.57%. In addition, it has an ash content of 0.117 ± 0.009%. Therefore, considering these characteristics, flour obtained at 60 °C is the best option for food production.

CONCLUSIONS

The flours analyzed in this study have physicochemical characteristics that make them potentially suitable for food formulations and the development of new products. Another relevant aspect is the low moisture of the flours, which contributes to the conservation, quality of the product, convenient handling and the success of the production processes of various formulations.

It can be inferred that flour derived from avocado seeds presents itself as a promising option for food supplementation, with potential to be used in the development of new food products. In addition, avocado seed flour has significant nutritional value and plays a key role in reducing waste from agro-industrial waste.

REFERENCES

1. Aguiar, J., Pandolfi, M. A. C., & Estracine, L. T. (2020). Avocado oil market analysis. *Revista Interface Tecnológica, 17*(1), 352–362.

2. Alissa, K., Hung, Y., Hou, C. H., Lim, G. C. W., & Ciou, J. Y. (2020). Developing new health material: The utilization of spray drying technology on avocado (*Persea americana* Mill.) seed powder. *Foods, 9*(2), 139. https://doi.org/10.3390/foods9020139

3. Amado, D. A. V., Helmann, G. A. B., Detoni, A. M., Carvalho, S. L. C., Aguiar, C. M., Martin, C. A., Tiuman, T. S., & Cottica, S. M. (2019). Antioxidant and antibacterial activity and preliminary toxicity analysis of four varieties of avocado (*Persea americana* Mill.). *Brazilian Journal of Food Technology, 22*, e2018097. https://doi.org/10.1590/1981-6723.09718

4. Araújo, R. G., Rodriguez-Jasso, R. M., Ruiz, H. A., Pintado, M. M. E., & Aguilar, C. N. (2018). Avocado by-products: Nutritional and functional properties. *Trends in Food Science & Technology, 80*, 51–60. https://doi.org/10.1016/j.tifs.2018.07.027

5. Avocados from Brazil. (2019). Different types of avocado – Crops and recipes. https://abacatesdobrasil.org.br/

6. Bangar, S. P., Dunno, K., Dhull, S. B., Siroha, A. K., Changan, S., Maqsood, S., & Rusu, A. V. (2022). Avocado seed discoveries: Chemical composition, biological properties, and industrial food applications. *Food Chemistry, 10*(16), 1–14. https://doi.org/10.1016/j.fochx.2022.100153

7. Baptistella, C. S. L., & Coelho, P. J. (2019, March 25). Avocado in the State of São Paulo: 2009 to 2018. São Paulo: Governo do Estado. http://www.iea.sp.gov.br/out/TerTexto.php?codTexto=14581

8. Barbosa, T. A., & Lobato, F. S. (2016). Determination of drying kinetics of food products using genetic algorithms. *Journal of Neotropical Agriculture, 3*(3), 28–37.

9. Baruffaldi, R., & Oliveira, M. N. (1998). *Fundamentals of food technology* (3rd ed.). Atheneu Editora.

10. Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology, 37*(8), 911–917. https://doi.org/10.1139/o59-099

11. Booth, S. (2020, July 14). Avocado. *WebMD*. https://www.webmd.com/food-recipes/all-about-avocados

12. Brazil, Ministry of Health. (2005). *RDC Resolution No. 263, of September 22, 2005: Technical Regulation for cereals, starches, flour and bran products*. http://www.planalto.gov.br

13. Caro, D., Alessandrini, A., Sporchia, F., & Borghesi, S. (2021). Global virtual water trade of avocado. *Journal of Cleaner Production, 285*, 124917. https://doi.org/10.1016/j.jclepro.2020.124917

14. CEAGESP. (2015). Classification standards. *Brazilian Program for the Modernization of Horticulture, 13*(1).

15. Chisenga, S. M., Workneh, T. S., Bultosa, G., & Alimi, B. A. (2019). Progress in research and applications of cassava flour and starch: A review. *Journal of Food Science and Technology, 56*(6), 2799–2813. https://doi.org/10.1007/s13197-019-03814-7

16. Coelho, O. V. (2014). Influence of bakery additives on the bioaccessibility of wheat bread minerals [Master's dissertation, FCT/UFNL]. Lisbon.

17. Cole, M. B., Augustin, M. A., Robertson, M. J., & Manners, J. M. (2018). The science of food security. *npj Science of Food, 2*(1), 14. https://doi.org/10.1038/s41538-018-0021-9

18. Daihan, S., Aldbass, A. M., Alotebi, L. M., & Bhat, R. S. (2016). Antioxidant and antimicrobial activity of whole seed extracts of *Persea americana* Mill. *Indian Journal of Pharmaceutical and Biological Research, 4*(4), 15–18. https://doi.org/10.30750/ijpbr.4.4.3

19. Defraeye, T. (2017). When to stop drying fruit: Insights from hygrothermal modelling. *Applied Thermal Engineering, 110*, 1128–1136. https://doi.org/10.1016/j.applthermaleng.2016.09.008

20. Dincer, İ., & Zamfirescu, C. (2016). *Drying phenomena: Theory and applications*. John Wiley & Sons.

21. Ezeagu, M. B., Ejiofor, N. C., Ayoola, I. E., & Umera, E. A. (2018). Determination of the chemical composition of avocado (*Persea americana*) seed. *Advance Journal of Food Technology & Nutrition Sciences*, 51–55.

22. FAO - Food and Agriculture Organization. (2017). *Food and agricultural commodities production*. http://faostat.fao.org/site/567/desktopdefault.aspx?pageid=567#ancor

23. Fellows, P. J. (2006). *Food processing technology: Principles and practice* (2nd ed.). Artmed.

24. Ferrari, R. A. (2015). Physicochemical characterization of avocado oil extracted by centrifugation and processing by-products. *Brazilian Journal of Food Technology, 18*(1), 79–84. https://doi.org/10.1590/1981-6723.0114

25. Figueroa, J. G., Linares, I. B., Sánchez, J. L., & Carretero, A. S. (2018). Comprehensive characterization of phenolic and other polar compounds in the seed and seed coat of avocado in HPLC-DAD-ESI-QTOF-MS. *Food Research International, 105*, 752–763. https://doi.org/10.1016/j.foodres.2017.11.082

26. Fijalkowska, A., Nowacka, M., Wiktor, A., Sledz, M., & Witrowa-Rajchert, D. (2016). Ultrasound as a pretreatment method to improve drying kinetics and sensory properties of dried apple. *Journal of Food Process Engineering, 39*(3), 256–265. https://doi.org/10.1111/jfpe.12217

27. Freitas, L. S., Dutra, C. S. Y., Medeiros, M. B. O. de, Rodrigues, A. R. P., & Lima, D. C. M. (2021). Obtaining and physicochemical characterization of avocado seed flour for addition to cakes. *Cadernos UniFOA, 16*(45).

28. Gomes, M. S., Fraga, S., Moura, N. F., & Silva, R. S. (2016). Use of banana peels for the production of flour and application as an ingredient in cakes. *Annals of the XXV Brazilian Congress of Food Science and Technology*.

29. Goneli, A. L. D., Corrêa, P. C., Magalhães, F. E. A., & Oliveira, G. H. H. (2014). Mathematical modeling and effective diffusivity of mastic leaves during drying. *Pesquisa Agropecuária Tropical, 44*(1), 56–64. https://doi.org/10.1590/S1983-40632014000100009

30. IAL - Instituto Adolfo Lutz. (2008). *Analytical standards of the Adolfo Lutz Institute: Chemical and physical methods for food analysis* (4th ed.). IAL.

31. Knight, R. J. (2002). History, distribution and uses. In A. W. Whiley, B. Schaffer, & B. N. Wolstenholme (Eds.), *The avocado: Botany, production, and uses* (pp. 1–12). CABI Publishing.

32. Koller, O. C. (1984). *Tobacco growing*. Editora da Universidade/UFGRS.

33. Leonardi, J. G., & Azevedo, B. M. (2018). Food preservation methods. *Saúde em Foco Magazine, 10*.

34. Lobato, R., Sousa, M., Landim, L., & Bezerra, K. (2021). Potential of avocado seed flour in the development of food products: A literature review. *Scientific Archives Journal, 4*(1), 33–37.

35. Macena, J. F. F., Souza, J. C. A. D., Camilloto, G. P., & Cruz, R. S. (2020). Physico-chemical, morphological and technological properties of the avocado (*Persea americana* Mill. cv. Hass) seed starch. *Ciência e Agrotecnologia, 44*, e008620. https://doi.org/10.1590/1413-7054202044008620

36. Mahmassani, H. A., Avgerinos, E. E., Raman, G., & Johnson, E. J. (2018). Avocado consumption and risk factors for heart disease: A systematic review and meta-analysis. *The American Journal of Clinical Nutrition, 107*(4), 523–536. https://doi.org/10.1093/ajcn/nqx078

37. Marques, A. R. (2022). Effects of freeze-dried flour from avocado seed (*Persea americana*) in mice fed a high-fat diet [Scientific work].

38. McCarthy, U., Uysal, I., Badia-Melis, R., Mercier, S., O'Donnell, C., & Ktenioudaki, A. (2018). Global food security—Issues, challenges and technological solutions. *Trends in Food Science & Technology, 77*, 11–20. https://doi.org/10.1016/j.tifs.2018.05.002

39. Mendonça, A. P., Sampaio, P. D. T., Almeida, F. D. A., Ferreira, R. F., & Novais, J. M. (2015). Determination of drying curves of crabwood in solar dryer. *Brazilian Journal of Agricultural and Environmental Engineering, 19*(4), 382–387. https://doi.org/10.1590/1807-1929/agriambi.v19n4p382-387

40. Mora-Sandí, A., Ramírez-González, A., Castillo-Henríquez, L., Lopretti-Correa, M., & Vega-Baudrit, J. R. (2021). *Persea americana* agro-industrial waste biorefinery for sustainable high-value-added products. *Polymers, 13*(11), 1727. https://doi.org/10.3390/polym13111727

41. Mouco, M. A. C., & Lima, M. A. C. (2014). Plant regulators in the management of avocado production and quality in the Brazilian semi-arid region. Embrapa Semiárido - *Research and Development Bulletin*, 23.

42. Moura, B. D. (2016). Rotary dryer with intermittent feeding [Thesis]. Federal University of Rio Grande do Norte.

43. Nascimento, M. R. F., Souza, V. F. de, Bomdespacho, L. de Q., & Ascheri, J. L. R. (2017). Fatty acid profile in the oil extracted from the flours of jackfruit seeds (*Artocarpus integrifolia* L.), avocado (*Persea gratissima* Gaertner F.), and seriguela (*Spondias purpurea* L.). *Blucher Chemical Engineering Proceedings, 1*(4), 88–93.

44. Nascimento, M. R. F., Souza, V. F. de, Marinho, A. F., Ascheri, J. L. R., & Meleiro, C. H. de A. (2016). Centesimal composition and minerals of avocado seed flour (*Persea gratissima* Gaertner F.). *Embrapa Food Agroindustry - Brazilian Congress of Food Science and Technology*.

45. Oliveira, E. C. M. (2017). Determination of the dispersion coefficient of a channel for validation of a computational fluid dynamics (CFD) software [Scientific work]. State University of Campinas, Faculty of Technology.

46. Ong, E. S., Low, J., Tan, J. C. W., Foo, S. Y., & Leo, C. H. (2022). Valorization of avocado seeds with antioxidant capacity using pressurized hot water extraction. *Scientific Reports, 12*(1), 1766. https://doi.org/10.1038/s41598-022-05514-5

47. Onwude, D. I., Hashim, N., Janius, R. B., Nawi, N. M., & Abdan, K. (2016). Modeling the thin-layer drying of fruits and vegetables: A review. *Comprehensive Reviews in Food Science and Food Safety, 15*(3), 599–618. https://doi.org/10.1111/1541-4337.12196

48. Parise, T. D., & Coser, P. (2020). Wholemeal biscuits: Pertinent legislation and consumer perception. *Food, Nutrition and Health, 15*, 1–11.

49. Peixoto, M. (2018). Food losses and waste: International panorama and legislative propositions in Brazil. *Food waste: Old habits, new challenges, 134*.

50. Santos, N. C., Barros, S. L., Monteiro, S. S., Silva, S. N., Ribeiro, V. H. A., Silva, V. M. A., Gomes, J. P., Santiago, A. M., Luiz, M. R., Vieira, D. M., Araujo, R. D., Vilar, S. B. O., & Barros, E. R. (2019b). Kinetics of drying and physical-chemical quality of peach cv. Hubimel. *Journal of Agricultural Science, 11*(16), 223–232. https://doi.org/10.5539/jas.v11n16p223

51. Santos, N. C., Barros, S. L., Silva, S. N., Ribeiro, V. H. A., Melo, M. O. P., Silva, W. P., Almeida, R. L. J., Pereira, T. S., Araújo, A. J. B., Gomes, J. P., Nascimento, A. P. S., Silva, V. M. A., & Vieira, D. M. (2019a). Physico-chemical characterization and kinetics of drying of organic yellow bell pepper (*Capsicum annuum* L.). *African Journal of Agricultural Research, 14*(29), 1247–1253. https://doi.org/10.5897/AJAR2019.14006

52. Silva, F. A. S., & Azevedo, C. A. V. (2016). The Assistat software version 7.7 and its use in the analysis of experimental data. *African Journal of Agricultural Research, 11*(39), 3733–3740. https://doi.org/10.5897/AJAR2016.11522

53. Silva, I. G., Andrade, A. P. C., Silva, L. M. R., & Gomes, D. S. (2019). Elaboration and sensory analysis of cookies made from avocado lump flour. *Brazilian Journal of Food Technology, 22*, e2018064. https://doi.org/10.1590/1981-6723.06418

54. Silva, J. C. C. (2019). Elaboration of a cookie added with jackfruit seed flour and vegan dulce de leche: Physical and sensorial evaluation [Bachelor's thesis, Federal University of Campina Grande]. Cuité, Paraíba.

55. Silva, L. A., Resende, O., Virgolino, Z. Z., Bessa, J. F. V., Morais, W. A., & Vidal, V. M. (2015). Drying kinetics and effective diffusivity in genipap leaves (*Genipa americana* L.). *Brazilian Journal of Medicinal Plants, 17*(4), 953–963. https://doi.org/10.1590/1983-084X/14_075

56. TACO - Brazilian Food Composition Table. (2011). *Brazilian food composition table* (4th ed.).

57. Tomé, P. P. (2020). Development of avocado flour and a technological application [Scientific study]. Caxias do Sul.

58. Viana, L. M., Pires, C. V., Macedo, M. C. C., Trombete, F. M., & Silva, L. S. (2019). Aspects of the quality of artisanal cassava flours (*Manihot esculenta* Crantz) produced in the municipality of Santana de Pirapama/MG. *Enciclopédia Biosfera, 16*(30), 23–37.

59. Vieira, B. M., & Moraes, B. K. B. (2019). Determination of the centesimal composition of avocado seed flour [Scientific study].

60. Zanoelo, E. F., Celso, G. M., & Kaskantzis, G. (2007). Drying kinetics of mate leaves in a packed bed dryer. *Biosystems Engineering, 96*(4), 487–494. https://doi.org/10.1016/j.biosystemseng.2006.12.006

61. Zhang, L., Liu, T., Xue, Y., Liu, C., Ru, H., Dong, M., & Yu, Z. (2016). Effects of drying methods on the aroma components and quality of *Capsella bursa-pastoris* L. *Journal of Food Process Engineering, 39*(2), 107–120. https://doi.org/10.1111/jfpe.12202