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Production, fortification, stabilization, and physical-chemical characterization of peanut batter local in Mozambique

Produção, fortificação, estabilização e caracterização físico-química da pasta de amendoim local em Moçambique

Producción, fortificación, estabilización y caracterización físico-química de la pasta de maní local en Mozambique

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Felizardo Severino Paulo[1]
ORCID : https://orcid.org/0009-0008-5609-8584
Southwest Bahia State University, Brazil
Eduardo Mondlane University, Mozambique
Email: felizsepa@gmail.com
Pérsio John de Jesus[2]
ORCID: https://orcid.org/0009-0009-4785-6635
Eduardo Mondlane University, Mozambique
Southwest Bahia State University, Brazil
E-mail: persio.dejesus@uem.ac.mz
José da Cruz Francisco[3]
ORCID: https://orcid.org/0009-0009-7220-6597
Eduardo Mondlane University, Mozambique
E-mail: jose_dacruz@yahoo.com

Abstract
This investigation aimed to use vitamin A as a fortifying agent and hydrogenated palmitic acid as a stabilizer to fortify, stabilize, and perform physicochemical characterization of peanut butter. The stabilizer and the fortifying agent were manually added to the produced peanut butter and then homogenized. Each formulation: plain (F1), with salt (F2), with sugar (F3), and with a mixture of sugar and salt (F4), was prepared in triplicate, both stabilized and non-stabilized, to measure of the following parameters: moisture, water activity, ash, lipids, proteins, carbohydrates, and metabolizable energy. The results indicated an optimal fortification level achieved at the second and third levels of fortifier addition, and good stability was obtained with a 3% level of stabilizer. Physicochemical analyses yielded the following average results: moisture 1.40%, ash 1.00%, proteins 25.24%, lipids 50.86%, and carbohydrates 21.51%. The average metabolizable energy was 2727.20 kcal/kg. The water activity before the addition of the stabilizer was 0.71, 0.57, 0.54, and 0.53 for formulations F1, F2, F3, and F4, respectively; after stabilization, water activity was 0.13, 0.13, 0.13, and 0.12 for F1F, F2F, F3F, and F4F, respectively. Fortification levels of 29 mg/kg and 43 mg/kg allowed for the maintenance of fortifier contents above the minimum stipulated by Mozambican law for fortified foods.
Keywords: Peanut butter; Fortification; Stabilization; Vitamin A; Water activity.

Resumo
Esta pesquisa foi realizada com o objetivo de fortificar, estabilizar e fazer a caracterização físico-química a pasta de amendoim, usando ácido palmítico hidrogenado para a estabilização e vitamina A para a fortificação. A pasta de amendoim produzida adicionou-se manualmente o estabilizante e o fortificante em seguida homogeneizou-se. Foram coletadas em triplicata cada formulação simples(F1), com sal(F2), com açúcar(F3) e mistura de açúcar e sal(F4)) estabilizada e não estabilizada para determinação dos parâmetros: Umidade, actividade da água, cinzas, lipídeos, proteínas, carboidratos e energia metabolizável. Os resultados, obtidos indicam um nível de fortificação óptimo conseguido no segundo e terceiro níveis de adição do fortificante e atingiu-se boa estabilidade com um nível de 3% do estabilizante. Os resultados das análises físico-químicas em média foram: Umidade 1.40%, cinzas 1.00%, proteínas

[1] Southwest Bahia State University, Vitória da Conquista, Bahia, Brazil; Eduardo Mondlane University, Maputo, Maputo City, Mozambique.
[2] Eduardo Mondlane University – ESUDER, Mozambique; Southwest Bahia State University, Vitória da Conquista, Bahia, Brazil.
[3] Eduardo Mondlane University, Maputo, Maputo City, Mozambique.

25.24%, lipídeos 50.86%, carboidratos 21,51%. A energia metabolizável média foi de 2727.20kcal/kg. A atividade de água antes da adição do estabilizante foi de 0.71, 0.57, 0.54 para as formulações F1, F2, F3 e F4, respectivamente, e depois da estabilização foi de 0.13, 0.13, 0.13 2e 0.12 para as F1F, F2F, F3F e F4F, respectivamente. Com os níveis de fortificação de 29mg/kg e 43mg/kg conseguiu-se manter teores de fortificante acima do nível mínimo permitido pela legislação moçambicana para alimentos fortificados.
Palavras-chave: Amendoim; Pasta; Fortificação; Estabilização; Vitamina A; Actividade de água.

Resumen
Esta investigación se realizó con el objetivo de fortificar, estabilizar y realizar la caracterización físico-química de la pasta de maní, se utilizó ácido palmítico hidrogenado para la estabilización y vitamina A para la fortificación. La pasta de maní elaborada fue añadida manualmente al estabilizante y fortificante, y posteriormente se homogeneizó. Se recolectaron por triplicado cada una de las formulaciones simples (F1), con sal (F2), con azúcar (F3) y con mezcla de azúcar y sal (F4), tanto estabilizadas como no estabilizadas, para la determinación de los siguientes parámetros: humedad, actividad del agua, cenizas, lípidos, proteínas, carbohidratos y calorías. Los hallazgos indican un nivel óptimo de fortificación en los segundos y tercer niveles de adición del fortificante, y se alcanzó una estabilidad óptima con un nivel del 3% de estabilizante. Los resultados promedio de los análisis físico-químicos fueron: humedad 1,40%, cenizas 1,00%, proteínas 25,24%, lípidos 50,86%, carbohidratos 21,51%. Las calorías promedios fueron de 2727,20 kcal/kg. La actividad del agua antes de la adición del estabilizante fue de 0,71, 0,57 y 0,54 para las formulaciones F1, F2, F3 y F4, respectivamente; y después de la estabilización fue de 0,13, 0,13, 0,13 y 0,12 para las F1F, F2F, F3F y F4F, respectivamente. Con los niveles de fortificación de 29 mg/kg y 43 mg/kg, se consiguió mantener niveles de fortificante superiores al mínimo permitido por la ley de Mozambique para alimentos fortificados.
Palabras clave: Pasta de maní; Fortificación; Estabilización; Vitamina A; Actividad del agua.

1. Introduction

Peanut butter or peanut creams, popularly known as products obtained from roasted and crushed peanuts, which can be added with other ingredients to enhance flavor and texture (Bodan, 2021).

Peanut butter is a product that composed of lipids, proteins, carbohydrates and a smaller percentage of water. When these components are blended, the fat globules tend to cluster, causing phase separation of the liquid phase, known as buttermilk.

Lipid is the main component of the peanut butter, which also contains water, proteins, vitamins, acids, lactose and solids, making it a product with high nutritional value.

To this day, populations with food insecurity still exist globally and particularly in Mozambique, where approximately 37% of children under the age of five suffer from chronic malnutrition, especially in the provinces of Nampula, Cabo Delgado, and Zambézia, which have malnutrition rates of 47%, 45%, and 44%, respectively (Instituto Nacional de Estatística [INE], The DHS Program & ICF, 2023).

Food scarcity leads to the primary concern being simply having food, without regard for whether the food is rich in proteins and vitamins—especially among low-income populations facing hidden hunger caused by micronutrient deficiencies, particularly vitamin A (Institute of Medicine, 2001). The lack of this micronutrient is considered a public health problem (Castro et al., 2023).

Due to their wide availability and low cost, peanuts play an important role in Mozambique's diets. The inclusion of peanut butter fortified with vitamin A, can minimize this deficiency, in addition to enriching the diet. Vitamins are organic substances required, in very small amounts, for many essential bodily processes. Generally, only a few milligrams (mg) or micrograms (μg) per day are needed, but these amounts are essential for health. Most vitamins cannot be synthesized by human body, and as is the case with vitamin A, which is obtained from food (EFSA, 2015). In the case of Mozambique, a lot of money is spent trying to solve problems related to malnutrition. Efforts have been made to supplement children with vitamin A drops. However, the problems prevail not only in children but also in adults. On the other hand, it is mandatory to fortify foods such as cooking oil, for human and animal consumption, produced, marketed and imported in accordance with the

Mozambican Standards in force (Conselho de Ministros, Decreto n.º 9/2016).

Despite the lack of statistical data, the presence of peanut butter on supermarket shelves in Mozambique suggests that large quantities of peanut butter are consumed in various forms. One of the technological challenges of peanut butter that are mainly composed of lipids and proteins is syneresis, caused by the low miscibility between proteins and lipids, and one of forms of control the syneresis in peanut butter is modifying the particle size or using stabilizers such as mono- and diglycerides of palmitic acid.

By fortifying locally produced peanut butter, consumers will be minimizing their vitamin A deficiency and there may also be a balance in the prices of the product on the national market, enabling a better supply to consumers, consequently reducing malnutrition problems, minimizing the import of this product, a possible export and consequent contribution to improving the country's economy.

In this context, the present research aims to evaluate the effect of the addition of hydrogenated palmitic acid on the stabilization and levels of vitamin A for the fortification of peanut butter.

2. Methodology

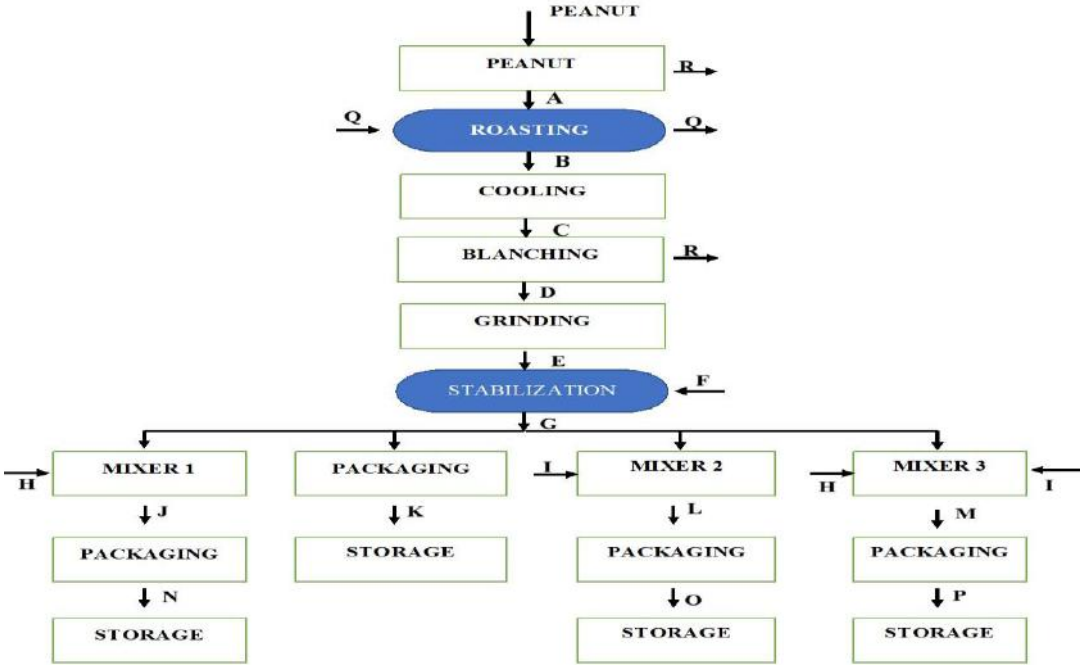
The study was conducted in the province of Maputo, in the municipality of Matola, within the scope of solving a specific problem in a small food industry. The municipality of Matola is bordered to the northwest and north by the District of Moamba , to the west and southwest by the District of Boane , to the south and east by the city of Maputo and to the northeast by the District of Marracuene (https://www.pmaputo.gov.mz/por/A-Provincia/Perfis-Distritais/Matola).

The raw material was acquired on the national market through a supplier of peanut grains (*Arachis hypogaea* L.) used in the production of peanut butter. The activities of this company follow the management of quality programs, that is, Good Manufacturing Practices.

The analyses were carried out at the Engineering Faculty and at the Water and Hygiene Laboratory of Mozambique.

The fortifier used was vitamin A 100,000 IU, produced and supplied by Laboratoires Sterop Laboratoria, located at Scheut 46-50 Avenue, Scheutlaan Bruxelles 1070 Brussel- Belgium. The stabilizer used was palmitic acid which is a combination of Tri-, Mono- and Diglyceride supplied by TARCH which is a distributor of food and pharmaceutical ingredients. The iodized salt and sugar used for the formulations was purchased from the local supermarket.

Figure 1 - Flowchart of peanut butter preparation.



Where: A = Raw and cleaned peanuts; B = Hot roasted peanuts; C = Roasted peanuts cooled at room temperature; D = Roasted and cleaned peanuts; E =, Unstabilized and plain peanut butter; F = Stabilizer + Fortifier; G = Stabilized and plain peanut butter; H = Salt; I = Sugar; J = Salted peanut butter; K = Plain peanut butter; L = Sweetened peanut butter; M = Sweetened and salted peanut butter; N = Packaged salted peanut butter; O = Packaged sweetened peanut butter; P = Packaged sweetened and salted peanut butter; Q = Heat; R = Impurity.
Source: Authors.

2.1 Roasting

Peanut roasting is a thermal process applied before grinding, with the purpose of intensifying the flavor, aroma and color of the peanut by inducing complex chemical reactions, such as the Maillard reaction (Sithole et al, 2022).

In the industry, the roasting stage is currently performed either dry or in oil, using batches, continuous lines or rotary ovens (Bondan, 2021).

In this study, during the initial days of the roasting experiment, peanuts were roasted using traditional methods and the limited equipment available to the company, as illustrated in Figure 2a. With the installation of the conventional oven, the roasting began to be carred out using o conventional method with good efficiency and uniformity of the roasted peanuts. This conventional oven was provided by partners who supported the small producer in acquiring and assembling standard of conventional equipment, as illustrated in Figure 2b.

The samples analyzed in this study were those roasted using the conventional oven, as it ensured better uniformity in the product and in the physicochemical properties, which are probably associated with trends in phase separation of peanut butter.

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Figure 2 - Roasting peanuts for analysis. a) Traditional method. b) Conventional method.

a) b)

Source: Authors.

The roasting was carried out according to the methodology described by Shrestha (2017), with some modification which consisted of changing the operating temperature from 150 ° C to 160 ° C. The traditional roaster has a capacity of 5 kg and the roasting takes approximately 30 minutes on average for each operation, while the industrial roaster has a capacity of 25 kg and the roasting takes around 10 minutes each operation.

In the traditional process, firewood was used as the energy source for roasting. The roaster was placed over the fire, the cleaned peanuts were added, and stirring constantly until the peanuts were roasted which took about 30 minutes, then roaster was removed and peanuts ware poured a sieve and left to cool at room temperature.

In the conventional process, the oven was turned on, the temperature was adjusted to 160ºC, and the cleaned peanuts were introduced at the top of the oven and the door was closed for 10 minutes. Roasting lasted 10 minutes, starting after the temperature had stabilized. The oven was then opened at the bottom, and the peanuts were removed and cooled. In both processes, batch operation was used. The duration of the roasting operation is influenced by heat losses to the environment, as is the case in the traditional process (Fellows, 2017).

2.2 Peeling

Peeling of roasted peanuts is the mechanical process of removing the skin that covers the kernel after roasting. Peeling was preformed using both household and industrial methods as shown in Figure 3.

Figure 3 - a) Peeling machine. b) Peanuts peeled using the conventional method.

Source: Authors.

Peeling consisted of rubbing the peanuts manually using a cylindrical stick and sieving them. Conventional peeling consisted of placing the roasted peanuts on top of the peeler.

Formulations:

The formulations were prepared according to Table 1, which presents the operational parameters and percentages of the ingredients in each formulation.

Table 1 - Percentage of ingredients, temperature and time of peanut roasting.

Formulation	Ingredients	Temperature (º C)	Time (me)
F1	-	160	10
F2	1% salt	160	10
F3	1% sugar	160	10
F4	1% salt + 1% sugar	160	10

Source Authors.

2.3 Grinding

The homemade colloidal mill was turned on, and clean water was passed through for washing. Then, peanuts were introduced and ground until the butter was formed, as illustrated in Figure 4. This step is very important and must be well controlled to ensure the rheological profile of the butter (Sithole et al, 2022).

Figure 4 -Peanut processing in the colloidal mill**.**

Source: Authors.

2.3.1 Quantification of vitamin A

The vitamin A content in the butter was quantified according to the methodology of (Rodriguez - Amaya, 2 001). Absorbance readings ware preformed using an Agilent Technologies Cary 60 UV-Vis spectrophotometer (S/N: MY13320011, manufactured in Malaysia, 2011), at a wavelength of 470 nm. The vitamin A content was quantified using Equation 1:

$$\frac{\mu g \text{ Vitamin A}}{g \text{ of butter}} = \frac{AxVx10^{6}}{A^{1\%}xMx10} \quad (1)$$

Where: A = absorbance of the solution at 470 nm; V = final volume of the solution; A $^{1\%}$ 1cm is the extinction coefficient or molar absorptivity coefficient of a pigment in a specific solvent; M = mass of the sample used in the analysis; for vitamin A in petroleum ether, the value of the extinction coefficient value is 3450.

2.3.2 Evaluation of vitamin A recovery

Vitamin A recovery in the samples was evaluated using equation 2:

$$\%\text{recovery rate of vitamin A} = \frac{\text{Amount of Vitamin A in the sample}\left(\mu\frac{gRE}{g}\right)}{\text{Vitamin A added}\left(\mu\frac{gRE}{g}\right)} \times 100\% \quad (2)$$

2.4 Moisture Determination

A total of 3g of sample was weighed in previously tared crucibles and placed in an oven with air circulation at 105ºC for 6 hours according to AOAC (1995).

2.5 Ash Determination

Ash content was determined after incineration of the samples used moisture determination, in a muffle furnace at 550ºC for 6 hours according to AOAC (1995) as cited by Park and António (2006).

2.6 Protein Determination

Protein content was determined using the Kjeldahl method, which involves three steps: sample digestion in sulfuric

acid (H_2SO_4), release of ammonia (NH_4) by addition of sodium hydroxide (NaOH), and titration of ammonia with hydrochloric acid (HCl). A factor of 6.25 was used to convert the detected nitrogen into crude protein (AOAC, 2005; Park & António, 2006).

2.7 Determination of lipids

Lipids extraction was carried out using a Soxhlet for 8 hours followed by solvent evaporation of the solvent (AOAC, 2005; Nielsen, 2010a).

2.8 Carbohydrate content

Carbohydrate content was determined by difference. The percentage of moisture, proteins, lipids and ash ware calculated, and the remainder was considered carbohydrate according to AOAC (1997) cited by Boen *et al*. (2007).

2.9 Metabolizable Energy (ME)

Metabolizable energy was determined according to the methodology described by Gibney et al., (2009), using equation 3 which calculates caloric content from average values of carbohydrates, proteins and lipids.

ME (KJ/g) = (Proteins*17) + (Lipids*38) + (Carbohydrates*17), where 1Kcal = 4.2KJ (Eq.3).

2.10 Determination of water activity

It was determined by reading a water activity meter (AQUA LAB, series 3 TE from Decagon Devices).

2.11 Statistical data analysis

An analysis of variance (ANOVA) was performed using SAS statistical software. ANOVA was used to test for significant effects between treatments, and Tukey's test at 5% significance was applied for multiple comparisons of treatment means.

3. Results and Discussion

Characterization of the prepared formulations as shown in Table 2. These values are expressed as means s (n=3).

Table 2 - Physical-chemical and nutritional composition of peanut butter.

Analysis	Tratamentos				Global Means	P (value)	CV (%)
	F1	F2	F3	F4			
Moisture (%)	1.43[a]	1.39[a]	1.36 [a]	1.40 [a]	1.39	0.870	7.05
Ash (%)	0.97 [a]	1.02 [a]	1.03 [a]	0.99 [a]	1.00	0.467	5.11
Proteins (%)	25.93 [a]	24.68 [a]	25.73 [a]	24.63 [a]	25.24	0.008	1.63
lipids (%)	49.98 [b]	51.04 [ab]	50.51 [b]	51.89 [a]	50.86	0.001	0.70
Carbohydrates (%)	21.70 [a]	21.87 [a]	21.36 [a]	21.09 [a]	21.51	0.527	3.12
ME (Kcal/kg)	2708.80 [b]	2730.88 [ab]	2720.10[b]	2719.02 [a]	2727.20	0.001	0.28

Source: Authors.

Means followed by the same letter in the row do not differ from each other by Tukey 's test at 5% significance level. ME – metabolizable energy, Kcal – kilocalorie, CV – coefficient of variation.

Data on the composition of peanut butter in Mozambique were not found in the literature, for this reason, at times, Brazilian literature or regulations were used.

3.1 Moisture

The results of the peanut butter moisture content in Table 2, did not show significant differences between the four treatments, having presented approximately 1.39% moisture content on average. This percentage enables the butter to be microbiologically stable. According to Brazilian law, the amount of this percentage must be less than or equal to 8% for the sale of raw, peeled peanuts and products made from them (Lima; Saraiva; Souza, 2009); (ANVISA, 2020). It is also in accordance with that established by Normative Instruction (IN) No. 32 of 2016 (MAPA, 2016).

3.2 Ashes

The ash or mineral content did not show significant differences between the four treatments, having presented approximately 1.00% on average. This result is below the range proposed by NEPA (2011) and TBCA (2023), which indicate ash or mineral content in peanuts of approximately 2.06% to 2.2%.

3.3 Proteins

The protein content of peanut butter analyzed did not show significant differences among the four formulations, with an average of 25,242 %. This result demonstrates that peanut butter is a good source of plant-based proteins. Results reported by NEPA (2011), TBCA (2023) in a peanut sample, indicate that an expected protein percentage of approximately 25% to 27%.

3.4 lipids

The lipid content in formulations F1, F2 and F3 did not show significant differences among them, but formulation F4 showed statistically significant differences compared to formulations F1 and F3, while Formulations F2 and F4 did not differences between them. This difference may be attributed to the presence of salt for F2 and F4.

The higher lipid content in the salted peanut butter samples may be associated with the salting -out effect, as this effect may have promoted the precipitation of proteins and the consequent release of lipids that previously bound to these proteins, especially under low moisture conditions as in this study. The overall average lipid content was approximately 50.855%, which showed a difference from the composition presented by NEPA (2011), and TBCA (2023) for lipids content in peanuts is around 43% to 49%.

3.5 Carbohydrates

The carbohydrate content did not show significant differences among the four formulations, having been quantified around 21.09%. on average. This result is slightly above the range established by NEPA (2011) and TBCA (2023), which indicate a carbohydrate content of around 20%. Since the value was obtained by difference, and one of the parameters used in the equation showed differences, this may have contributed to the observed result.

3.6 Metabolizable Energy (ME)

Metabolizable energy or caloric value behaved as follows: formulations F1, F2, and F3 did not show significant differences among them, but formulation F4 showed statistically significant differences compared to F1 and F3, while F2 and

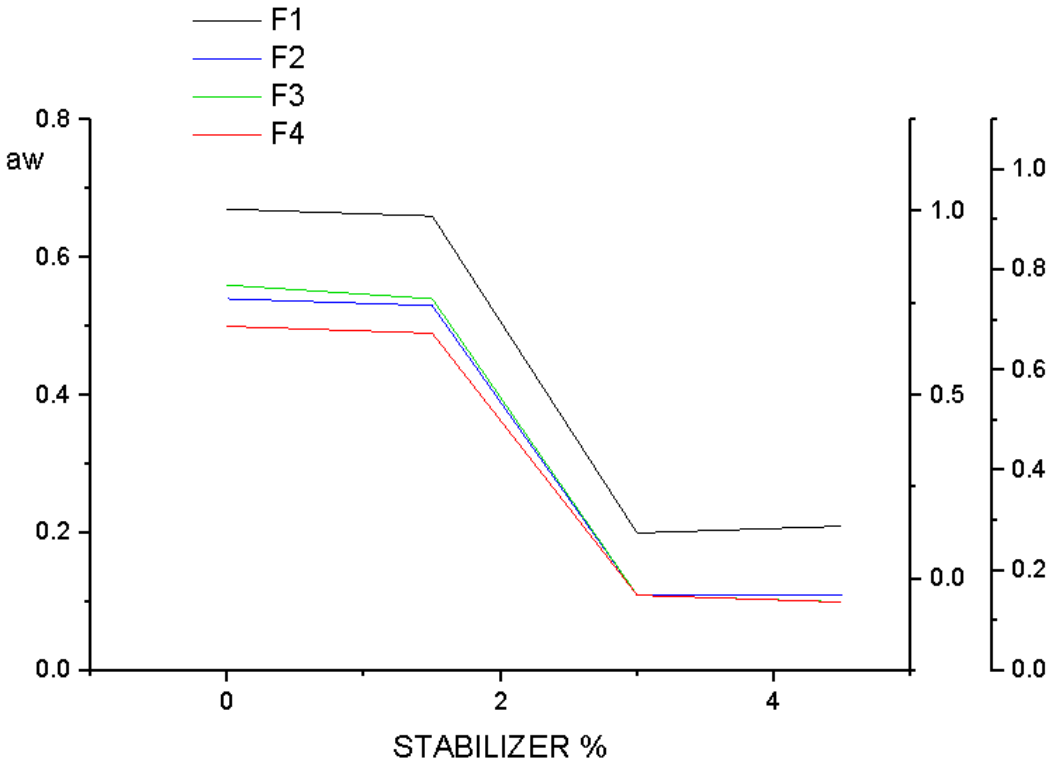
F4 did not differ significantly. These differences can be attributed to the constituents in formulations F2 and F4, as they presented higher lipid content, which has a higher coefficient in the metabolizable energy calculation (Gibney et al., 2009).

The overall average of metabolizable energy was 2727.20 kcal/kg, this value is below the values established by TBCA (2023) which indicate 5570 kcal/k. The differences found in this study in relation to the results for which the comparison was made may be associated with the differences in the characteristics of the sample matrices, since the comparison was made with studies carried out in different countries, with different climatic and soil conditions.

3.7 water activity

Graph 1 shows the behavior of water activity in the simple, salty, sweetened and the salt and sugar mixture butter. This graph shows the water activity behavior according to the level of fortifier in each formulation.

Graph 1 - Water activity as a function of stabilizer percentage.



Source: Authors.

The results show that with the addition of the stabilizer the water activity was considerably reduced, consequently leading to greater stability of the paste. From Graph 1, it is evident that in the range of 3% to 4.5%, the water activity remains nearly constant. This allows the use of a relatively low percentage of stabilizer without affecting the water activity and, thus, the stability of the product.

According to Rahman (2007), for a butter to be considered stable, the water activity value should be within the range of 0.50–0.60. If there is a need to extend the stability period of the product, conditions must be created to reduce the range of water activity values. In the results obtained in this study, the water activity values after stabilization were below this range, confirming the maintained stability of the peanut butter.

Table 3 - Moisture content and water activity of peanut butter in the first and eighth week.

Nalysis	Treatments							
	Week 1				Week 8			
	F1	F2	F3	F4	F1F	F2F	F3F	F4F
Aw	0.71±0.04[a]	0.57±0.03[b]	0.54±0.04[b]	0.50±0.01[b]	0.13±0.05[c]	0.13±0.05[c]	0.13±0.05[c]	0.12±0.04[c]
Umidity	1.43±0.06[c]	1.39±0.10[c]	1.34±0.12[c]	1.40±0.10[c]	1.76±0.05[b]	2.91±0.17[a]	2.76±0.03[a]	2.75±0.1[a]

Source: Authors.

The results of water activity before the addition of the stabilizer and fortifier, evaluated at the beginning of the study represented by the formulations (F1, F2, F3 and F4) and after stabilization with 3% of the stabilizer and fortified (F1F, F2F, F3F and F4F).

Formulation F3 (3%) was chosen for this stage because it was considered the most effective in stabilizing the butter, with an even lower percentage of stabilizer, as it promoted a significant decrease in water activity, suggesting that this condition provided a possible balance between the mechanisms of interaction of the stabilizer with the other constituents of the butter. The interaction between stabilizer and the constituents of the butter probably reduced the solubility of water molecules, due to the salting-out effect. Lipids, such as palmitic acid, which is a long-chain saturated acid, may have formed micelles and interacted hydrophobically with proteins and lipids present in the butter (Damodaran et al., 2010). This effect did not change even after 8 weeks; although moisture increased, water activity remained low, thus evidencing the effect of possible interactions between the stabilizer and the other constituents of the butter. On the other hand, moisture or water content is not directly related to food stability, but water activity can better explain stability (Rahman, 2007).

Table 4 - Vitamin A content in the three fortification levels and in the three packaging, evaluated in the first week and in the eighth week.

Treatment	Fortifying (mg/kg)	week 1	week 8
TVCC	15	14.33 ± 0.31[c]	11.10 ± 0.24[g]
TVCPL	15	14.11 ± 0.21[c]	4.74 ± 0.07[h]
TVCSCT	15	14.47 ± 0.36[c]	6.09 ± 0.15[i]
TVCC	29	27.784± 0.09[b]	21.52 ± 0.07[d]
TVCPL	29	27.31 ± 0.66[b]	9.17 ± 0.22[f]
TVCSCT	29	27.16 ± 0.15[b]	11.44 ± 0.06[e]
TVCC	49	41.57 ± 0.39[a]	32.20 ± 0.30[a]
TVCPL	49	42.31 ± 0.41[a]	14.20 ± 0.14[b]
TVCSCT	49	41.44 ± 0.60[a]	17.46 ± 0.25[c]

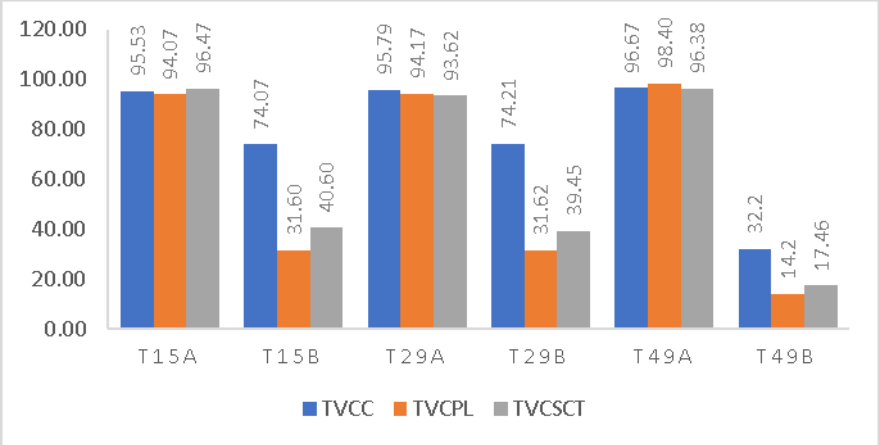
TVCC—Vitamin content in samples preserved in a suitable manner; TVCPL—Vitamin content in samples preserved in the presence of light; TVCSCT—Vitamin content in samples preserved without temperature control. Source: Authors.

The vitamin A content in the three fortification levels was as follows: in the first week after fortification, there were no statistically significant differences in the three treatments for each fortification level. The evaluation carried out in the 8th week showed significant differences in all fortification levels, and in all the three treatments behaved with the same trend,

where the TVCC treatment had greater preservation of the fortifier, followed by the TVCST treatment and the TVCC treatment had less preservation of the fortifier. Study carried out by Garcia e Penteado, (2004), points out the influence of packaging conditions on the stability of vitamin A.

Graph 2 shows the percentages of vitamin A retained at the beginning and end of the study at the three levels of fortification (minimum, medium and maximum) permitted by Mozambican regulations on the conditions of fortified foods. (Conselho de Ministros, Decreto n.º 9/2016).

Graph 2 - Percentage of retained vitamin A at the three fortification levels and under the three preservation conditions of the paste, evaluated at the first and eighth weeks.



Source: Authors.

With a level of 15mg/kg of fortifier addition, shown in the graph, it can be observed that the retained vitamin A content decreased by the end of the study. Considering the minimum fortifier quantity allowed by the current fortified foods regulation in Mozambique, which is at least 15 mg/kg, the retention reduction falls below the levels required by Mozambican legislation (Council of Ministers, Decree No. 9/2016).

The reduction in vitamin A content recorded not only results from the addition of a minimal quantity of the fortifier, but may also have been lost due to the instability of vitamin A triggered by subtle variations in the storage conditions of the product. This behavior is also observed in samples with intermediate and maximum fortification levels, as shown in Graph 2. Vitamin A retention in foods can be achieved in appreciable quantities if the processing and packaging of the product are controlled (EFSA, 2015).

According to the Graph 2, is observed that the samples preserved under controlled conditions presented higher retention rates at the all three fortification levels, while those stored under conditions with little light control and those stored without strict temperature control showed lower retention rates.

Study conducted by Garcia e Penteado, (2004) and EFSA (2015), indicates that vitamins are not stable throughout their shelf life. The parameters temperature, light and presence of oxygen must be controlled, as they affect vitamin stability (Guiamba, 2016)

4. Conclusion

Based on the data collected and analyzed in this study, it was possible to verify that the addition of 3% palmitic acid

for the stabilization of peanut butter solved the problem of phase separation tendency and also managed to reduce and maintain low the water activity of the peanut butter.

The results also showed that at medium and maximum levels allowed by Mozambican fortification regulations, vitamin A retention was above the minimum amount permitted by this regulation after 8 weeks of evaluation.

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References

ANVISA. (2020). Instrução Normativa - IN nº 75, de 8 de outubro de 2020: Estabelece os requisitos técnicos para declaração da rotulagem nutricional nos alimentos embalados. Diário Oficial da União.

AOAC. ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS Official. (1995). methods of analysis. (15th ed.). Washington.

Boen, T. R., Soeiro, B. T., Pereira Filho, E. R., & Lima-Pallone, J. A. (2007). Avaliação do teor de ferro e zinco e composição centesimal de farinhas de trigo e milho enriquecidas. *Revista Brasileira de Ciências Farmacêuticas*, 43, 4, www.scielo.br/scielo.php?pid=S1516...script=sci.

Bondan, M. B. (2021). Alternativas para incremento de novos atributos em pasta de amendoim conforme demanda do mercado de alimentos (Trabalho de conclusão de curso, Universidade Federal do Rio Grande do Sul).

Castro, I. R. R., dos Anjos, L. A., de Aquino Lacerda, E. M., Boccolini, C. S., Farias, D. R., Alves-Santos, N. H., Normando, P., de Freitas, M. B., Andrade, P. G., Bertoni, N., Schincaglia, R. M., Berti, T. L., Vertulli Carneiro, L. B., & Kac, G. (2023). Nutrition transition in Brazilian children under 5 years old from 2006 to 2019. *Cadernos de Saude Publica*, *39*(S2). https://doi.org/10.1590/0102-311XEN216622.

Conselho de Ministros. (2016). *Decreto n.º 9/2016, de 18 de abril: Aprova o Regulamento de Fortificação de Alimentos com Micronutrientes Industrialmente Processados*. Boletim da República, I Série, (46), 1–9. Imprensa Nacional de Moçambique. https://www.portaldogoverno.gov.mz/.

European Food Safety Authority. (2015). *Scientific opinion on dietary reference values for vitamin A: EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA)*. *EFSA Journal, 13*(3), 4028. https://doi.org/10.2903/j.efsa.2015.4028.

Damodaran, S., Parkin, K. L., & Fennema, O. R. (2010). *Química de alimentos de Fennema* (4ª ed., A. Brandelli et al., Trads.). Editora Artmed.

Fellows, P. (2017). Food Processing Technology: Principle and Pratice. Ed. 4. Woodhead. ISBN: 978-0-08-101907-8.USA.

Garcia, T., & Penteado, M. V. C. (2004). Qualidades de balas de gelatina fortificadas com vitaminas A, C e E. *Acervo - Artigo Científico*, 1–7.

Gibney, M. J., Lanham-New, S. A., Vorsten, H. H., & Cassidy, A. (2009). Introduction to human nutrition, 2nd edition. *The Nutrition Society* Text book Series, Wiley Black well, 31-33.

Guiamba, Isabel. (2016). *Nutritional value and quality of processed mango fruits*. Chalmers University of Technology.

Institute of Medicine. (2001). *Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc*. National Academy Press. https://doi.org/10.17226/10026.

Instituto Nacional de Estatística (INE), The DHS Program, & ICF. (2023). *Moçambique: Inquérito demográfico e de saúde 2022–23 – Relatório de indicadores-chave*. Maputo, Moçambique: INE; Rockville, Maryland, EUA: ICF.

Lima, J. R., Saraiva, S. C., & Sousa, A. V. (2009). Preparação e características de pastas de amêndoas de castanha de caju e amendoim. *Comunicado Técnico on-line*. https://www.embrapa.br/busca-de-publicacoes/-/publicacao/580691/preparacao-e-caracteristicas-de-pastas-de-amendoas-de-castanhade-caju-e-amendoim.

Ministério da Agricultura e Pecuária (MAPA). (2016). Instrução Normativa n° 32, de 24 de agosto de 2016: Estabelece o Regulamento Técnico do Amendoim em Casca e em Grãos, destinado à alimentação humana, definindo o seu padrão oficial de classificação, com os requisitos de identidade e qualidade, a amostragem, o modo de apresentação e a marcação ou rotulagem, nos aspectos referentes à classificação do produto. Diário Oficial da União.

Nielsen, S. S. (2010a). *Food analysis laboratory manual*, (2nd ed.). Pardue University, Springer, USA, 19-100.

Núcleo de Estudos e Pesquisas em Alimentação (NEPA). (2011). Tabela Brasileira de Composição de Alimentos (TACO) (164 p.). Universidade Estadual de Campinas – UNICAMP.

Park, K. J. & António, G. C. (2006). *Análises de materiais biológicos*. Universidade Estadual de Campinas, Faculdade de Engenharia Agrícola, pp2-17.

Pereira A. S. et al. (2018). Metodologia da pesquisa científica. [free e-book]. Editora daUAB/NTE/UFSM.

Rodriguez-Amaya, D. B. (2001). Guide to Carotenoids Analysis in Food; Washington: International Life Sciences Institute Press.
Rahman, M. S. (Ed.). (2007). *Handbook of food preservation* (2nd ed.). CRC Press.

Shitsuka et al. (2014). Matemática fundamental para a tecnologia. Editora Érica.

Shrestha, A. (2017). Roasting time-temperature optimization for preparation of peanut butter and study on its shelf life [Dissertação de mestrado, Tribhuvan University].

Sithole, T. R., Ma, Y.-X., Qin, Z., Liu, H.-M., & Wang, X.-D. (2022). Technical aspects of peanut butter production processes: Roasting and grinding processes review. Journal of Food Processing and Preservation, 46(4), 1–13.

Tabela Brasileira de Composição de Alimentos (TBCA). (2023). Tabela Brasileira de Composição de Alimentos. Universidade de São Paulo (USP). Food Research Center (FoRC). Versão 7.2. São Paulo, 2023. http://www.fcf.usp.br/tbca. http://www.tbca.net.br/.