

## **Cryoconcentrated soymilk and xanthan gum acted in stability of creamy sauce during storage**

**Extrato de soja crioconcentrado e goma xantana atuaram na estabilidade do molho cremoso durante o armazenamento**

**El extracto de soja crioconcentrado y la goma xantana actuaron en la estabilidad de la salsa cremosa durante el almacenamiento**

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### **Abstract**

The formation of an emulsion with reduced lipid content can cause instability in the product during storage, requiring adaptations in the formulation. The objective of this work was to analyze the stability of the creamy sauce of cryoconcentrated soymilk stored for 60 days. The creamy sauce was prepared and packed in polyethylene bottles, sealed with aluminum seals and kept at room temperature. In physicochemical analyzes was noticed that the proteins and ashes were similar in all the samples and small differences in moisture and lipids contents, the pH remained below 4.0 and the beginning of the lipid oxidation was not verified in the follow-up period. The color of sauce showed slight differences during storage, but it remained a clear food, with yellow and green color. The microstructure of creamy sauce stored for two months was not altered, presenting polydisperse structures, packed and very close. Thus, the efficiency of the associated use of soy proteins and xanthan gum in the formation and stabilization of the emulsion for 60 days was proven. Therefore, this creamy sauce can be an alternative to increase the consumption of soy proteins, in food with half the lipid level when compared to the traditional ones.

**Keywords:** Emulsion; Soy products; Microstructure; Proteins; Oil-water interface.

### **Resumo**

A formação de emulsão com reduzido teor lipídico pode ocasionar instabilidade do produto durante o armazenamento, necessitando de adaptações na formulação. O objetivo do trabalho foi analisar a estabilidade do molho cremoso de extrato de soja crioconcentrado armazenado por 60 dias. O molho cremoso elaborado foi acondicionado em frascos de polietileno, vedados com selos de alumínio e mantidos sob temperatura ambiente. Nas análises físico-químicas notou-se que as proteínas e cinzas foram similares em todas as amostras e pequenas diferenças em umidade e lipídios, o pH manteve-se menor que 4,0 e não foi verificado o início da oxidação lipídica no período de acompanhamento. A cor do molho apresentou pequenas diferenças durante a estocagem, mas continuou sendo um alimento claro de cor amarela e verde. A microestrutura do molho cremoso armazenado por dois meses não foi alterada, apresentando estruturas polidispersas, empacotadas e muito próximas. Sendo assim, a eficiência do uso associado das proteínas de soja e da goma xantana na formação e estabilização da emulsão durante 60 dias foi comprovada. Portanto, esse molho cremoso pode ser uma alternativa para aumentar o consumo de proteínas de soja, em um alimento com a metade do valor lipídico quando comparado aos tradicionais.

**Palavras-chave:** Emulsão; Produtos de soja; Microestrutura; Proteínas; Interface óleo-água.

## Resumen

La formación de emulsión con contenido de lípidos reducido puede provocar inestabilidad del producto durante el almacenamiento, requiriendo adaptaciones en la formulación. El objetivo de este trabajo fue analizar la estabilidad de la salsa cremosa de extracto de soja crioconcentrada almacenada durante 60 días. La salsa cremosa elaborada fue envasada en frascos de polietileno, sellados con precintos de aluminio y mantenidos a temperatura ambiente. En los análisis fisicoquímicos se observó que las proteínas y las cenizas eran similares en todas las muestras y pequeñas diferencias en la humedad y los lípidos, el pH se mantuvo por debajo de 4.0 y no se verificó el inicio de la oxidación de lípidos en el período de seguimiento. El color de la salsa mostró pequeñas diferencias durante el almacenamiento, pero siguió siendo un alimento amarillo claro y verde. La microestructura de la salsa cremosa almacenada durante dos meses no se alteró, mostrando estructuras polidispersas, empaquetadas y muy juntas. Así, se comprobó la eficacia del uso asociado de proteínas de soja y goma xantana en la formación y estabilización de la emulsión durante 60 días. Por tanto, esta salsa cremosa puede ser una alternativa para incrementar el consumo de proteínas de soja, en un alimento con la mitad del valor lipídico en comparación con los tradicionales.

**Palabras clave:** Emulsión; Productos de soja; Microestructura; Proteínas; Interfaz aceite-agua.

## 1. Introduction

Semi-solid oil-in-water emulsions, such as mayonnaise and other creamy sauces, contain 70 to 80% lipids. Traditionally its commercial preparation is carried out using, in addition to oil, egg yolk, vinegar, salt and spices, especially mustard (Nikzade, Tehrani & Tarzjan, 2012). The ingredients, their proportions and mixing method are factors that influence the stability of these foods. Egg yolk is the most critical component for the stability of mayonnaise, because it is rich in lecithin, which is a substance whose molecules have a polar end, which interacts with water, and another non-polar end, which interacts with oil, forming a water-in-oil dispersion (Krstonosic, Dokic, Nikolic & Milanovic, 2015).

The stability of the emulsions involves the prevention of coalescence of drops, flocculation and creaminess. Normally, creaminess is not a problem for mayonnaise with a high fat content, because the droplets are well grouped, and so they don't move. However, in reducing fat mayonnaise it is necessary to use some thickener to slow down the movement of the drop (Nikzade, et al., 2012).

By making an adequate substitution of fat in appropriate quantities, it is possible to obtain a product with a texture close to traditional mayonnaise (Liu, Xu & Guo, 2007). In order to obtain a creamy sauce with appropriate emulsion characteristics and high stability, several investigations were conducted, using proteins, starch, fibers and gums, such as xanthan and guar gum (Hedayati, Shahidi, Koocheki, Farahnaky & Majzoobi, 2020, Ruan, Yang, Zeng & Qi, 2019, Chang, Li, Li, Wang, Zhou, Su & Yang, 2017). The gum-protein interaction may play an important role in mayonnaise compared to the unique contribution of the individual polymer. Hedayati, et al. (2020), mention that the greater the amount of water absorbed by the emulsifying agents, the greater the viscosity of the continuous phase, preventing the collision of the droplets and the interaction between them, avoiding creaming.

Soy milk is a product of high nutritional value, rich in proteins, cholesterol and lactose free, low cost and easy to obtain, however, it has a high water level (Seibel, 2018). To reduce the amount of water, cryoconcentration can be applied, which process is based on the total freezing of a solution, followed by a partial defrosting procedure, using simple gravitational separation.

The reduction in the oil level, the removal of eggs and the incorporation of cryoconcentrated soy milk in the preparation of creamy sauce, can be an alternative of functional food, contributing to a nutritional gain, with decreased caloric value. Thus, the aim of this work was to analyze the stability of the creamy sauce of cryoconcentrated soy milk stored for 60 days at room temperature.

## 2. Methodology

The soy milk (SM) was prepared according to Seibel (2018) and the cryoconcentration was carried out in two steps,

according to Paulo, Silva & Seibel (2018), obtaining a concentration about six times in the total soluble solids content of the soymilk. The creamy sauce was prepared according to José, Paulo, Silva, Ida and Seibel (2020), it was packaged in polyethylene bottles, sealed with aluminum seals and kept at room temperature until carrying out the analyses to assess the stability of the elaborated product.

Moisture, ashes, lipids and proteins of creamy sauce of cryoconcentrated SM was carried out by AOAC (2016), carbohydrates were calculated by difference. The pH value of creamy sauce was obtained in the potentiometer with glass electrode (Tecnopon, model NT PHM). Titratable total acidity content was determined by titration with standardized 0.1 M sodium hydroxide solution and expressed in g of citric acid per 100 mL of sample. Water activity ( $a_w$ ) of creamy sauce was determined at  $25\text{ }^\circ\text{C} \pm 1$  using the electric hygrometer (AQUALAB 4TE, Decagon CX-2, Pullman, Unites States) calibrated with distilled water. Peroxide index was determined by dissolving the sauce in acetic acid : chloroform solution (3:2 v/v) and adding saturated solution of potassium iodide. After resting in the dark, the solution was titrated with 0.01 M sodium thiosulfate solution. The content of total soluble solids (TSS), expressed in  $^\circ\text{Brix}$ , was measured with a direct reading on the bench refractometer (type Abbe, Instrutherm, model RTA-100). Color analysis of creamy sauce was performed using a colorimeter (Konica Minolta CR 400s) and the result was expressed according to the CIELAB system. The equipment was calibrated using the calibration plate and the reading was performed in 10 different points of the creamy sauce of cryoconcentrated SM. The coordinates measured were:  $L^*$ ,  $a^*$  and  $b^*$ . Where  $L^*$  is luminosity, that varies from 0 (black) to 100 (white). Value of  $a^+$  = color trend to red; value of  $a^-$  = color trend to green; value of  $b^+$  = color trend to yellow and value of  $b^-$  = color trend to blue. Microstructures of creamy sauce were analyzed using an optical microscope (Leica, model MDS50) according to Liu, et al. (2007).

The creamy sauce of cryoconcentrated SM was characterized in terms of chemical composition, pH measurement, titratable total acidity content, water activity, peroxide index, all in triplicate, every 10 days, during two months of storage. The same time was also conducted to color analyses, only microstructures were performed every 20 days. The results of chemical composition, physicochemical and color analysis were evaluated using analysis of variance (ANOVA) and Tukey's test at 5% significance in Statistic Program.

### 3. Results and Discussion

In chemical composition of creamy sauce of cryoconcentrated SM stored for 60 days, it was noted that the levels of proteins and ashes were similar in all samples (Table 1). But small statistical differences were shown in the sauce stored for 10, 20 and 30 days, which had lower moisture content and higher lipids, probably due to the emulsion formation process, despite the fact that the sauce was made only once and distributed in the packages. However, the amount of creamy sauce produced was much bigger than that produced in the tests, and it is known that changes can occur with the increase in scale.

During the formation of the emulsion, a positive change in the free energy must occur to provide total stability to the product. According to Mc Clements (2007), food emulsions may become unstable due to a variety of different physicochemical mechanisms including gravitational separation (creaming/sedimentation), flocculation, coalescence, partial coalescence, Ostwald ripening and phase inversion. It should be stressed that these various physicochemical instability mechanisms are often interrelated. For example, an increase in mean particle size due to flocculation, coalescence or Ostwald ripening usually leads to an increase in the instability of the droplets to gravitational separation.

**Table 1.** Chemical composition of creamy sauce of cryoconcentrated soymilk stored by 60 days (%).

	Storage in days						
	1	10	20	30	40	50	60
<b>Moisture</b>	51.61±	47.27±	48.19±	49.95±	49.61±	50.97±	51.39±
	0.12 <sup>a</sup>	0.25 <sup>c</sup>	0.21 <sup>c</sup>	0.09 <sup>b</sup>	0.87 <sup>bc</sup>	0.73 <sup>a</sup>	0.66 <sup>a</sup>
<b>Ashes</b>	1.58±	1.58±	1.62±	1.70±	1.68±	1.68±	1.67±
	0.02 <sup>a</sup>	0.08 <sup>a</sup>	0.09 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.01 <sup>a</sup>	0.01 <sup>a</sup>
<b>Proteins</b>	2.61±	3.48±	3.04±	2.39±	2.16±	2.57±	2.47±
	0.41 <sup>a</sup>	0.76 <sup>a</sup>	0.48 <sup>a</sup>	0.12 <sup>a</sup>	0.84 <sup>a</sup>	0.54 <sup>a</sup>	0.15 <sup>a</sup>
<b>Lipids</b>	38.03±	41.28±	42.92±	41.41±	37.81±	38.13±	38.64±
	2.03 <sup>b</sup>	0.83 <sup>a</sup>	2.68 <sup>a</sup>	2.19 <sup>a</sup>	0.66 <sup>b</sup>	0.01 <sup>b</sup>	0.01 <sup>b</sup>
<b>Carbohydrates*</b>	6.17	6.39	4.23	4.55	4.55	6.65	5.83

Mean values ± standard deviation, followed by identical letters on the same line, it didn't differ by Tukey's test at 5% significance.

\*Carbohydrates were calculated by difference. Source: Authors (2021).

The properly formed emulsion depends on the proportion of hydrophilic and lipophilic groups, the equipment, and the type and amount of emulsifier used. In the elaboration of this creamy sauce, the cryoconcentrated soymilk acted as an emulsifier and the equipment was the same used in the tests, however with greater volume, thus, small changes in the formation of the emulsion may have occurred. According to Dickinson (2010), low concentrations of emulsifiers and suppressed electrostatic interactions help in the coalescence of the drops formed at the beginning of the emulsion, until their surfaces are protected by a stabilizing layer. And normally this phenomenon is also associated with flocculation bridges, because of the sharing of adsorbed particles between neighboring drops.

The moisture values of creamy sauce of cryoconcentrated SM stored for 60 days varied between 47.27 and 51.61%. Higher levels than those reported by Cornelia, Siratantri and Prawita (2015) for a mayonnaise made with different percentages of gum as an emulsifier. Liu et al. (2007), analyzed the rheological, texture and sensory properties of a mayonnaise, with low fat content and different substitutes for it, and found that the moisture content increased with the addition of fat substitutes, such as pectin, for example. This increase was justified, due to the high percentage of moisture used in the preparation, which was considered a typical characteristic of fat substitutes based on carbohydrates or proteins.

During the 60 days of storage, the proteins levels in creamy sauces of cryoconcentrated SM, did not differ statistically, these results demonstrated that when the proteins remained stable, they helped in the stability of emulsion. Because the same ones associated with polysaccharides, such as xanthan gum, can act in the oil-water interface as emulsifiers and stabilizers of emulsions for a long time. According to Dickinson (2003), the interaction between proteins and polysaccharides can help maintain and even optimize the emulsifying property of proteins in the pH ranges close to the isoelectric point. The authors stated that the active surface of the protein-polysaccharide complexes can also contribute to the stability of the emulsions by increasing the viscosity of the aqueous phase immediately adjacent to the emulsion interface.

The average protein content of the creamy sauce was 2.67%, much higher than that of the traditional Hellmann's mayonnaise (0.73%) quantified by the Institute of Metabolism and Nutrition (IMeN, 2011), in order to analyze and make public the composition in relation to macronutrients. Also, higher than the mayonnaise made with different percentages of gum as an emulsifier by Cornelia, et al. (2015), that presented 0.16% of proteins. Johary, Fahimdanesh & Garavand, (2015) also found lower values (1.83 to 1.90%), when studying the effects of the partial substitution of oil with basil seed gum and tragacanth gum in mayonnaise.

Thus, the creamy sauce of cryoconcentrated SM showed satisfactory protein content, the intake of which is considered fundamental, since they confer too many health benefits, in addition to the technological effect of contributing to the formation and stability of the emulsion. According to Seibel (2018), soybean, and consequently its proteins, is useful in the prevention of cardiovascular diseases, breast and prostate cancer, in reducing the symptoms of menopause and osteoporosis, among others diseases.

The average lipid content of creamy sauce of cryoconcentrated SM was 39.75%, proving that it is a low-lipid and low-calorie product, comparing the traditional mayonnaise that have 70-80% lipids (Nikzade, et al., 2012). Cornelia et al. (2015) quantified a higher lipid content (60.36%) in mayonnaise made with different percentages of gum as an emulsifier. Rahbari, Aalami, Kashaninejad, Maghsoudlou and Aghdaei, (2015) found higher values in low cholesterol mayonnaise, produced with different concentrations of wheat germ protein isolate replacing egg yolk (66.38 to 68.17%).

The ashes content varied from 1.58 to 1.70% during the storage of the creamy sauce of cryoconcentrated SM. Li, Wang, Jin, Zhou and Li (2014) found similar values in mayonnaise added with konjac gum instead of oil (1.46 to 1.58%). However, Worrasinchai, Supphantharika, Pinjai and Jamnong (2006) found lower ash values, between 0.78 to 0.84%, in mayonnaise with partial replacement of oil by  $\beta$ -glucans extracted from the cell wall of beer yeasts. As in mayonnaise with different percentages of gum as an emulsifier (0.72%), prepared by Cornelia et al. (2015).

Total carbohydrates varied between 4.23 and 6.39%, being similar to the amount found by Cornelia et al. (2015) in mayonnaise with different percentages of gum as an emulsifier (6.54%). Liu et al. (2007) found lower values, from 1.54 to 2.10% in low fat mayonnaise prepared with oil replacement by pectin, wheyprotein/pectin and pectin microparticles. The amount of this nutrient is due to the use of the soy derivative, cryoconcentrated SM, because according to Seibel (2018) this bean has high carbohydrate content (around 30%).

The determinations of Hydrogenionic potential (pH), total titratable acidity, water activity and peroxide index in stored foods are essential for the knowledge of the occurrence of possible reactions and microbial development. In creamy sauce of cryoconcentrated SM stored at room temperature for 60 days there was a significant difference, starting from the 30th day of storage, in pH and total titratable acidity, which was probably due to chemical reactions (Table 2). Although the sauce has a high aw, average of 0.9825, facilitating countless degradation reactions, the pH remained below 4.0, characterizing a very acid product and inhibiting microbial development, in addition, the onset of lipid oxidation was not verified with the determination of the peroxide index during the follow-up period.

The permitted limit for the pH of mayonnaise is 4.2, so that it maintains microbiological stability, according to industrial practice. Reis (2013) developed three mayonnaise formulations: traditional, light and fat-free, where for the mayonnaises light and fat-free the pH values were 3.87 and 3.77 respectively, values similar to those obtained in this work. Like the mayonnaise formulated by Su, Lien, Lee and Ho (2010), pH of 3.96 in the control formulation, 3.82 in the product with citrus fiber and guar gum and 3.99 containing xanthan gum and guar gum. Worrasinchai et al. (2006), observed that after 64 days of storage there was a decrease in pH (from 3.85 to 3.33) in mayonnaise with  $\beta$ -glucan, used as a fat substitute, this compound may have fermented, resulting in greater production of lactic acid.

According to Guzey and McClements (2006), pH affects the charge density and the intra and intermolecular electrostatic balance, modifying the ability of proteins to participate in hydro and lipophilic interactions. The low pH can favor the oxidation of fatty acids, due to the release of the iron in the egg at the oil-water interface, because of this, the metal is complexed by specific additives added to the product. It is worth mentioning that these reactions did not occur during the storage of the creamy sauce of cryoconcentrated SM, because this formulation did not contain egg, and consequently, there was greater stability.

**Table 2.** Physicochemical analyses of creamy sauce of cryoconcentrated soymilk storage by 60 days.

	Storage in days						
	1	10	20	30	40	50	60
<b>pH</b>	3.98± 0.01 <sup>a</sup>	3.98± 0.01 <sup>a</sup>	3.84± 0.01 <sup>a</sup>	3.78± 0.18 <sup>b</sup>	3.83± 0.04 <sup>ab</sup>	3.81± 0.01 <sup>ab</sup>	3.75± 0.02 <sup>b</sup>
<b>Total titratable acidity (%)</b>	2.10± 0.02 <sup>b</sup>	2.07± 0.03 <sup>b</sup>	1.97± 0.12 <sup>b</sup>	2.79± 0.08 <sup>a</sup>	2.62± 0.22 <sup>a</sup>	2.57± 0.29 <sup>a</sup>	2.20± 0.21 <sup>b</sup>
<b>Water activity (aw)</b>	0.9841± 0.0001 <sup>a</sup>	0.9817± 0.0013 <sup>a</sup>	0.9826± 0.0023 <sup>a</sup>	0.9804± 0.0023 <sup>a</sup>	0.9797± 0.0011 <sup>a</sup>	0.9814± 0.0009 <sup>a</sup>	0.9873± 0.0008 <sup>a</sup>
<b>Peroxid index</b>	nd						

Mean values ± standard deviation, followed by identical letters on the same line, it didn't differ by Tukey's test at 5% significance. nd= not detected. Source: Authors (2021).

The acidity results increased and differed statistically from the 30th day of storage, corroborating the drop in pH. This event may be related to the presence of phosphoric and citric acid in the formulation, with an interaction between free acids that form a buffer with their salts, causing little variation in pH and, consequently, in acidity. Rasool, Hussain, Alam and Ibrahim, (2013), when analyzing the effects of corn oil on the properties of mayonnaise, observed that after 40 days of storage, the product showed an increase in acidity. Gomes, Lindenblatt, Masson, Gomes, Freitas-Silva and Silva, (2016), evaluated the effect of using oregano essential oil as a natural antioxidant in low-acid mayonnaise, when checking the acidity of the product for 8 weeks, found an increase in acidity (from 2.42 to 2.54) in control sample and decrease in aliquots with the addition of essential oil (from 2.33 to 2.13). According to the authors, the increase in the control sample is a consequence of the beginning of the lipid degradation process and the formation of free fatty acids.

The water activity of creamy sauce of cryoconcentrated SM showed no significant difference during the 60 days storage, demonstrating that the intensity of the forces that united the water with the other non-aqueous components, during the formation of the emulsion, remained stable. Worrasinchai et al. (2006), reported that the aw of mayonnaise made with β-glucan remained unchanged for 64 days of storage, as the samples were kept in closed containers and the loss of water by evaporation was avoided. Su et al. (2010), observed aw values of 0.945 (control formulation), 0.982 (citrus fiber and guar gum) and 0.984 (xanthan gum and guar gum). The water activity values for samples containing gums were very similar to those obtained in the creamy sauce of this work, because the gums have the ability to retain water between the molecules.

Regarding the peroxide index, it was undetectable, that is, there was no lipid oxidation in the product during storage for 60 days. Lipid oxidation is an important technological problem in the food industries and can occur in two different ways: oxidative rancidity, caused by the auto-oxidation of triacylglycerols with fatty acids unsaturated by atmospheric oxygen; or hydrolytic rancidity, caused by the hydrolysis of the ester bond by lipase or chemical agent in the presence of moisture (Damodaran, Parkin & Fennema, 2018).

The visual impact is a resource that the food industry adopts to make food more acceptable to the consumer, and the first sensory attribute evaluated is color, which is very subjective when evaluated by the human eye. Thus, the CIELAB color space can assist by providing color and light parameters of the food, with greater precision. Food color is a direct consequence of the ingredients used in the formulation. The creamy sauce of cryoconcentrated SM showed a statistical difference during storage, in the instrumental color analysis, which was not visually detected by the researchers (Table 3).

The luminosity values (L\*) of the prepared creamy sauce varied from 81.02 to 84.55, which represented that all samples were clear and with small variations in intensity. Being a clearer food than the emulsion prepared by Hedayati et al. (2020) containing 20% sunflower oil, 2% whey protein concentrate, as emulsifier, and 0-5% pregelatinized starch, that

reported brightness ranging from 64.00 to 73.33, which increased proportionally with the increase in starch. According to Worrasinchai et al. (2006), the luminosity is a very important parameter in the appearance of the mayonnaise, since the consumer has the preference of the most luminous ones over the most opaque ones.

**Table 3.** Color of creamy sauce of cryoconcentrated soymilk storage by 60 days.

	Storage in days						
	1	10	20	30	40	50	60
<b>L*</b>	83.31± 1.11 <sup>ab</sup>	82.36± 1.12 <sup>b</sup>	83.95± 1.21 <sup>ab</sup>	84.55± 1.34 <sup>a</sup>	82.96± 1.63 <sup>ab</sup>	81.14± 0.84 <sup>b</sup>	81.02± 1.11 <sup>b</sup>
<b>a*</b>	-6.55± 0.08 <sup>a</sup>	-5.14± 0.37 <sup>a</sup>	-5.82± 0.25 <sup>a</sup>	-5.68± 0.11 <sup>a</sup>	-5.55± 0.21 <sup>a</sup>	-4.03± 0.12 <sup>b</sup>	-4.28± 0.05 <sup>b</sup>
<b>b*</b>	16.57± 0.28 <sup>b</sup>	15.60± 0.38 <sup>c</sup>	15.92± 0.39 <sup>c</sup>	17.02± 0.40 <sup>a</sup>	17.23± 0.74 <sup>a</sup>	15.23± 0.24 <sup>c</sup>	15.52± 0.29 <sup>c</sup>

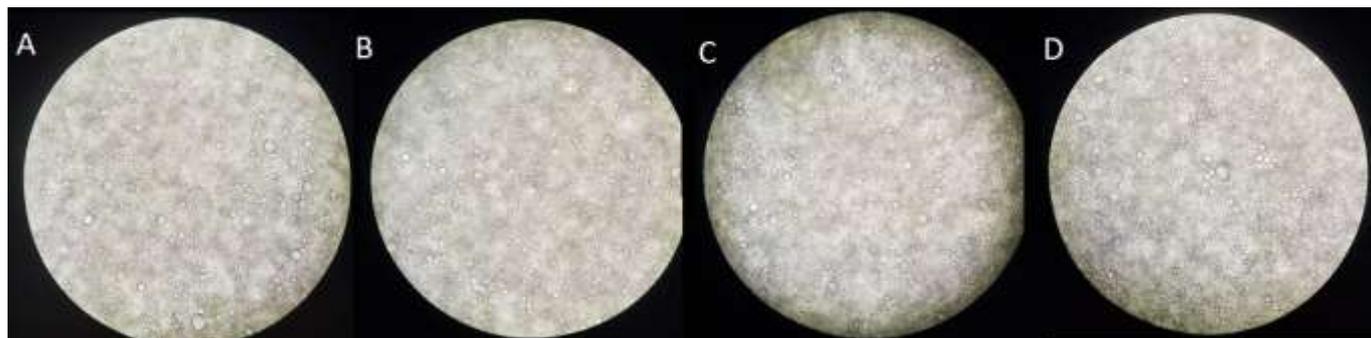
Mean values ± standard deviation, followed by identical letters on the same line, it didn't differ by Tukey's test at 5% significance. Source: Authors (2021).

The color values of creamy sauce measured by parameter a\* only showed a statistical difference on the 50th and 60th days of storage, where they were smaller than the others, indicating a tendency to decrease the green color. The values of parameter b\* indicated a trend towards yellow color, but showed a significant difference in hue during the storage period. The mean value of parameter b\* (16.16) of the creamy sauce was very similar to the emulsion prepared by Hedayati et al. (2020) with 20% sunflower oil, 2% whey protein concentrate, as emulsifier, and 2% pregelatinized starch, that the value was 16.67, so both products had the same hue of yellow. In light mayonnaise with protein and pectin microparticles developed by Chang et al. (2017), the parameter b\* varied between 15.27 and 22.55 due different proportions of proteins added in emulsions.

Commercially, traditional mayonnaise has a bright yellow color and in its composition, it contains different additives to avoid changes in the product during storage. Laca, Sáenz, Paredes and Diaz (2010), studying mayonnaise with low cholesterol content, found a general tendency to change the total color during storage time. These changes are mainly due to lipid oxidation and instability in the emulsion formed, which were not observed in the creamy sauce of cryoconcentrated SM during the evaluated period.

To analyze the stability of the emulsion, over two months of storage at room temperature, optical analyzes of the creamy sauce cryoconcentrated SM were performed (Figure 1). The microstructure carried out right after the preparation of the creamy sauce (Figure 1A) showed the same characteristics of microstructures Figures 1B, 1C and 1D, which were performed after 20, 40 and 60 days of food production, respectively. Four images presented oil droplets with different sizes (polydispersed structures), packaged and very close together. The droplet size distribution and rheological behaviors of emulsion are of outstanding importance for the sensory properties and perceived texture as well as for the physical stability (Ruan, et al., 2019). According to Laca et al. (2010), an ideal emulsion consists of spherical drops packaged together in the continuous phase. The presence of components, such as emulsifiers and stabilizers, is important to determine the stability and speed with which the degradation process may occur.

**Figure 1.** Microstructures of creamy sauce of cryoconcentrated soymilk storage by 60 days.



A: creamy sauce after preparation; B: creamy sauce after 20 days of storage; C: creamy sauce after 40 days of storage D: creamy sauce after 60 days of storage. Source: Authors (2021).

The use of xanthan gum in formulation of creamy sauce of cryoconcentrated SM, helped in the integrity of the emulsion and stability of the product during the storage period analyzed. Su et al. (2010) developed a low-fat mayonnaise containing polysaccharide gums as functional ingredients and found that the sample with xanthan gum had a polydispersed structure. According to McClements (2007), the smaller the drop size, the greater the extension of the three-dimensional gel network formed in products with lower oil volume, leading to higher emulsion viscosity. The stability of the emulsion depends on the viscosity of the liquid surrounding the oil droplets, the more viscous the continuous phase, the lower the movement of the drops and the collision between them, preventing creaming (Hedayati et al., 2020).

The insertion of the cryoconcentrated SM in the creamy sauce, made with lower lipid content, contributed vigorously to the stabilization of the emulsion during the storage period, because during the process of obtaining this food, the soy proteins were able to reduce the interfacial tension between hydrophobic and hydrophilic components. According to Nikzade, et al. (2012), vegetable proteins are indicated as stabilizers of food emulsions, as they are amphiphilic molecules, spontaneously migrating to the oil-water interface, indicating that the free energy of proteins is less at the interface than in the total aqueous phase. Unlike low molecular weight surfactants, proteins form a highly viscoelastic film, in an interface, which has the capacity to withstand mechanical shocks during storage and handling. As these interfacial films have charged groups, they cause electrostatic repulsions between the neighboring droplets, preventing their approach and avoiding the emulsion instability phenomenas, such as coalescence (Damodaran, et al., 2018).

Roesch and Corredig (2003) studied the texture and microstructure of emulsions prepared with concentrated soy protein (PSC) by high pressure homogenization and found that at higher quantity of PSC there was a decrease in the space between the aggregates, and the movement of particles was more limited, making stable emulsions and showing no phase separation after centrifugation, that is, it increased the elastic and viscous modules of the emulsions. According to the authors, the soy fiber present in the PSC played a role in the stability of the emulsions, taking up space in the continuous phase, competing for water and perhaps interacting with the oil droplets covered with proteins. This fact may have further limited the movement of the droplets, increasing their stability in the formation of the cream. The presence of large particles could be, at least in part, attributed to these large structures of insoluble fiber from soy.

The creamy sauce of cryoconcentrated SM elaborated and analyzed in this work proved to be a new option of product based on soy proteins, it can be an alternative to increase the consumption of proteins from this bean, in food with half the lipid value when compared to the traditional ones. Nutritionally, soy proteins are the only ones in the vegetable kingdom equivalent to animal proteins, as they contain practically all essential amino acids, and in an adequate proportion. The composition of essential fatty acids in refined soybean oil is also important, as it contains 21.5% oleic acid; 55.1% linoleic acid and 4.8% linolenic acid (Seibel, 2018). Technologically, this product was safe, without oxidation, with the color characteristic of

traditional mayonnaise and with a stable emulsion during the evaluated period.

#### 4. Conclusion

Creamy sauce of cryoconcentrated soymilk, packed in polyethylene bottles, sealed with aluminum seals, stored for 60 days at room temperature presents a stable emulsion and no lipid oxidation. The pH values and total titratable acidity ensure the safety of the product during the evaluated period, despite the high water activity. The color shows small changes, but it remains a clear food with a tendency to yellow and green color. The microstructure of creamy sauce exhibits the same characteristics during two months. Efficiency of the associated use of cryoconcentrated soymilk proteins and xanthan gum in formation and stabilization of the emulsion during two months is confirmed. However, more research should be carried out to test the product's viability in a longer period of time.

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