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Effect of convective drying conditions on the physicochemical, microbiological, and thermophysical properties of cincho artisanal cheese

Efecto de las condiciones de secado convectivo sobre las propiedades fisicoquímicas, microbiológicas y termofísicas del queso cincho artesanal

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Abstract

Cincho cheese is a semi-hard cheese rich in protein, with an intense flavor, slightly acidic, lumpy, soft, and firm texture, white or yellowish-white in color. Fresh cincho cheese is a highly perishable product because it doesn't have an additional conservation technique and is exposed to environmental conditions. This work aimed to study how artisanal cheese's physical, microbiological, and thermophysical properties were affected by the drying process at different temperatures. The cincho artisanal cheese was dehydrated in a prototype forced convection dryer at drying temperature (50 °C, 55 °C, and 60 °C), air velocity (0 m/s, 0.5 m/s, and 1 m/s), and particle size (0.5 mm, 25 mm, and 50 mm). The final moisture content and water activity values of dried cheese ranged from 2.74 % to 4.67 % and from 0.23 to 0.43, respectively. The microbiological analysis of the raw sample showed the presence of total coliform microorganisms (5.15 log CFU), molds and yeasts (4.99 log CFU), and lactobacillus (7.17 log CFU). The initial sodium chloride content, fat, ash, and protein content were 2.66 %, 2.75 %, 5.94 %, and 19.14 %, respectively. An increment in the sodium chloride, fat, and protein content was observed at the end of the drying process; the increment in these properties ranged from 3.8% to 6.21%, from 40.75 % to 53.90 %, and from 32.16% to 47.11 %, respectively. These properties can be combined with other foods providing the characteristics of fresh cheese.

Keywords: Cincho cheese drying, physicochemical properties, lactobacillus, convective drying, thermophysical properties, artisanal cheese.

Resumen

El queso cincho es un queso semiduro rico en proteínas, con un intenso sabor, ligeramente ácido, grumoso, de textura blanda y firme, de color blanco o blanco amarillento. El queso cincho es un producto altamente perecedero porque no tiene una técnica de conservación adicional y está expuesto al medio ambiente. El objetivo de este trabajo fue estudiar cómo las propiedades físicas, microbiológicas y termofísicas del queso artesanal fueron afectadas por el proceso de secado a diferentes temperaturas. El queso cincho artesanal fue deshidratado en un secador prototipo de convección forzada a una temperatura de secado de (50 °C, 55 °C, y 60 °C), velocidad de aire de (0 m/s, 0.5 m/s, y 1 m/s), y tamaño de partícula de (0.5 mm, 25 mm, y 50 mm). El contenido de humedad final y valores de actividad de agua del queso seco osciló de 2.74 % a 4.67 % y de 0.23 a 0.43, respectivamente. El análisis microbiológico de las muestras frescas mostró la presencia de microorganismos coliformes totales (5.15 log UFC), hongos y levaduras (4.99 log UFC), y lactobacilos (7.17 log UFC). El contenido inicial de cloruro de sodio, grasas, cenizas y contenido de proteínas fue 2.66% 2.75%, 5.94%, y 19.14%, respectivamente. Se observó un incremento en el contenido de cloruro de sodio, grasa y proteína al final del proceso de secado; el incremento de estas propiedades osciló de 3.8 % a 6.21%, de 40.75% a 53.90% y de 32.16% a 47.11%, respectivamente. Estas propiedades se pueden combinar con otros alimentos aportando las características del queso fresco.

Palabras clave: Secado de queso cincho, propiedades fisicoquímicas, lactobacilos, secado convectivo, propiedades termofísicas, queso artesanal.

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1 Introduction

Cheeses are made from cow's milk or other animal species by coagulating casein with rennet; cheeses are a good source of minerals, proteins, fat, vitamins, and calcium (Plante *et al*., 2021). Traditional cheeses are part of the culture and gastronomic of the country, contribute to food security, encourage economic activity and rural employment, and value local, territorial resources such as the climate, landscape, water. Hnosko *et al*., (2009) have reported a study about the Latin American cheeses and their classification; however, there are different varieties of cheeses that have unique characteristics according to the region where they are made, the characteristics of the milk, and the methods used to produce them. Traditional cheeses are made in an artisanal process using rudimentary equipment from raw milk, which most of the time contain pathogenic microorganisms; therefore, cheeses made from unpasteurized milk should be stored at a temperature of 1.7 °C for up to two months maximum. However, this procedure is unfavorable because the shelf life of cheeses made with raw milk is from 5 to 7 days (Hnosko *et al*., 2009). More than 40 varieties of artisan cheeses are produced in Mexico, all of them genuine; that is, those made from raw cow's milk, with the minimum use of additives, incorporating those allowed by current regulations (Cervantes *et al*., 2019). Therefore, the cheeses can be classified as soft, semi-hard, and hard based on moisture content. Cheeses classified as soft are high-moisture as fresh cheese and white cheese; semi-hard cheeses such as Chihuahua cheese, Manchego cheese, Cincho cheese, and Oaxaca cheese. The smallest group of hard cheeses are Cotija, and Añejo; these cheeses have low moisture content (Hnosko *et al*., 2009). Cincho cheese is a semi-hard cheese rich in protein, with an intense flavor, slightly acidic, lumpy, soft, and firm texture, white or yellowish-white in color. Sometimes it is found aged and spicy with a chili layer around it. It is made artisanal in the states of Morelos and Guerrero, Mexico. The term cincho originally refers to a type of palm leaf belt placed around the cheese; now, it is a plastic rope, its maturation ranges from two weeks to 12 months, depending on commercial demand (Castro *et al*., 2012). They are generally eaten grated, roasted, fried, or in small pieces (Virues *et al*., 2018). Although cincho cheese can remain stored under refrigeration for an extended time, it is not exempt from presenting physicochemical and microbiological alterations related to its moisture content (35% - 37%) and its nutritional constituents. The shelf-life of cheeses is about 7-10 days under aerobic conditions (Anli, 2020). Drying is a process that prevents the growth and reproduction of microorganisms, increases the shelf life, transforms the food into a new product, and reduces packaging, storage, and transportation (Bedir and Kuleasan, 2019). In this way, the production of stabilized foods from hazardous raw materials is ensured by reducing water activity to adequate levels, thus avoiding microbial deterioration and quality losses due to biochemical reactions (Bedir and Kuleasan, 2019). Convective drying is one of the processes most used for food dehydration. Some of the drying methods applied in the food industry for cheese drying are freeze-drying, fluidized bed drying, spray drying, osmotic dehydration, and combined drying (Bedir and Kuleasan, 2019; Domínguez *et al*., 2016; Erbay *et al*., 2015; Giannoglou *et al*., 2020; Ergene and Arslan, 2019). However, freeze-drying results are expensive due to long drying times, low temperatures, and a vacuum system. On the other hand, spray drying usually is applied to liquids, and it is not feasible to apply it to solid foods such as cincho cheese. Although fluidized bed drying is an alternative for the dehydration of solids products, a disadvantage is that the air velocity to the drying chamber cannot be regulated since it is already predetermined. For this reason, a prototype forced convection dryer was used for the drying process of cincho cheese. Dried cheese is generally used as a food ingredient to improve the taste and mouthfeel of food products (Koca *et al*., 2015). Some of these uses are in salad dressings, soufflé, cakes, and some specialty bakery products such as chips, pasta, cookies, pizzas, and soups in the industry (Bedir and Kuleasan, 2019). Simultaneously, it is used directly as a flavoring in hot dishes such as spaghetti and soups (Pisecky, 2005). As mentioned before, fresh cincho cheese is highly perishable because it doesn't have an additional conservation technique and is exposed to the environment and transport. For this reason, a convective drying method was employed not only to extend the shelf life of the cheese but also to present a new product for the consumer; in this case, traditional dried cheese in the form of powder, ground cheese, and strips. In the literature, no reports have been found directly related to the study on the drying of cincho cheese with forced convection at different temperatures. Therefore, this work aimed to study how artisanal cheese's physical, microbiological, and thermophysical properties were affected by the drying process at low temperatures.

2 Material and methods

2.1 Raw material

The cincho cheese was made with raw cow's milk in an artisanal process using rudimentary equipment from raw milk. Therefore, it doesn't have an additional conservation technique, only the addition of sodium chloride. During the investigation, 15 kilograms of cincho cheese was donated by cheese producers in Temixco, Morelos, Mexico (18.84° N, 99.2356 ° W at 1258 mamsl), their physicochemical and microbiological properties are shown in Table 1.

Table 1. Physicochemical, microbiological and thermophysical analysis of cincho cheese.

Analysis	Mean values$^{\pm \text{ standard deviation}}$
Moisture content (w.b)	$36.47^{\pm 0.44}$
Water activity	$0.914^{\pm 0.01}$
Protein content (%)	$19.79^{\pm 0.16}$
Carbohydrates (%)	$35.05^{\pm 0.23}$
Sodium chloride	$2.66^{\pm 0.11}$
Fat content (%)	$2.75^{\pm 0.80}$
Ash content (%)	$5.94^{\pm 0.15}$
L	$90.87^{\pm 0.32}$
a	$-0.06^{\pm 0.14}$
b	$16.63^{\pm 0.16}$
Hue angle	$90.19^{\pm 0.21}$
Chroma	$16.63^{\pm 0.14}$
Lactobacillus (Log CFU)	$7.17^{\pm 0.70}$
Yeast and molds (Log CFU)	$4.99^{\pm 0.42}$
Total coliforms (Log CFU)	$5.15^{\pm 0.08}$
Thermal conductivity (W/m°C)	$0.491^{\pm 0.11}$
Specific heat (kJ/kg °C)	$2.591^{\pm 0.13}$
Density (kg/m^3)	$1263.071^{\pm 0.21}$

L= Lightness
a= (green-red)
b= (blue-yellow

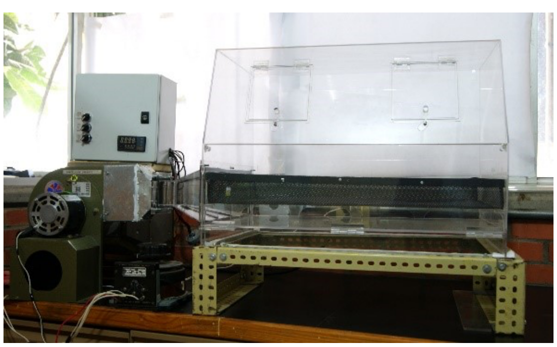

Fig. 1 Photograph of the forced convection dryer (Domínguez *et al*. 2021).

Table 2. Design and experimental analysis of the drying process of cincho cheese.

Independent variables	Symbol coded	Coded variables (-1)	(0)	(+1)
Temperature (°C)	X_1	50	55	60
Air velocity (m/s)	X_2	0	0.5	1
Particle size (mm)	X_3	0.5	25	50

2.2 Drying process

A prototype forced convection dryer is shown in Figure 1 (Domínguez Niño *et al*., 2021). The dryer chamber is made of acrylic; it has a metallic tray with an area of 0.35 m^2. The airflow circulates longitudinally through the drying tray to the outside. The fan has a volumetric flow capacity of 570 m^3/h. The cincho cheese was dehydrated at three different temperatures, 50 °C, 55 °C, and 60 °C. The air velocity was established at 0 m/s, 0.5 m/s, and 1 m/s. A stainless-steel cutter was used to obtain three different particle sizes: 0.5 mm, 25 mm, and 50 mm. The levels of the independent variables were selected according to preliminary experimentation.

2.3 Experimental design

A central composite design $2^3 + 2(3) + 1$ was adopted. This experimental design required three levels for each independent variable, with one central point, thus making 15 experiments instead of 27 with full factorial design. Table 2 shows the factors, including the coding symbols and codes. The response variables were obtained in triplicate. The data were analyzed statistically using analysis of variance (ANOVA) by NCSS 2004. The response variables were the final moisture content (Y_1), water activity (Y_2), sodium chloride (Y_3), fat (Y_4), lactobacillus (Y_5), protein (Y_6), thermal conductivity (Y_7), specific heat (Y_8), of the dried product. Eight mathematical functions f were obtained as shown in equation 1:

$$Y_k = f_k(X_1, X_2, X_3) \quad (1)$$

Where X_1 is the drying temperature (°C), X_2 is the air velocity (m/s), and X_3 is the particle size (mm). Then, a second-degree polynomial equation was utilized to generate the response surface plots (equation 2).

$$Y_k = b_k 0 + \sum_{i=1}^{3} b_{ki} X_i + \sum_{i=1}^{3} b_{kii} X_i^2 + \sum_{i \neq j=1}^{3} b_{kij} X_i X_j \quad (2)$$

Where b_{k0}, b_{ki}, b_{kij} and b_{kij} are the regression coefficients of the intercept, linear, quadratic, and interaction coefficients, respectively; X_i are the coded independent variables, which are linearly related to X_1, X_2, and X_3.

2.4 Analytical methods

A thermobalance OHAUS, MB45 measured the samples' initial and final cheese moisture content (~3 g) at 105 °C. The water activity (a_w) was determined at 25 °C using a Rotronic water activity meter (Higrolab C1). The raw and dried samples' color was determined using a portable colorimeter (NR60CP) and expressed in terms of lightness, redness and greenness, yellowness and blueness, Hue, and saturation (L, a, b, H, C), respectively. The protein content was determined by the standard Kjeldahl method using a Novatech Instrument device (KJ2DI) (James, 1995). The fat content was determined by using the Soxhlet method extraction James, 1995). The sodium chloride content was quantified following the method in dairy products described by James, (1995). The determination of available carbohydrates was quantified by difference following the method described by James, (1995). The microbiological analyses were performed using the inverted plate method using potato dextrose agar to determine yeast and molds at 25 °C for 5 days. The lactobacilli determination was assessed at 35 °C for 3 days using Man Rogosa and Sharpe Agar. Finally, the total coliforms determination was assessed at 35 °C for 2 days using Violet Red Bile Lactose Agar (NOM-110-SSA1-1994; NOM-121-SSA1-1994; Vargas *et al.*, 2006; González, 2010).

2.5 Thermophysical properties

Thermal conductivity (k) is the rate of heat transfer through a unit cross-sectional area and was determined according to the equation 3 proposed by Choi and Okos, (1986).

$$k = \sum_i k_i X_i \tag{3}$$

Where X_i is the mass fraction, and k_i in the equation dependent of the main components of the food, considering T (°C) as follows:

$$k_{protein} = 1.7881 \times 10^{-1} + 1.1958 \times 10^{-3} T - 2.7178 \times 10^{-6} T^2$$
$$k_{fat} = 1.8071 \times 10^{-1} - 2.7604 \times 10^{-4} T - 1.7749 \times 10^{-7} T^2$$
$$k_{carbohydrate} = 2.0141 \times 10^{-1} + 1.3874 \times 10^{-3} T - 4.3312 \times 10^{-6} T^2$$
$$k_{ash} = 3.2962 \times 10^{-1} + 1.4011 \times 10^{-3} T - 2.9069 \times 10^{-6} T^2$$
$$k_{water} = 5.7109 \times 10^{-1} + 1.7625 \times 10^{-3} T - 6.7036 \times 10^{-6} T^2$$

The density (ρ) was calculated by using the compositional values of foods as suggested Choi and Okos, (1986) in equation 4:

$$\rho = \frac{1}{\sum(X_i/\rho_i)} \tag{4}$$

Where ρ_i is calculated as following and considering T (°C):

$$\rho_{protein} = 1.3299 \times 10^3 - 5.1840 \times 10^{-1} T$$
$$\rho_{fat} = 9.2559 \times 10^2 - 4.1757 \times 10^{-1} T$$
$$\rho_{carbohydrate} = 1.5991 \times 10^3 - 3.1046 \times 10^{-1} T$$
$$\rho_{ash} = 2.4238 \times 10^3 - 2.8063 \times 10^{-1} T$$
$$\rho_{water} = 9.9718 \times 10^2 + 3.1439 \times 10^{-3} T - 3.7574 \times 10^{-3} T^2$$

The specific heat (C_P) measures the amount of energy required by a unit mass to raise its temperature by a unit degree. The model for calculated specific heat was proposed by Choi and Okos, (1986), as seen in equation 5

$$C_P = \sum C_{P,i} X_i \tag{5}$$

Where values of $C_{P,i}$ is calculated as following and considering T (°C)

$$C_{P,Protein} = 2.0082 + 1.2089 \times 10^{-3} T - 1.3129 \times 10^{-6} T^2$$
$$C_{P,fat} = 1.9842 + 1.4733 \times 10^{-3} T - 4.8008 \times 10^{-6} T^2$$
$$C_{P,carbohydrate} = 1.5488 + 1.9625 \times 10^{-3} T - 5.9399 \times 10^{-6} T^2$$
$$C_{P,ash} = 1.0926 + 1.8896 \times 10^{-3} T - 3.6817 \times 10^{-6} T^2$$
$$C_{P,water} = 4.1289 - 9.0864 \times 10^{-5} T + 5.4731 \times 10^{-6} T^2$$

Fig. 2 Samples of dehydrated cheese at different drying conditions.

3 Results and discussions

3.1 Physicochemical and microbiological characterization of the fresh cincho cheese

As seen from Table 1, the moisture content and water activity of the cincho cheese (36.47 % and 0.914) implies some undesirable physicochemical and microbiological changes can occur. The color parameters indicated a lightness value of 90.87, corresponding to a product near the white color. On the other hand, the *a* and *b* values (-0.06 and 16.63) showed that the cheese tends the yellowness. The hue angle (90.19°) corresponds to the positive values of the *b* parameter, so the cincho cheese has a yellow hue. Some researchers have related this yellow hue to carotenoid pigments transmitted through the milk and the fat content, which is why cheese made from cow's milk appears to be yellow (Aday and Yuceer 2014). Figure 2 shows the samples of dehydrated cheese at different drying conditions. The microbiological analysis showed the presence of total coliform microorganisms (5.15 log CFU), yeast and molds (4.99 log CFU), lactobacillus (7.23 log CFU). Castro *et al*., (2012) reported the microbiological composition of the fresh and semi-aged cincho cheese. Their results showed 6.41 log CFU of total coliforms microorganisms, 7.8 log CFU of lactic bacterias, 7.83 log CFU of molds and yeast in the fresh cincho cheese, and 4.44 log CFU of total coliforms microorganisms, 6.2 log CFU of lactic bacterias, and 6.04 log CFU of molds and yeast in the semi-aged cincho cheese. As mentioned before, traditional cheeses usually contain pathogenic microorganisms due to the artisanal process. Some researchers have reported the microbiological characterization of different types of cheese, such as traditional Oaxaca cheese (Castro *et al*., 2013). Their results demonstrated 9.0 log CFU in coliforms microorganisms and 9.9 log CFU/g of yeast and molds. Romero *et al*., 2019 reported a total coliform microorganisms from 6.66 log CFU /g to 7.44 log CFU /g in tropical cream cheese. González and Franco (2015) reported a total coliform microorganisms from 6 to 7.98 log CFU /g in hoop cheese. Bedir and Kuleasan reported a mesophilic bacteria content of 7.71 log CFU/g in Tulum cheese, 5.70 log CFU/g in white cheese, and a total count of yeast and molds 7.37 log CFU/g for Tulum cheese and 4.92 log CFU/g for Kashar cheese. As seen from the data, all the microbiological characterization was not complying with NOM-243-SSA-2010 which regulates the sanitary practices for cheese manufacture. The Official Mexican Standard NOM-243-SSA1-2010 establishes that the permissible limits of microbial load for cheeses elaborated with pasteurized milk are: <100 CFU / g or mL for total coliforms, <100 CFU / g or mL for matured and processed cheeses 1000 CFU / g of fresh cheeses, and serum for Staphylococcus aureus; 500 CFU / g or mL fresh and matured cheeses and whey cheeses 100 CFU / g or mL processed cheeses for molds and yeasts. As can be seen from the microbiological analysis of fresh cincho cheese, these permissible limits are not complying with NOM-243-SSA-2010 because artisanal cheeses are made from raw milk. Finally, sodium chloride content (2.66%), fat (2.75%), ash (5.94%), and protein content (19.79%) in cincho cheese were evaluated. These values were similar to those reported by Virues *et al*., (2018) in the physicochemical and mechanical characterization of cincho cheese produced in southern Veracruz, México. Nevertheless, some variations in fat content were observed. According to their results, the cincho cheese had the following composition: humidity (31.92%), ashes (5.32%), fat (16.34%), proteins (32.765%). The variations in the cheeses with the same name depends to the region where they are made, the characteristics of the milk, and the methods used to produce them.

3.2 Moisture content and water activity of dried cheese

Figures 3a and 3b show the effect of the factors on the final moisture content and dried cheese's water activity, respectively. An analysis of variance (ANOVA) indicated that the factors did not significantly affect ($p \geq 0.05$) the moisture content; however, the aw was affected ($p \leq 0.05$) significantly by the particle size, as seen from Appendix 1. As a result, the initial moisture content was reduced from 36.47% to values that ranged from 2.74 % to 4.51 %. In Figure 3a, the moisture content increased as the particle size increased from 0.5 mm to 50 mm and decreased when the air velocity increased from 0 m/s to 1 m/s.

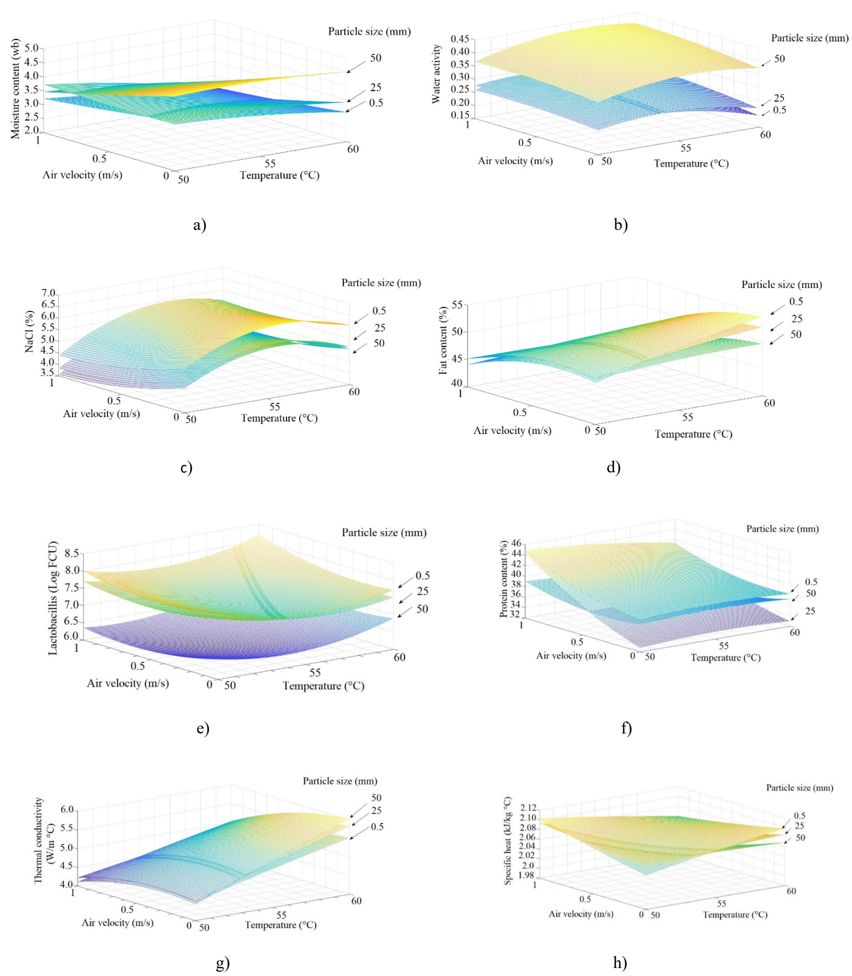

Fig. 3 Plots of: a) Moisture content, b) Water activity, c) Sodium chloride, d) Fat content, e) Lactobacillus, f) Protein content, g) Thermal conductivity, and h) Specific heat, as a function of drying temperature, air velocity and particle size.

Table 3. Experimental results of physicochemical and microbiological properties of dehydrated cincho cheese.

Test	Coded factors			Responses							
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
1	50	0	0.5	3.95	0.27	5.4	47.49	7.81	34.74	4.43	2.05
2	50	1	0.5	3.56	0.29	4.3	45.39	8.06	42.03	4.24	2.06
3	60	0	0.5	2.74	0.16	6.06	53.82	7.76	32.16	5.96	2.04
4	60	1	0.5	2.74	0.23	5.5	45.61	8.02	42.13	5.09	2.05
5	50	0	50	4.51	0.34	4.96	47.74	6.77	36.3	4.45	2.07
6	50	1	50	3.78	0.39	3.93	46.07	6.16	39.83	4.3	2.14
7	60	0	50	4.67	0.36	5.3	48.39	6.9	39.64	5.39	2.1
8	60	1	50	2.46	0.4	4.73	40.75	7.32	33.42	4.57	1.99
9	55	0	25	3.77	0.31	5.43	53.9	7.08	36.31	5.48	2.08
10	55	1	25	2.86	0.26	4.96	41.52	7.85	47.11	4.28	2.05
11	55	0.5	25	3.12	0.26	5.53	50.31	7.48	38.23	5.13	2.06
12	50	0.5	25	3.25	0.23	3.8	47.63	7.58	41.52	4.44	2.06
13	60	0.5	25	3.12	0.29	4.4	50.97	7.6	38.37	5.65	2.07
14	55	0.5	25	3.41	0.28	6.21	49.31	7.28	38.14	5.03	2.06
15	55	0.5	0.5	3.91	0.43	4.8	48.96	6.16	36.59	5	2.06

X_1= Temperature (°C), X_2= Air velocity (m/s), X_3= Particle size (mm), Y_1= Moisture content (%), Y_2= Water activity, Y_3= sodium chloride (%), Y_4= fat content (%), Y_5= lactobacillus (log CFU), Y_6= Protein content (%), Y_7=Thermal conductivity (W/m°C), Y_8= Specific heat (kJ/kg °C).

The distance through which moistures must travel to reach the particle surface is small in small particles. On the other hand, the lowest moisture content values were obtained at 60 °C; however, the drying temperature did not significantly affect this response variable. The final aw values of the dried cheese are represented in Figure 3b. As seen from Figure 3b, the aw tended to increase as the particle size increased from 0.5 mm to 50 mm. The final aw values of dried cheese ranged from 0.23 to 0.43. The present results allow extending the shelf life of the cheese because it has less free water available for biochemical reactions (García *et al*., 2022). Izadi *et al*., (2020) reported a final moisture content from 2.51% to 4.28 % and aw values from 0.090 to 0.21 in cheese powder samples dehydrated from 50 °C to 80 °C. Dominguez *et al*., (2016) reported the final moisture content and a_w values in fresh Mexican cheese from 0.3% to 1.66% and from 0.218 to 0.44, respectively, when the cheese samples were dehydrated at drying temperature 50 °C to 70 °C in a fluidized bed drying. According to the literature, dried food with aw values less than 0.60 is microbiological stable during storage (Izadi *et al*., 2020).

3.3 Sodium chloride in dried cheese

The ANOVA revealed that the independent variables significantly affected sodium chloride (p≤0.05), as shown in the Appendix. According to Table 3, the sodium chloride content in the dried cheese ranged from 3.8% to 6.21%. In Figure 3c the sodium chloride content increases as the particle size decrease from 50 mm to 0.5 mm. This latter observation could be related to the dried product's final moisture content because the lowest moisture content was obtained at the lowest particle size (Figure 3a). The same behavior occurred when the temperature increased from 50 to 60 °C. According to Figures 3b and 3c, the higher the sodium chloride content, the lower a_w. The sodium chloride content in cheese is essential because it reduces the water activity in the food; therefore, it exerts control over microbial growth and enzyme activity in food. Previous studies have reported an increment in the sodium chloride content in dried cheese; Anli, (2020) reported an increment in salt content in Lor cheese from 3% to 3.7%. Da Silva *et al*., (2018) reported a final salt content from 4% to 4.5% in cheese feed powdered by spray drying. Domínguez *et al*., (2016) reported an increment in salt content from 1.28% to 3.36% during the fluidized bed drying of fresh Mexican cheese at drying temperature from 50 °C to 70 °C. Koka *et al*., (2015) reported an increment in salt content from 4.3% to 8.30% during the spray drying of White cheese at an inlet temperature of 180 °C and outlet temperature of 80 °C. In the study of cincho cheese, an increment of the salt content from 2.6% to

6.21% was observed. According to Anli, (2020), lactic acid bacteria are inhibited in salt concentrations near 5%.

3.4 Fat content in dried cheese

The experimental data of dried cheese are shown in Table 3 and represented in Figure 3d. The statistical analysis showed that fat content was significantly affected (p≤0.05) by the air velocity, as shown in Appendix 1. According to the results shown in Table 1, the initial fat content of the cincho cheese was 2.75%; however, at the end of the drying process, the dehydrated samples of cincho cheese showed a significant increase in fat content from 40.75% to 53.90%. According to Kim *et al*., (2009), when food is dehydrated at low temperatures, the components have more time to migrate within the food. Therefore, high-fat content was observed in dehydrated cheese. Erbay and Koka, (2012) reported a final fat content of 46.69% in spray-dehydrated cheese in an inlet temperature range of 160 °C to 230 °C, the outlet temperature of 60 °C to 100 °C, and atomization pressure from 294.2 kPa to 588 kPa. Domínguez *et al*. (2016) reported a final fat content of 46.24% during the fluidized bed drying of fresh Mexican cheese at drying temperatures from 50 °C to 70 °C. According to the study, high temperatures can damage the fat globules, causing it to flow towards the surface, increasing free fat. Felix da Silva *et al*., (2017) reported a final fat content from 39% to 43% in Camembert cheese, 41.2% in Emmental cheese, and 32.4% to 43% in Dambo cheese during the spray drying process. Figure 3d shows an increasing trend of the fat content as the drying temperature increases from 50 °C to 60 °C.

Similarly, it was observed that as the particle size increased from 0.5 mm to 50 mm, the fat content decreased; Therefore, the samples with the highest fat content were those of 0.5 mm. This behavior is related to the moisture content since the samples that presented the lowest moisture content were those with the smallest particle size and, therefore, the highest fat content. Figure 3d shows the increase in fat content when the air velocity increases from 0 to 0.5 m/s. Although the percentage of fat in dehydrated cincho cheese seems high, there are fresh cheeses with a high-fat content that are consumed and used in traditional food such as cheddar cheese with 33% fat (McCarthy *et al*., 2015), goat cheese with 44.32% (Fresno and Álvarez, 2012), Fresco cheese with a percentage of 18 to 29%, Chihuahua cheese with 31 to 35%, Cotija cheese 28 to 31%, Manchego cheese 26% (Hnosko *et al*., 2009). The nutritional qualities of the dehydrated cheese make it an excellent source of protein, fat, sodium chloride, lactobacillus, and taste to be used in the food industry as an additive and be combined with other foods providing the organoleptic characteristics of fresh cheese.

3.5 Lactobacillus in dried cheese

Lactobacillus are live microorganisms that confer a health effect on the host, they are included in products such as fermented milk, yogurt, and cheese (Jimenez *et al*., 2021). Figure 3e shows the effect of the factors on the lactobacillus colonies. As seen from the Appendix, the variance analysis showed that the lactobacillus content was significantly affected (p≤0.05) by the particle size. The initial lactobacilli count in the fresh sample was 7.17 log CFU/g. Table 3 shows the lactobacillus count at different drying conditions, the results ranged from 6.16 log CFU/g to 8.06 log CFU/g. The increment in lactobacillus colonies is desirable because of the health effects; however, to provide health benefits, the level of bacteria should be > 10^7 CFU/g (Borrás *et al*. 2018). Although an increment in the lactobacillus colonies was observed in this study, the number of colonies is low to be considered a probiotic food. As seen from Figure 3e the lactobacillus count increases slightly as the drying temperature increases from 50 °C to 60 °C at a size of 50 mm; however, when the particle size decreases from 25 mm to 0.5 mm, the lactobacillus count decreases. On the other hand, the lactobacillus count increased as the particle size decreased from 50 mm to 0.5 mm. This behavior could be related to the final moisture content. As the particle size decreased from 50mm to 0.5 mm, the final moisture content decreased, as seen in Figure 3a; therefore, high lactobacillus colonies were observed. Some authors have evaluated the influence of drying temperature on the viability of microorganisms. Joshi and Thorat, (2011) carried out the drying of probiotic yeast (*Sccaromyces boulardii*). They found that the presence of colonies of microorganisms in cheese is restricted factors such as temperature and drying time. According to the report, the temperature of 20 to 50 °C reduces viability by only 0.4 log units. Koc *et al*., (2010) found that the survival rate of lactic acid bacteria in dehydrated yogurt decreases with increasing outlet air temperature during spray drying. They concluded that the inlet temperature of 171 °C, the outlet temperature of 60.5 °C, and the food temperature of 15 °C is the optimal conditions for the process.

3.6 Protein content in dried cheese

The initial protein content in the cincho cheese sample was 14.41% (Table 1). However, during the drying process, an increment in the cheese protein content was observed (Table 3), the protein content in dried cheese samples ranged from 32.16 % to 47.11 %. Erbay and Koca, (2012) reported an increment of 36.32 % in protein content of white cheese during the spray drying process. Dominguez *et al*., (2016) reported an increment in the protein content of fresh cheese from 15.24% to 40.47% in the fluidized bed drying process at drying temperature from 50 to 70 °C. According to Anandharamakrishnan *et al*., (2007), the denaturation of proteins is prevented by reducing the movement of molecules during the remotion of water. In this study, the temperatures ranged from 50 to 60 °C. In Figure 3f, the protein content increased when the air velocity increased from 0 to 1 m/s in cheese samples with a particle size of 0.5 mm and 25 mm. According to the ANOVA, the independent variables did not significantly affect ($p \geq 0.05$), as seen from Appendix 1. Schuck *et al*. (2013) report that protein denaturation indicates the intensity of heat treatment and the quality of dehydrated products. Anandharamakrishnan *et al*., (2007) confirmed that low outlet air temperatures (60 °C and 80 °C) produce less denaturation and loss of solubility in whey proteins.

3.7 Thermophysical properties in dried cheese

Figure 3g shows the effect of the factors on the thermal conductivity of dried cheese samples. The variance analysis revealed that drying temperature and air velocity significantly affect the thermal conductivity, as seen from Appendix 1. The thermal conductivity increased as the drying temperature increased from 50 to 60 °C (Figure 2g). On the other hand, the increment in the air velocity from 0 to 1 m/s did not significantly affect the thermal conductivity. The fresh cincho cheese presented a thermal conductivity of 0.491 W / m ° C; however, it increased in a range from 4.24 to 5.96 W / m °C during the drying process, as seen from Table 3. According to Donsí *et al*., (1996), thermal conductivity is a function of the water mass fraction of the sample, and it increases as the moisture content increases. The test number five dehydrated at 50 °C was compared (Table 3). Test 5 showed a maximum moisture content of 4.51%. As a result, the thermal conductivity was 4.45 W / m °C, the highest value concerning the other 4 samples (Test 1,2,6, 12) as shown in Table 3. This same behavior can be observed in the cheese samples dehydrated at 60 °C in which it was shown that the higher moisture content produces a higher thermal conductivity (Table 3). However, the thermal conductivity can also be affected by the other food constituents, such as the content of fat, protein, and carbohydrates. The specific heat results are shown in Table 3 and represented in Figure 3h. The variance analysis indicated that the factors did not affect specific heat, as seen from Appendix 1. According to with results, the lowest specific heat in samples ranged from 1.991 to 2.142 kJ/kg °C. In the literature few reports were found about thermophysical characteristics of some types of cheeses as Sovetskiy cheese, Dutch cheese, and Ozernyiy cheese. According to Ermolaev *et al*., 2020 the density, thermal conductivity and heat capacity of Sovetskiy cheese was 1070 kg/m^3, 0.34 W/(m·K), and 2570 J/(kg·K), respectively. In the other hand, the Dutch cheese had a density of 1060 kg/m^3 , the thermal conductivity was 0.35 W/(m·K), and the heat capacity was 2530 J/(kg·K). Finally, the density for Ozernyiy cheese was 1040 kg/m^3, the thermal conductivity was 0.35 W/(m·K), and the heat capacity was 2540 J/(kg·K). Some differences can be observed with our results; however, thermal properties depend on the composition of food and conductivity, and the heat capacity are affected by the formation of pores during the drying process. Our study suggested that using a temperature of 50 °C, the particle size of 0.5 mm and an air velocity from 0 to 0.5 m/s retain the most properties of cheese in a better way.

Conclusions

The drying process gives it stability because there is less free water available for biochemical reactions; therefore, it can be consumed at any time since it preserves its properties as protein content, fat, sodium chloride, lactobacillus, and taste. The stability of the cincho cheese was ensured, reducing the moisture content to values that ranged from 2.74 % to 4.51 % and the water activity to final values that ranged from 0.23 to 0.43. The study suggested that using a temperature of 50 °C, a particle size of 0.5 mm, and an air velocity of 0.5 m/s retain the properties of cheese in a better way. At these drying conditions, the final moisture content, water activity, sodium chloride, fat content, lactobacillus, and protein content were 3.95%, 0.27, 5.40%, 47.49, 7.81 log CFU, and 34.74%, respectively. The findings imply that dried cincho cheese has a high nutritional quality to be used and combined with other foods providing the organoleptic characteristics of fresh cheese. In a future investigation, a complete study will be carried out on the sensorial analysis of dehydrated cheese with discrimination tests, hedonic tests, analytical tests, and a study of the effect of the storage on sensorial properties. The studies will be done once the presentation of the product to be commercialized has been completely defined.

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Appendix 1. Analysis of variance of dependent variables

		Responses				
Factor	DF	Sum of squares	Mean squares	F-Ratio	Prob. level	$a = 0.05$
		Moisture content				
X_1	2	1.127386	0.56369	2.65	0.1309	0.3816
X_2	2	1.800249	0.90012	4.23	0.0558	0.5648
X_3	2	1.222243	0.61112	2.87	0.1148	0.4094
S	8	1.702471	0.21280			
Total (adjusted)	14	5.892133				
Total	15					
		Water activity				
X_1	2	3.252E-03	1.626349E-03	1.01	0.406402	0.1694
X_2	2	1.595E-03	7.977778E-04	0.50	0.626886	0.1058
X_3	2	5.619E-02	2.809778E-02	17.45	0.001210*	0.9931
S	8	1.288E-02	1.610556E-03			
Total (adjusted)	14	7.169E-02				
Total	15					
		Sodium chloride				
X_1	2	3.197829	1.598914	15.75	0.001684*	0.987452
X_2	2	1.533297	0.7666486	7.55	0.014384*	0.820155
X_3	2	2.170029	1.085014	10.69	0.005504*	0.930940
S	8	0.81232	0.10154			
Total (adjusted)	14	7.098094				
Total	15					
		Fat content				
X_1	2	3.127177	1.563588	0.20	0.820495	0.072036
X_2	2	112.5377	56.26884	7.30	0.015707*	0.806682
X_3	2	10.23641	5.118206	0.66	0.541051	0.126171
S	8	61.67314	7.709142			
Total (adjusted)	14	196.5905				
Total	15					
		Lactobacillus				
X_1	2	0.4598	0.2299	2.20	0.1735	0.3238
X_2	2	0.2464	0.1232	1.18	0.3562	0.1908
X_3	2	3.8597	1.9298	18.44	0.0010*	0.9952
S	8	0.8372	0.1046			
Total (adjusted)	14	5.1530				
Total	15					
		Proteins				
X_1	2	8.2643	4.1321	0.32	0.7323	0.0857

X_2	2	68.349	34.174	2.68	0.1286	0.3854
X_3	2	25.881	12.940	1.01	0.4049	0.1699
S	8	102.05	12.756			
Total (adjusted)	14					
Total	15	205.53				
Thermal conductivity						
X_1	2	2.3052	1.15263	14.18	0.002341*	0.978398
X_2	2	1.1438	0.57192	7.04	0.017245*	0.791791
X_3	2	0.1151	5.75E-02	0.71	0.520923*	0.131620
S	8	0.6500	8.12E-02			
Total (adjusted)	14	4.2982				
Total	15					
Specific heat						
X_1	2	1.62E-03	8.10E-04	0.57	0.584375	0.115364
X_2	2	2.53E-04	1.26E-04	0.09	0.914915	0.059612
X_3	2	9.73E-04	4.86E-04	0.35	0.718092	0.088222
S	8	1.12E-02	1.40E-02			
Total (adjusted)	14	1.41E-02				
Total	15					