RESUMEN

In the present research work, the objective was to evaluate the effect of partial substitution of milk by whey in the sensory and physicochemical characteristics of quinoa ice cream. Four formulations with different concentrations of whey (0, 25, 75 and 100%) were made. The sensory analysis of the formulations was carried out with 31 panelists using a five-point hedonic scale that allowed the taste, aroma, color, and sweetness of the ice cream to be evaluated. The physicochemical characteristics of the formulation that obtained the highest score in the sensory analysis were evaluated for 40 days. The characteristics consisted of the determination of acidity, pH, soluble solids content and overrun percentage. A statistical analysis was performed to evaluate the means and statistical significance of sensory and physicochemical characteristics. The F1 formulation obtained the highest score in the perception of taste, aroma and color, compared to the control formulation F0 (p <0.05). The 40-day storage of ice cream with 25% whey and 75% milk (F1), showed an increase in acidity and pH, and a decrease in the percentage of overrun. The content of soluble solids remained constant from day 10. In conclusion, whey can be a substitute for milk in the elaboration of ice cream at a level of 25%, improving the taste and aroma of the product, also of nutritional quality, since it has a higher protein content than milk.

PALABRAS CLAVE: Ice cream, whey, overrun, quinoa.

ABSTRACT

El presente trabajo de investigación tuvo como objetivo evaluar el efecto de la sustitución parcial de leche por lacto suero en las características sensoriales y fisiocoquímicas del helado de quinua. Se elaboraron cuatro formulaciones de helado con diferentes concentraciones de lacto suero (0, 25, 75 y 100%). El
1. INTRODUCCIÓN

Whey is a byproduct of the cheese industry, obtained from milk after the precipitation of casein (Jelen, 2003). According to Motta-Correa and Yeisson (2015), 90% of the milk used in cheese making is eliminated as whey. Of this value, 47% is discarded in rivers, lakes and seas and 43% is used as animal feed. Whey contains about 55% of functional milk ingredients such as calcium, mineral salts, lacto proteins (albumin lacto, globulin lacto), soluble proteins, and lipids. However, it is considered as an environmental pollutant, because it chemically and physically affects the soil and water, causing a decrease in the yield of crops and dissolved oxygen in the water, respectively (Londoño 2006; Parra 2009; Cury et al. 2014; Aider et al. 2009).

Whey can be used as an ingredient in the preparation of various food products, such as ice cream, yogurts, beverages, gels and low-calorie spreads, due to the presence of potentially interesting compounds, so that their use can serve as new alternative for the reduction of environmental pollution (Boumba and Rodríguez 2011; Real Del Sol and Ortega 2011; Koutinas et al. 2009).

Ice creams are frozen dairy products that are characterized by proteins, minerals and high carbohydrate and fat content. The high content of fats and carbohydrates, limits their consumption by various population sectors, which follow strict diets or have some type of disease (Ayar et al. 2017; Ozdemir et al. 2008).

In the study carried out by Delgado and Moran (2016), whey was used for the preparation of ice cream flavored with cocoa and cookie filling, to analyze the organoleptic characteristics. Two formulations were made, F1 contained 74.4% whey, 2.21% powdered milk and 0% vegetable fat while F2 contained 69.89% whey, 0% powdered milk and 1.6% vegetable fat. During the sensory analysis performed on 20 untrained panelists, F2 obtained a score of 4 on a hedonic scale of 5 points. Regarding the color, taste, aroma and texture of the ice cream, both formulations did not show significant differences (p > 0.05), however, F2 obtained a higher score. The authors concluded that whey can be a substitute for milk powder during ice cream. A similar study was conducted by Nahui (2017). The author used whey to make ice cream from aguaymanto, and to evaluate its...
physically, chemically and organoleptically. The study worked with three concentrations of whey, 25% (F1), 50% (F2) and 75% (F3), and two concentrations of aguaymanto pulp, 10% and 15%. The ice cream containing 50% whey and 15% aguaymanto pulp showed greater acceptability by the panelists and its organoleptic characteristics were similar to the control (100% milk). Regarding its physicochemical characteristics showed a higher pH (3.67) and Brix degrees (27.5%) than F1.

In another study, Ventura (2018) evaluated the effect of different concentrations of whey (8, 12 and 16%) on acidity, overrun and on the organoleptic characteristics of ice cream. The formulation containing 12% whey, 88% milk obtained a higher percentage of overrun (40%) than the formulation of 8% and 16%. The sensory analysis performed with 30 semi-trained panelists, indicated that the formulation of 8% whey and 92% milk showed greater sensory acceptability and an acidity of 0.14%.

According to Neira (2011) and Carreño et al. (2011), ice cream may contain other ingredients that can increase their nutritional quality. These ingredients can be fruits, cereals, and legumes. It has been proven that quinoa is the only cereal that has all the essential amino acids, trace elements and vitamins that human beings require. Essential amino acids are found in the grain, unlike other cereals that have them in the exosperm or husk, such as rice or wheat. In 1996, quinoa was listed by FAO as one of humanity’s promising crops not only for its great beneficial properties and for its multiple uses as an ingredient in food, but also for considering it as an alternative to solve the serious problems of human nutrition (FAO 2019).

In this context, the present research is aimed at taking advantage of the components of the whey to give it an alternative use so as not to discard it and thus provide a nutritious product low in fat. The objective of this research was to evaluate the effect of partial substitution of milk by whey on the sensory characteristics of quinoa ice cream.

2. MATERIAL AND METHODS

2.1. Raw material and supplies
For the preparation of the formulations, whey from the production of fresh cheese was used, which was duly pasteurized. The milk was extracted by milking dairy cattle (Jersey cows) from CEFOP-Cajamarca and supplies such as quinoa, glucose, carboxymethyl cellulose stabilizer (CMC) and sugar were acquired from local establishments in the province of San Miguel, Peru.

Preparation of ice cream formulations
Quinoa jam was made following the methodology of Iza (2013). Quinoa was desaponified with washing and heat treatment at 75°C for 30 minutes. A small stainless steel pot and a kitchen were used, for the mixing of quinoa and sugar until reaching a concentration of 32 ° Brix, additives (CMC and citric acid) were added and the final cooking was carried out until reaching a concentration of 63 ° Brix, it was finally packaged in previously sterilized glass containers.

Three ice cream formulations and a control formulation were made. The ingredients were weighed according to table 1 and mixed by mechanical stirring. Pasteurization was carried out in a closed container using an industrial kitchen, and cooling in a refrigeration chamber until it reached 6 ° C. The molding was done in stainless steel molds and the ice cream packaging was carried out in polypropylene packaging. Figure 1 shows the flow chart for the production of quinoa ice cream partially substituted with whey.

Table 1 shows the ice cream base formulation (F0) and substitution ratio F1, F2 and F3.

Physicochemical characterization of milk and whey
The physicochemical characterization of milk and whey consisted of three methods which were: Determination of acidity, following the method of the Peruvian Technical Standard NTP 202.116 (INDECOPI 2008), determination of pH following the method of the Technical Standard Mexican NMX-F-317-S (Mexican Standards 1984), and density determination following the method of Peruvian Technical Standard NTP 202.008 (INDECOPI 1998).

Sensory analysis of quinoa cream ice cream
The evaluation of the organoleptic characteristics of the different ice cream formulations was carried out using a sensory analysis of 31 untrained panelists between the ages of 18 and 23 years. Samples were offered in plastic cups with a glass of water. The evaluation sheet consisted of a hedonic 5-point scale, where 1 corresponds to “I dislike it
a lot” and 5 “I like it a lot”. The parameters to evaluate were aroma, color, taste and degree of sweetness.

Physicochemical characteristics of quinoa ice cream
Total soluble solids of quinoa cream ice cream. The determination of soluble solids was carried out in a digital refractometer brand Atago model PAL-3 Pocket, following the methodology proposed by the Peruvian technical standard NTP 202.118 (INDECOPI 1998). The results were expressed in ° Brix.

Acidity index of quinoa cream ice cream.
The acidity determination was performed by titration with 1N sodium hydroxide (NaOH) and phenolphthalein as an indicator, following the NTC -4978 methodology (ICONTEC 2001). The calculation was performed using the following equation:

\[ \text{%Acidity} = \frac{(mL \text{ NaOH used}) - N (\text{NaOH}) \times 9 \times 100}{\text{sample weight}} \]

The results were expressed as a percentage of lactic acid. 1 mL of 1 N NaOH equals 0.009 mg lactic acid. “N” is the normality of NaOH.

Determination of pH of quinoa cream ice cream.
The pH determination was performed on a WTW model 3210 AZAZI12 portable potentiometer. The potentiometer was calibrated with buffer pH 4 and pH 7, the value was obtained directly by introducing the electrode into the sample.

Determination of Overrun
The measurement of overrun or aeration was determined using the method mentioned by Arbuckle (1977). The weight of the base mixture and the ice cream in a fixed volume container was compared, according to the following equation:

\[ \text{% Overrun} = \frac{(\text{ice cream volume weight} - \text{mix volume weight}) \times 100}{\text{mix volume weight}} \]

The results were expressed as a percentage of air incorporated after mixing for the base mixture; the temperature of the base will be 4°C and the ice cream at the exit of the beater of -5°C.

Statistical analysis of the data
The results were treated statistically using the StatGraphics Centurion program (2014 version USA) by calculating means and standard deviations. The analysis of variance (ANOVA) and the Tuckey test were performed to compare means of the different formulations and to determine if there are significant differences between them, respectively. The differences were considered statistically significant at a level of p <0.05.

3. RESULTS AND DISCUSSION

Physicochemical characteristics of milk and whey
The milk used to make quinoa ice cream presented 0.24 ± 0.01% acidity, density 1.02 ± 0.01 g cm-3 and pH 6.6. Whey showed 0.15 ± 0.03% acidity, density 1.03 ± 0.01 g cm-3 and pH 6.49. These values were similar to that obtained by Ventura (2018) in milk and whey used for the production of aguaymanto ice cream. Panesar et al. (2007) mentions that the whey that has a pH of 6.5 is considered a sweet whey while below this value is considered an acid whey. Sweet whey has a higher lactose and protein content. According to Parra (2009), when the whey presented at pH values greater than 5, it has good emulsifying properties.

Sensory analysis
Table 2 details the average scores assigned by panelists to each quinoa ice cream formulation. The increase in whey slightly decreased the perception of aroma in 7% and the degree of sweetness in 3% (p <0.05). F2 did not show significant differences with the control (F0) in the color and taste characteristics and F1 presented a higher score in the four organoleptic characteristics evaluated compared to F0.

(Table 2)

According to Pintor and Totosaus (2013), the percentage of milk fat used in the preparation of ice cream has an important role in the characteristics of ice cream since it favors the formation of ice crystals, increases viscosity and imparts the aroma in the product final. On the other hand, the content of carbohydrates present in the food also gives it aroma, because these participate in chemical reactions together with proteins to form aromatic compounds such as pyrroles, thiophenes, pyrazines and oxazoles (Illy and Viani 2005). It can be inferred that the high content of reducing sugars present in ice cream together with the high protein content of whey gave rise to chemical reactions that produced various volatile nitrogen and sulfur compounds that gave the quinoa ice cream an aromatic profile.
Effect of partial substitution of milk
cream taste.
In comparison to other authors, quinoa ice cream with 25% whey (F1) presented a score of 4.22 in terms of taste, higher than that obtained in Ventura (2018) in ice cream that contained 8% whey, but lower than obtained by Nahui (2017) in aguaymanto ice cream containing 50% whey (4.8). Guy et al. (1974) mentions that the acceptability in taste is inversely proportional to the amount of hydrolyzed lactose in the product, the greater the taste, the less hydrolyzed lactose.

**Physicochemical characteristics of quinoa ice cream**

These characteristics were evaluated in the ice cream formulation that obtained the highest score in the sensory analysis. The characteristics were evaluated every ten days for a period of 40 days. Table 3 shows the content of soluble solids, pH, acidity and overrun.

(Table 3)

The pH increased directly proportionally with the days (0-30 days) of storage. This increase was 5% (p <0.05). Between day 10 and day 30 the increase was not significant (p > 0.05), however, there was a significant decrease of 9% from day 30 to day 40 (p <0.05). The acidity increased as the pH increased, this behavior was similar to that obtained by Guner et al. (2007) in yogurt cream ice cream. From day 0 to 30, the increase in acidity was 11% and between days 10 and 40 the acidity remained constant. Guner et al. (2007), mentions that the increase in pH and acidity during the first month of storage may be the result of the degradation of protein and carbohydrates by microorganisms. However, Serdaroglu (1992) reported a decrease in pH in yogurt cream ice cream, between day 1 and day 60, these values were 4.30 and 3.90, respectively, while the acidity increased 1.16% and 1.35%, respectively.

The soluble solids content decreased slightly from day 0 to day 20, however, this decrease was significant (p <0.05) by day 30. These values were similar to those obtained by Nahui (2017) and, Delgado and Moran (2016). According to Chacón (2008), the high total solids content is associated with the quality that dairy derivatives will have, mainly in texture. Besides, can have a directly proportional relationship with the% overrun of ice cream, as the total ice cream solids increase so does the amount of air incorporated (Chacón et al. 2016).

Concerning overrun, the values decreased from day 0 to day 40 by 12%. From day 0 to day 10 there was a significant decrease in % overrun while from day 30 to 40, the decrease was not significant (p> 0.05). Similar results were obtained by Abdullah et al. (2003) in ice cream based on skim milk and soy, in which the percentage of overrun decreased from day 1 to 30 in 0.08%. According to Barrionuevo et al. (2011), the decrease in % overrun is related to the decrease in casein present in the product, which causes the ice cream to be dense, hard and cold in the mouth, obtaining a grainy structure. In comparison to other authors, quinoa ice cream had a higher percentage of overrun than that obtained by García (2015) in ice cream based on carrot pulp (10%) and by Ventura (2018) in ice cream with partial milk substitution by 8% whey (40%). According to Martínez (2002), commercial ice cream presents 22.66% soluble solids, 0.20% acidity, 6.65 pH and a percentage of overrun between 42.92 and 51.69% (Michue et al. 2015). The characteristics obtained from quinoa ice cream, prepared in the present investigation, presented characteristics similar to commercial ice cream.

4. **Análisis del estado del arte**

The partial substitution of milk by whey had significant effects on the sensory characteristics of quinoa ice cream, such as taste, color, aroma and degree of sweetness compared to ice cream with 100% milk. Quinoa ice cream containing 25% whey proportion obtained a higher score in the perception of taste, aroma and color, but lower in the perception of the degree of sweetness. Also, the ice cream did not show considerable changes in the content of soluble solids between day 0 and day 40 of storage. The parameters such as acidity, pH and overrun were within the parameters established for a commercial ice cream.

This research shows the potential value of whey as a partial substituent of milk in ice cream, so it is an ingredient with good quality characteristics, being able to be economically and ecologically sustainable. Quinoa ice cream can be a good source of natural substitutes and additives.

5. **Conclusiones**

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degree of sweetness compared to ice cream with 100% milk. Quinoa ice cream containing 25% whey proportion obtained a higher score in the perception of taste, aroma and color, but lower in the perception of the degree of sweetness. Also, the ice cream did not show considerable changes in the content of soluble solids between day 0 and day 40 of storage. The parameters such as acidity, pH and overrun were within the parameters established for a commercial ice cream.

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Table 1. Base formulation (F0) and substitution ratio F1, F2 and F3 for ice cream.

| Formulation | Ingredients (% p/p)² |
|-------------|----------------------|
|             | X₁³ | X₂³ | X₃ | X₄ | X₅ | X₆ | X₇ |
| F₀          | 100 | 0   | 7  | 0.5| 5  | 12 | 7  |
| F₁          | 75  | 25  | 7  | 0.5| 5  | 12 | 7  |
| F₂          | 50  | 50  | 7  | 0.5| 5  | 12 | 7  |
| F₃          | 0   | 100 | 7  | 0.5| 5  | 12 | 7  |

X₁: Milk, X₂: whey, X₃: quinoa jam, X₄: CMC, X₅: glucose, X₆: sugar, X₇: milk cream.

³Whey and milk mixture 68.5%.

²Formulations for 2L ice cream.

Table 2. Organoleptic characteristics of the formulations F0, F1, F2 and F3 of quinoa ice cream.

| Formulation | X₁ | X₂ | Aroma | Color | Taste | Degree of sweetness |
|-------------|----|----|-------|-------|-------|---------------------|
| F₀          | 100| 0  | 4.22±1.22⁹ | 3.93±1.27⁹ | 4.12±1.10⁸ | 4.22±1.04⁸ |
| F₁          | 75 | 25 | 4.51±1.00⁸  | 4.19±1.09⁸  | 4.22±1.10⁸  | 4.16±1.16⁸  |
| F₂          | 50 | 50 | 4.06±1.30⁸  | 3.96±1.17⁸  | 4.16±1.32⁸  | 4.19±1.38⁸  |
| F₃          | 0  | 100| 3.93±1.13⁹  | 3.41±1.33⁹  | 3.87±1.26⁹  | 4.09±0.93⁹  |

* Data are presented as means ± standard deviation (n = 3). Equal letters indicate that there are no significant differences between the formulations for each organoleptic characteristic (p <0.05, Tukey test).