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Industrial use of whey in the production of a yogurt-type fermented milk drink with *Aloe vera* L. (Asphodelaceae) crystals and *Passiflora ligularis* Juss. (Passifloraceae)

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Abstract

Currently, the food industry searches for innovation and the use of natural and more economical resources. With this in mind, the industrial application of whey was used to elaborate a yogurt-type fermented milk drink with *Aloe vera* L. crystals (Asphodelaceae) and *Passiflora ligularis* Juss. (Passifloraceae). For this purpose, *A. vera* crystals and granadilla or passionfruit pulp, were extracted and added to the four formulations established. Physicochemical, bromatological, microbiological, and sensory analyses (hedonic test) were carried out. The formulations with the highest content of *A. vera* (F4) and granadilla (F2) showed the best results in bromatological, microbiological, and sensory properties. The *A. vera* crystals and the granadilla pulp are of great industrial value due to the improvement that their addition gave to the physicochemical, bromatological, microbiological, and sensory properties of the yogurt-type fermented milk drink.

Keywords: microbiological properties, pasteurization, sensory evaluation, storage, temperature

Aprovechamiento industrial del lactosuero en la elaboración de una bebida láctea fermentada tipo yogur con cristales de *Aloe vera* L. (Asphodelaceae) y *Passiflora ligularis* Juss. (Passifloraceae)

Resumen

Actualmente, la industria alimentaria busca la innovación y el aprovechamiento de recursos naturales que sean más económicos. Pensando en ello, este trabajo tuvo como finalidad el aprovechamiento industrial del lactosuero mediante la elaboración de una bebida láctea fermentada tipo yogur con cristales de *Aloe vera* L. (Asphodelaceae) y *Passiflora ligularis* Juss. (Passifloraceae). Para esto, se extrajeron cristales de *A. vera* y pulpa de granadilla, y se adicionaron a las cuatro formulaciones establecidas. Se realizaron análisis fisicoquímicos, bromatológicos, microbiológicos y sensoriales (prueba hedónica). Las formulaciones que tuvieron mayor contenido de *A. vera* (F4) y granadilla (F2) presentaron los mejores resultados en las propiedades bromatológicas, microbiológicas y sensoriales. Se estableció que los cristales de *A. vera* y la pulpa de granadilla pueden ser de gran valor industrial, dado que su adición mejoró las propiedades fisicoquímicas, bromatológicas, microbiológicas y sensoriales de la bebida láctea fermentada tipo yogur.

Palabras clave: almacenamiento, evaluación sensorial, pasteurización, propiedades microbiológicas, temperatura

Introduction

The production of dairy beverages obtained through the fermentation of whey or lacto-serum has grown significantly worldwide due to the simplicity of its process and, above all, to its excellent consumer acceptance (Boynton & Novakovic, 2014; Janiaski et al., 2016). Whey is a by-product generally obtained in artisanal cheese industries considered a low-value raw material, frequently discarded in water sources or sewers, causing serious pollution problems. Despite possessing lactose in significant quantities as structural carbohydrates that allow the growth and multiplication of lactic acid bacteria, it is mostly used for animal feed (Arce-Méndez et al., 2016; Miranda et al., 2014). Producer ignorance about the nutritional properties of whey and the lack of resources to access adequate technologies for its management and processing leads to the loss of this by-product (Mazorra-Manzano et al., 2019; Poveda, 2013).

In the food industry, *Aloe vera* L. (Asphodelaceae) and its derivatives (e.i., gel), have several applications due to its wide variety of nutritional properties. Therefore, it has been used as a food supplement in juices, drinks, capsules, and gels, and it is consumed fresh or as an ingredient in culinary preparations (salads and pastry products) due to its content of vitamins and minerals. Thus, it is considered a raw material or main ingredient in the preparation of functional foods (Acevedo et al., 2017; Bonilla & Jiménez, 2016; Sánchez & Caballero, 2020). The by-products of this plant are usually extracted through heating, dehydration, or grinding processes, which can irreversibly affect the bioactive components, including polysaccharides and antioxidant compounds, producing changes in the biochemical properties of the product (Serván, 2018; Villa-Uvidia et al., 2020).

The *Passiflora* L. genus that belongs to the family Passifloraceae has different species with industrial interest. Granadilla (*Passiflora ligularis* Juss.), after yellow passion fruit (*P. edulis* f. *flavicarpa* Degener), occupies the second place in economic importance due to its participation in national and international markets. It is a fruit that contains multiple seeds surrounded by a sweet aril with great organoleptic attributes that is mostly consumed as fresh fruit (Arias et al., 2016; Gaona-Gonzaga et al., 2020). It is produced mainly in Colombia with a national production in 2018 of 47,458.04 tons, being Huila the main producer department with 23,674.55 tons, followed by Nariño, Cundinamarca and Antioquia, according to the statistics reported by Agronet (2020).

In general, the information obtained allowed establishing a study in which lactose, being of great importance for the industrial sector, could be used as it allows the utilization of this by-product that is typically discarded. This generates, in turn, significant damage to the environment. However, whey can be used together with *A. vera* crystals, implementing techniques that utilize nutrients from this plant, and those provided by granadilla. This allows obtaining a yogurt-type fermented milk drink with adequate physicochemical, microbiological, bromatological, and sensory parameters for this type of product. For this reason, the aim of this work was to make industrial use of whey in the elaboration of a yogurt-type fermented milk drink with *A. vera* crystals and *P. ligularis* pulp.

Materials and methods

Raw material and extraction of *Aloe vera* crystals and granadilla pulp

Sweet whey was used to make the yogurt-type fermented milk drink obtained from a local cheese company, while the rest of the material was obtained from the local market in the city of Cartagena de Indias (Colombia).

Aloe vera leaves (from 2 or 3-year-old plants) were immersed in a sodium hypochlorite solution and left for 3-5 min to remove any remaining dirt. Then, the aloin content was removed, leaving the leaves in water for 24 h. After this time, the epidermis was removed, and the pulp was cut into cubes of 1.5 × 1.5 × 1.5 cm obtaining what is known in the region as "*Aloe vera* crystals".

The granadilla fruits in maturity states 7 and 8, and similar sizes, were washed in the same way as the *A. vera* leaves. Then, these were scalded in water at 100 °C for 5 min. Subsequently, they were taken to a pulping machine (CI TALSA D1000) to extract the pulp that was not pasteurized.

Formulation and production of a yogurt-type fermented milk drink

The drink formulations assessed can be seen in table 1. The percentages were based on % w/v in relation to sweet whey.

Table 1. Yogurt-type fermented milk drink formulations (F) assessed

Component	F1	F2	F3	F4
Whey (%)	100	100	100	100
Sugar (%)	4	4	4	4
Lactic culture (%)	5	5	5	5
Semi-skimmed milk powder (%)	23	23	23	23
***Aloe vera* (%)**	0	7.5	10	12.5
Granadilla (%)	0	12.5	10	7.5

Source: Elaborated by the authors

Sweet whey was pasteurized at a temperature of 62 ± 0.5 °C for 30 min. Subsequently, sugar and semi-skimmed milk powder were added until a homogeneous solution was obtained. To the resulting product, the lactic culture (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) attained from a mother

culture, was added. The fermentation process took place for 210 min (3.5 h) at 44.5 ± 1.0 °C. The percentages of *A. vera* crystals and granadilla pulp according to the formulations established (table 1) were added once this process was finished.

Physicochemical and bromatological evaluations

The analyses were made according to the Association of Official Agricultural Chemists (AOAC,1990) as follows: pH (943.02), percentage of titratable acidity (942.15), protein (979.09), moisture (927.05), ash (923.03), fat (920.39), carbohydrates (by difference), Na (985.35), Mg (985.35), K (985.35), Fe (944.02), Ca (944.03), and vitamin C (2,6-dichloroindophenol titrimetric method). Further, 2,2-diphenyl-1-picrylhydrazyl (DPPH) was established according to Repo and Encina (2008).

Microbiological analysis

The microbiological analyses performed on the finished product according to the Colombian Technical Standard 805 (Instituto Colombiano de Normas Técnicas y Certificación [Icontec], 2005) were the following: Total coliforms (Icontec, 2007), and molds and yeasts (Icontec, 1997).

Sensory analysis

A 5-point hedonic test was chosen to determine the sensory acceptability of the four samples or formulations, ranging from "I really dislike it" with a score of 1, to "I really like it" with a score of 5. Fifty persons of both genders between 20 and 30 years of age were chosen to perform this test. The parameters to be evaluated were color, smell, viscosity, acidity, and general acceptability.

Storage behavior

The methodology proposed by Parra (2013) was used for this test with some modifications. Once the sample with the best consumer acceptance was chosen, pH (943.02) and titratable acidity (942.15) tests were performed using the AOAC (1990) methods for 21 days at 4 °C. Measurements were made every seven days in triplicate. In this way, the useful life of the yogurt that obtained the best consumer preference was established.

Statistical analysis

The obtained data were analyzed using standard analysis of variance (ANOVA), and its statistical significance was established utilizing Tukey's test with a confidence level of 95 %, employing the statistics Statgraphic Centurion XVI.I. program. All tests were performed in triplicate.

Results and discussion

Physicochemical properties

The pH behavior during the fermentation process of the yogurt-type fermented milk drink can be seen in figure 1, showing a linear decrease over 210 min. The milk drink recorded a pH value of 7.26 in its initial stage, decreasing its pH slowly during the fermentation process at a temperature of 44.5 ± 1 °C until reaching a pH value of 5.47 at the end of the fermentation period. In this process, the pH did not change abruptly, since the temperature was maintained between the optimal range indicated for this product in other studies for an adequate microorganism development (Adamberg et al., 2003; Hoyos et al., 2010). The pH-decrease phenomenon is due to the lactose fermentation action of lactic acid bacteria (LAB) found in yogurt (*L. bulgaricus* and *S. thermophilus*). These act on existing carbohydrates and the production of lactic acid activity that was generated in the fermentation process, whose bacteria can produce acids that eventually increase the H^+ concentration in the culture (Østlie et al., 2003; Vahedi et al., 2008; Widyastuti & Febrisiantosa, 2014; Zapata et al., 2015).

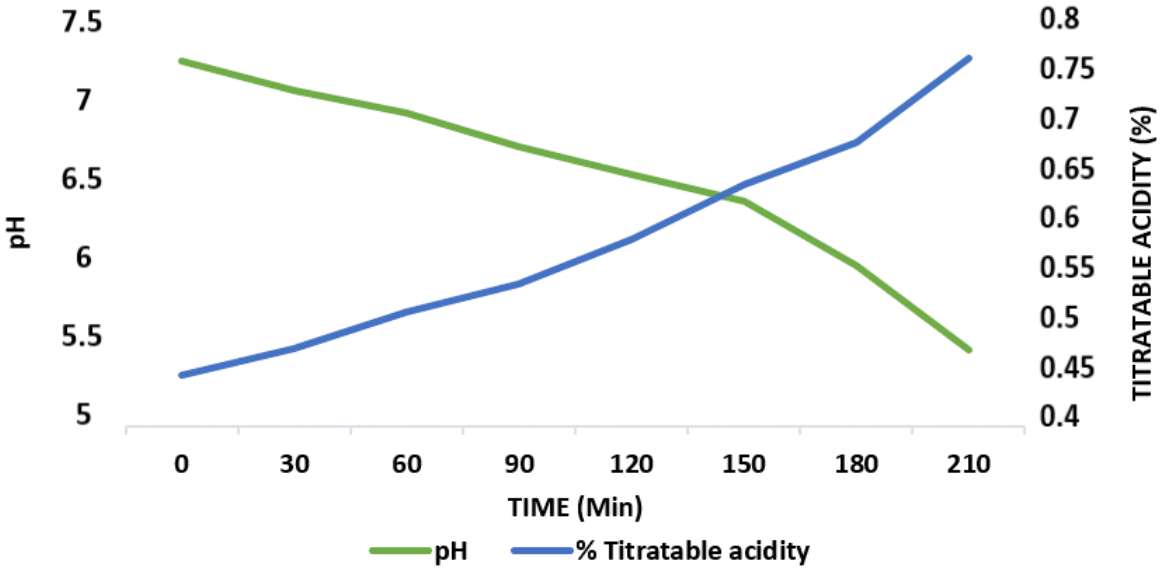

Figure 1. Variation in pH and percentage of titratable acidity during the fermentation process.
Source: Elaborated by the authors

The increase in the percentage of titratable acidity expressed as the percentage of lactic acid during the fermentation process can be seen in figure 1. The percentage of acidity observed at the end of the fermentation was 0.765, indicating that the lactic acid levels are within the ranges established by the Colombian Technical Standard 805, which stipulates that the minimum percentage of acidity must be 0.60 for dairy products. The results obtained showed the growth of the acidity percentage from 0.45 %

at the beginning of fermentation, to 0.765 % at 210 min, finishing at this point, the bacterial incubation phase. This last value is higher than the result obtained by Miranda et al. (2014); these authors elaborated a fermented drink from whey incorporating *L. acidophilus* and *S. thermophilus* with a titratable acidity of 0.63 %, and establishing that the content of nutrients and proteins in whey can generate the good behavior of lactic bacteria.

Bromatological properties

The bromatological properties of the four formulations of the yogurt-type fermented milk drink assessed are shown in table 2. *Aloe vera* and granadilla influenced the parameters evaluated due to the statistical differences ($p < 0.05$) found between the samples.

Table 2. Bromatological properties of the four formulations (F) of the yogurt-type fermented milk drink

Properties	F1	F2	F3	F4
Moisture (%)	82.55 ± 0.2a	80.43 ± 0.03b	80.33 ± 0.05b	80.37 ± 0.13b
Protein (%)	3.82 ± 0.05a	5.46 ± 0.04b	5.34 ± 0.03c	5.03 ± 0.03d
Fat (%)	4.17 ± 0.12a	4.17 ± 0.1a	4.12 ± 0.11a	4.16 ± 0.15a
Carbohydrates (%)	5.39 ± 0.02a	5.35 ± 0.10a	5.2 ± 0.16a	5.2 ± 0.12a
Ash (%)	4.54 ± 0.12a	5.43 ± 0.13b	5.4 ± 0.09b	5.27 ± 0.06b
Vitamin C (mg)	3.74 ± 0.27a	24.04 ± 0.69b	20.44 ± 0.38c	15.63 ± 0.45d
Ca (mg)	109.62 ± 1.97a	150.28 ± 2.68b	133.11 ± 2.96c	117.81 ± 2.57d
Fe (mg)	87.83 ± 2.44a	137.93 ± 3.13b	129.43 ± 3.64c	103.11 ± 1.94d
K (mg)	145.26 ± 2.78a	256.84 ± 2.52b	302.22 ± 2.14c	348.31 ± 2.92d
Mg (mg)	12.58 ± 1.11a	23.84 ± 1.71b	34.63 ± 2.09c	40.80 ± 1.55d
Na (mg)	56.93 ± 1.61a	61.5 ± 2.02b	66.60 ± 1.95c	73.10 ± 2.72d
DPPH (µmol trolox/100 g of extract)	0.17 ± 0.01a	22.8 ± 0.45b	18.03 ± 0.37c	15.2 ± 0.12d

DPPH: 2,2-diphenyl-1-picrylhydrazyl.
Note. Similar letters in the same row indicate a statistically significant difference, according to Tukey's test ($p < 0.05$); n = 3; average ± standard deviation
Source: Elaborated by the authors

The F2 sample obtained statistically significant differences ($p < 0.05$) and higher protein percentage, contents of vitamin C, Ca, Fe, and antioxidant capacity (DPPH) compared to the other samples. This is because F2 had the highest percentage of granadilla (12.5 %), and this fruit is rich in macro and micronutrients; moreover, *A. vera* crystals also possess vitamin C and antioxidants (Cabrera et al., 2014; Carvajal et al., 2014; López et al., 2006; Vega-Gálvez et al., 2011). Sample F4 showed the statistically highest values ($p < 0.05$) for K, Mg, and Na with respect to the other treatments or formulations. These

high percentages are because this sample had the highest percentage of *A. vera* crystals (12.5 %), providing these minerals to the product (Miranda et al., 2009; Vega et al., 2005; Zhang et al., 2018).

Concerning the moisture content, F1 showed the highest value. Meanwhile, regarding ash content, samples F2, F3, and F4 showed a statistically significant difference ($p < 0.05$) compared to F1, due to the percentages of ash that granadilla and *A. vera* have (Carvajal et al., 2014; Miranda et al., 2009). In relation to the percentages of carbohydrates and fat, no statistical differences were found ($p > 0.05$); these results are, however, similar to those reported by other authors (Miranda et al., 2014; Tirado et al., 2015).

Microbiological properties

The results of the microbiological evaluation carried out are shown in figure 2. The elaborated fermented milk drink complied with the microbiological requirements established in the Colombian Technical Standard 805, since according to the mold and yeast tests (limit of 500 CFU/mL), the samples showed values below the allowed limit. Likewise, for the total coliform tests (limit of 100 CFU/mL), these were within the allowed limit. The samples with higher *A. vera* content (F2, F3, and F4) had less contamination than the control sample (figure 2); according to Shaaban et al. (2010), this may be due to the antimicrobial properties of *A. vera*.

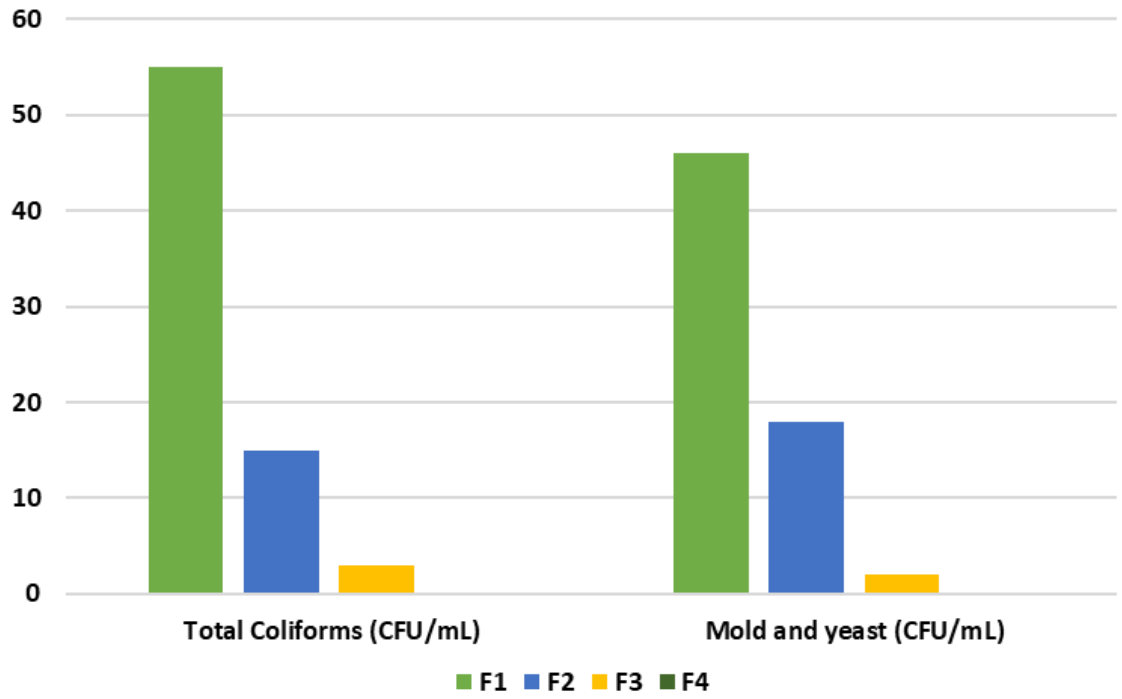

Figure 2. Microbiological properties of the four formulations of the yogurt-type fermented milk drink
Source: Elaborated by the authors

The yogurt-type fermented milk drink showed a low quantity of total coliforms, indicating the adequate hygienic quality with which they were elaborated, similar to the results in the coliforms count reported by Mukhekar et al. (2018) in the elaboration of a yogurt product enriched with *A. vera*.

Sensory properties

The results of the sensory analysis are shown in table 3. F4 obtained the best score in all parameters because it only had statistically significant differences ($p < 0.05$) over the other samples in smell, acidity, and general acceptability. Concerning color, there were statistically significant differences ($p < 0.05$) between the white sample (F1) and the rest. Furthermore, no statistically significant differences ($p > 0.05$) were found in viscosity.

Table 3. Sensory properties of the samples of the four formulations (F) of the yogurt-type fermented milk drink

	Color	Smell	Viscosity	Acidity	Overall acceptability
F1	3.73 ± 0.07a	3.43 ± 0.07a	4.05 ± 0.05a	3.69 ± 0.08a	3.07 ± 0.07a
F2	4.09 ± 0.07b	3.90 ± 0.1b	4.05 ± 0.13a	3.82 ± 0.19a	3.88 ± 0.10b
F3	4.08 ± 0.04b	4.06 ± 0.05c	4.03 ± 0.1a	3.84 ± 0.04a	3.81 ± 0.08b
F4	4.19 ± 0.18b	4.43 ± 0.08d	4.18 ± 0.05a	4.22 ± 0.08b	4.37 ± 0.41c

Nota. Similar letters in the same column symbolize a statistically significant difference, according to Tukey's test ($p < 0.05$); n = 50; average ± standard deviation.
Source: Elaborated by the authors

When there is a higher *A. vera* content, the assessment of the panelists was also higher. This coincides with Parra (2014), who indicated that *A. vera* provides sensory features that yogurt does not possess.

Behavior during storage

The behavior of pH and titratable acidity during storage is shown in figure 3. There was a slow linear decrease in pH, starting from 5.47 and 5.36, and ending with 5.17 and 5.12 during storage for the F1 and F4 formulations, respectively. These results were superior to those reported by Marulanda et al. (2016) and Ruiz and Ramírez (2009). Several authors consider that the acidification during storage may be due to the residual enzymes produced by the initiators during fermentation, remaining active at temperatures between 0-5 °C (Kailasapathy, 2006; Vahedi et al., 2008).

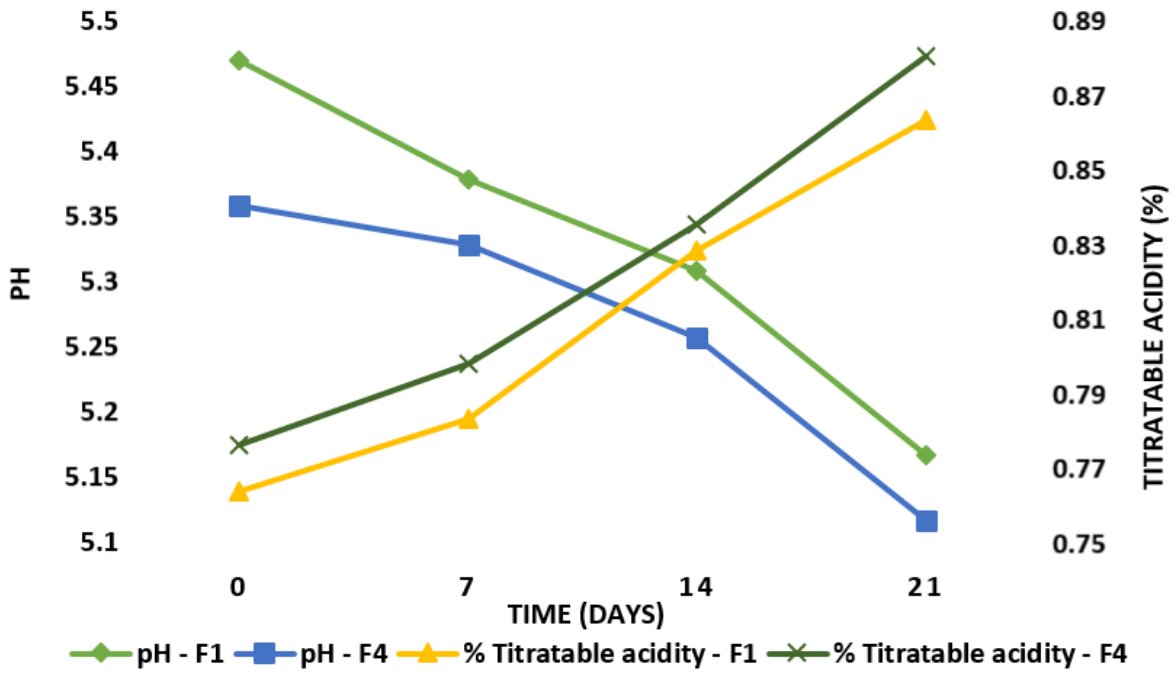

Figure 3. Variation in pH and percentage of acidity during the storage of the four formulations of the yogurt-type fermented milk drink.
Source: Elaborated by the authors

On the contrary, the percentage of acidity showed a linear increase, presenting an initial percentage of lactic acid of 0.765 to 0.864 for F1, and 0.777 to 0.881 for F4, values similar to those found by Londoño et al. (2008) and Londoño et al. (2017), who produced drinks fermented from whey with probiotics, obtaining a percentage of acidity of 0.90 at day 21. The *A. vera* crystals influenced pH and acidity, since the polysaccharides present in this species had a stimulant effect on the metabolic activity of the microorganisms (Wijesundara & Adikari, 2017; Yadav et al., 2007).

The acidity did not exceed the maximum stipulated in Colombia by Resolution 2310 (1986), which indicates that the maximum percentage of acidity that a fermented milk drink must have is 1.50. At the same time, for pH, there are no regulations in force in Colombia that stipulate a maximum value for this parameter. Therefore, the yogurt-type fermented milk drink had a useful life of more than 21 days at 4 °C.

Conclusions

According to the results obtained, the use of sweet whey, *Aloe vera,* and granadilla (*Passiflora ligularis*) as main ingredients in different elaborated products, can be of great industrial value due to the favorability imparted by the different properties that were evaluated in the yogurt-type fermented milk drink elaborated. Regarding the bromatological properties, the F2 and F4 samples showed the best values. The F4 sample obtained the best results in terms of microbiological and sensory properties, also

exhibiting good behavior under storage. As shown in all parameters evaluated, F4 (12.5 % of *A. vera* crystals and 5.5 % of granadilla pulp) was considered the best sample among the ones assessed.

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Disclaimers

All the authors made significant contributions to the document and agree to its publication; further, all authors state no conflicts of interest in this study.

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