Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.102122

Use of water-soluble soy extract and inulin as ingredients to produce a fermented dairy beverage made from caprine milk

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Abstract

A yogurt-like fermented dairy beverage was elaborated from a mixture containing 70% (v/v) caprine milk and 30% (v/v) water-soluble soy extract (WSSE), supplemented with inulin (4 g·100 mL^{-1}). Physicochemical, sensorial, and microbiological analyses were carried out to characterize the product and evaluate its stability during 28 days of refrigerated storage (5 °C). To compare the results, a yogurt made from whole caprine milk, without inulin supplementation, was elaborated as a control. The use of WSSE and inulin showed favorable to the physicochemical and physical properties of the product, increasing the water holding capacity, improving the rheological properties, and preventing over-acidification during refrigerated storage. Regarding the sensorial evaluation, the control treatment was better evaluated for aroma, flavor, and overall acceptability. No differences were observed between the treatments concerning the microbiological parameters.

Keywords: sensorial properties; rheological properties; prebiotic; microbial viability.

Practical Application: The technological limitations of caprine milk to produce fermented beverages can be overcome by adding WSSE and inulin.

1 Introduction

Yogurt is a conventional food product, which is obtained by the acid coagulation of milk proteins through the symbiotic activity of the mixed culture composed of *Streptococcus salivarius* subsp. *thermophillus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (Raza et al., 2022). Many studies have pointed out that the benefits of yogurt consumption are attached to the viability of these lactic acid bacteria (Hadjimbei et al., 2020), where, according to the Brazilian regulation, the minimum required is 10^6 CFU·g^{-1} (Brasil, 2007). Yogurts made from cow's milk are the most consumed, although, the use of goat's milk is an alternative to diversify the market and to obtain a product with nutritional properties of interest, with higher digestibility, lower allergenic properties, and higher content of polyunsaturated fatty acids (Ranadheera et al., 2012). However, technological limitations of goat's milk, such as the over-acidification due to its low buffering capacity and the rheological properties of the coagulum which is almost semi-liquid make it difficult to produce and commercialize goat's milk yogurt (Haenlein, 2004; Martín-Diana et al., 2003).

Soy products have been used for ages, and their consumption is correlated with additional health benefits (Kesika et al., 2022). The fermentation of water-soluble soy extract (WSSE) by lactic acid bacteria has been utilized to obtain fermented beverages as an alternative to improve the nutritional and sensory properties of soybean (Kesika et al., 2022). The use of WSSE as a partial substitute for milk in the manufacturing of dairy products has been evaluated as an alternative to innovate and improve some quality aspects of the products (Park et al., 2005; Tsai et al., 2009; Šertović et al., 2022).

Prebiotics are defined as substrates that are selectively utilized by host microorganisms conferring a health benefit (Gibson et al., 2017). Inulin is a well-known food ingredient, which exhibits high positive prebiotic activity (Ozcan & Eroglu, 2022). Besides the nutritional benefits, the use of inulin is also based on its excellent technological properties, being used as a fat replacer, a sugar replacer, and a texture modifier, improving the rheological properties of the products (Meyer et al., 2011; Rinaldoni et al., 2012).

The present research aimed to develop and characterize the quality aspects of a yogurt-like fermented beverage made from a substrate composed of a mixture of goat's milk and WSSE, supplemented with inulin.

2 Materials and methods

2.1 Raw materials

Whole goat's milk (Alpine breed) was obtained from the Laboratory of Goat and Cattle breeding of the Center for Humanities, Social and Agrarian Sciences at the Federal University of Paraíba (Bananeiras, Paraíba, Brazil). The milking was performed under recommended hygienic procedures (Brasil, 2000), and the

Received 05 Sept., 2022
Accepted 25 Oct., 2022
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milk was pasteurized (72 °C for 20 s) and then stored under refrigeration (5 °C) until use. WSSE was prepared following the procedure described by Li et al. (2012), with modifications. Whole dry soybeans (Yoki Alimentos®, Paraná, Brazil) were first washed and soaked overnight in a 0.5% $NaHCO_3$ solution. After decanting the water, the soaked soybeans were ground into a homogenate with 60 °C water of 7 times soybean dry weight using a blender, and the homogenate was then filtered through a cheesecloth to yield WSSE. The yogurt-like fermented beverages were flavored with an 18 °Brix grape pulp, made from mature grapes cv. Isabel.

2.2 Manufacture of the fermented beverages

Based on the results of previous formulation experiments using response surface methodology (Ribeiro et al., 2016), a yogurt-like fermented beverage (FB) was elaborated from the mixture containing goat's milk (70% v/v) and WSSE (30% v/v), supplemented with inulin (4 g·100 mL^{-1}). For comparison of the data, a control treatment (CT) using only whole goat's milk and without inulin supplementation was also prepared. The yogurt-like fermented beverage was manufactured according to the methodology described by Tsai et al. (2009), with modifications. Sucrose (União®, Brazil) was added to goat's milk (10 g·100 mL^{-1}) and WSSE (10 g·100 mL^{-1}). Then the goat's milk and WSSE were homogenized and heat-treated individually at 90 °C for 10 min and 95 °C for 15 min, respectively. Thereafter, goat's milk and WSSE were mixed, added of inulin (Clariant®, São Paulo, Brazil), and cooled to 42 °C. The thermophilic lactic culture (YF-L903-50U, Christian Hansen®, Valinhos, Brazil), composed of *Streptococcus salivarius* subsp. *thermophillus* and *Lactobacillus delbrueckii* subsp. *bulgaricus,* was then added by direct inoculation according to the manufacturer's recommendation (3 mg·100 mL^{-1}). The mixture was transferred to a fermentation chamber at 42 °C for 4 hours and cooled (5 °C) at the end of the fermentation process. Grape pulp (10 mL·100 mL^{-1}) was added and gently stirred with a sterile glass stem until it was homogenized. The products obtained were packaged in sterile high-density polyethylene bottles (180 mL) and stored under refrigeration (5 °C) until analyses. The control treatment was manufactured under the same conditions but using only goat's milk and without inulin supplementation.

2.3 Physicochemical evaluation

Goat's milk and WSSE physicochemical characterization

The following physicochemical parameters were evaluated: total solids, total protein, Titratable acidity, fat, lactose (only in the goat's milk), ash, and calcium. The pH was measured in a digital potentiometer (model Q400AS, Quimis, Diadema, São Paulo, Brazil). The density (only in the goat's milk) was also evaluated. All the analyses were carried out according to methodologies preconized by the *Association of Official Analytical Chemists methods* (Association of Official Analytical Chemists, 2005).

Physicochemical composition of the fermented beverages

After 1 day of refrigerated storage (5 °C) the fermented beverages were evaluated for the following parameters: total solids content, by drying in the oven at 105 °C for 24 h; ash content, by the gravimetric method through incineration in muffle at 550 °C; calcium content, by titration with EDTA; protein content, using the method Micro-Kjeldahl; fat content, by the method of Gerber and lactose content by the method of Fehling's reagent. All the analyses were made in triplicate according to the recommendations of the *Association of Official Analytical Chemists methods* (Association of Official Analytical Chemists, 2005).

2.4 Sensorial evaluation of the fermented beverages

A panel of 50 non-trained assessors, recruited among students at the Federal University of Paraíba (João Pessoa, Brazil), was used for the sensorial evaluation of the fermented beverages. The assessors were asked to evaluate the products regarding their color, appearance, aroma, texture, taste, and overall acceptability, using a nine-point structured hedonic scale (9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). The analysis was performed in individual booths and the samples were served at 7-10 °C in plastic cups and were coded with three-digit numbers. Water at ambient temperature was available for panel members to rinse their palates between samples. Crackers were also supplied to aid in removing any carryovers between tastings. The sensorial analysis was carried out after one week of refrigerated storage (5 °C). Before sensory evaluation, all samples were submitted to microbiological evaluation for the determination of the most probable number of total coliform and thermotolerant coliform per milliliter (MPN·mL^{-1}), the total count of *Staphylococcus* coagulase positive (CFU·mL^{-1}) and detection of *Salmonella* ssp., following the methodologies recommended by the *American Public Health Association* (American Public Health Association, 2001). The ethics approval was obtained from the Research Ethics Committee of the Federal University of Paraíba (Ethics approval number: 383.500/2013).

2.5 Stability during the refrigerated storage

The stability of the fermented beverages was evaluated after 1, 7, 14, 21, and 28 days of refrigerated storage (5 °C). Physicochemical (pH and acidity), physical (syneresis, WHC, and rheological characterization,) and microbiological analyses were performed.

pH, acidity, syneresis, and WHC

The pH of the fermented beverages was measured in a digital potentiometer (model Q400AS, Quimis, Diadema, São Paulo, Brazil). Acidity was determined by titration and expressed as g·100 g^{-1} of lactic acid. Syneresis susceptibility was measured using the drainage method (Hassan et al., 1996). Each sample was weighed and transferred to a funnel containing a filter paper. The amount of whey collected for 4 h at 5 °C was weighted and the syneresis index was considered as the amount of drained whey (g) per 100 g of sample. Water holding capacity was evaluated through centrifugation of the sample at 3.500 rpm for 15 min at 10 °C (Harte et al., 2003) in a refrigerated centrifuge (CIENTEC, model CT-5000R). The WHC was calculated as follows: (%) WHC = [(1-(supernatant weight/sample weight))×100].

Rheological characterization

The rheological behavior of the fermented beverages was determined using a rotational viscometer equipped with concentric cylinders MV/MV1 (Thermo Haake, model VT 550, Karlsruhe, Germany). The measurements were made at 10 °C and the temperature was controlled by a thermostatic bath coupled to the equipment (Thermo Haake, Karlsruhe, Germany). Rheowin Pro Job Manager software was used for controlling the process and recording the data. The rheological analysis was carried out by varying the shear rate from 1 to 600 s^{-1} (ascending curve) and from 600 to 1 s^{-1} (descending curve), within an interval of 300 s for each curve. The readings were taken twice and for each measurement, a new sample was used.

Rheological modeling

The rheological data obtained for the fermented beverages were fitted to four different non-Newtonian rheological models (Equations 1-4):

$$Ostwald-de-Waelle: t = k \cdot (g)^{n} \quad (1)$$

$$Herschel-Bulkley: t = t_0 + k \cdot (g)^{n} \quad (2)$$

$$Casson: t^{0.5} = k_{OC} + k_C \cdot (g)^{0.5} \quad (3)$$

$$Mizrahi-Berk: t^{0.5} = k_{OM} + k_M \cdot (g)^{n} \quad (4)$$

Where: τ is the shear stress (Pa); τ_0 is the yield stress (Pa); γ is the shear rate (s^{-1}); n is the flow behavior index (dimensionless); K is the consistency index ($Pa \cdot s^n$); K_{OC} is the Casson yield stress ($Pa^{1/2}$); K_C is the Casson plastic viscosity ($Pa^{1/2} \cdot s^{1/2}$); K_{OM} is the square root of the yield stress ($Pa^{1/2}$) and K_M is the consistency index ($Pa^{1/2} \cdot s^n$).

The software *Statistica* 5.0 (Statsoft, USA) was used for the calculation. Rheological modeling was carried out from the rheograms (ascending curves) obtained after one day of refrigerated storage (5 °C). Ostwald-de-Waelle model was adopted to describe the rheological behavior of the samples during the refrigerated storage (1, 7, 14, 21, and 28 days), once that model provided the best fit to the experimental data.

Microbiological evaluation

The count of *S. thermophilus* and *L. bulgaricus* populations as well as the determination of total and thermotolerant coliforms ($MPN \cdot mL^{-1}$), *Staphylococcus* positive coagulase ($UFC \cdot mL^{-1}$), and the presence of *Salmonella* ssp., were performed according to methodologies recommended by the American Public Health Association (American Public Health Association, 2001). Analyses were carried out weekly during the refrigerated storage at 5 °C.

2.6 Statistical analysis

Statistical analysis was performed using a one-way analysis of variance (ANOVA). Mean values were compared by Tukey's test at 5% of probability. Statistical analyses were performed using *Statistica* 7.0 (Statsoft, USA). Differences were considered significant when $p < 0.05$.

3 Results and discussion

3.1 Physicochemical evaluation

Raw material

When compared to WSSE, caprine milk presented a lower content of protein and higher contents of total solids, fat, ash, and calcium (Table 1). The results obtained for the caprine milk were similar to those found by Sant'Ana et al. (2013) in caprine (Alpine breed) milk. Density, acidity, lactose, fat, total protein, and ash values were in accordance with the Brazilian technical regulation of the identity and quality of caprine milk (Brasil, 2000). WSSE composition depends on soybean variety and on the processing conditions (Nik et al., 2009), however, the typical composition is about 3.6% of protein, 2% of fat, 2.9% of carbohydrates, and 0.5% of ash (Liu, 1997). Rekha & Vijayalakshmi (2008) elaborated WSSE using a soybean:water ratio of 1:6 (w/v) and obtained mean values of 2.3% of fat, 0.5% of ash, and 4.4% of protein. These values are not far from those obtained in the present study, where the soybean:water ratio used was 1:7 (w/v).

Fermented beverages

The physicochemical composition of dairy beverages may greatly change depending on the amount and type of ingredients used (Šertović et al., 2022). The fermented beverage containing WSSE and inulin (FB) presented higher values for dry material and protein, while the control treatment (CT) showed higher values for ash, lactose, and calcium (Table 2). According to Rinaldoni et al. (2012), fermented beverages such as yogurt must present minimum total solids of 12 $g \cdot 100\ g^{-1}$ in order to obtain products with adequate viscosity and texture. The higher values of protein and dry material in FB represent an important role in the technological properties of the product, as these parameters are determinants to obtain desirable rheological properties in fermented beverages (Rinaldoni et al., 2012; Raza et al., 2022; Oliveira et al., 2009). The higher values of dry matter and protein in FB can be explained either by the addition of inulin or by the higher protein content in WSSE when compared to the caprine

Table 1. Mean values ± standard deviation for the physicochemical parameters of caprine milk and WSSE.

Parameter	Caprine milk	WSSE
Dry material ($g \cdot 100\ g^{-1}$)	$10.29^a \pm 0.08$	$7.91^b \pm 0.04$
Total protein ($g \cdot 100\ g^{-1}$)	$2.97^b \pm 0.31$	$3.50^a \pm 0.11$
Fat ($g \cdot 100\ g^{-1}$)	$2.90^a \pm 0.10$	$2.46^b \pm 0.03$
Ash ($g \cdot 100\ g^{-1}$)	$0.80^a \pm 0.01$	$0.32^b \pm 0.00$
Lactose ($g \cdot 100\ g^{-1}$)	4.44 ± 0.09	NE*
Calcium ($mg \cdot 100\ g^{-1}$)	$145.61^a \pm 0.51$	$39.36^b \pm 0.02$
Acidity ($g \cdot 100\ g^{-1}$)	$0.14^a \pm 0.01$	$0.13^a \pm 0.02$
pH	$6.81^a \pm 0.01$	$6.77^a \pm 0.03$
Density ($g\ mL^{-1}$)	1.032 ± 0.00	NE*

*NE: not evaluated. a, b: different lowercase letters in the same line mean a significant difference by the Tukey test at 5% of probability.

milk used. Fat content did not differ ($p > 0.05$) between the treatments.

3.2 Sensorial evaluation

Fermented beverages were different ($p < 0.05$) in flavor, taste, and overall acceptability (Table 3). The lower values for these three attributes were found in the fermented beverage containing WSSE and inulin. This result can be a consequence of the characteristic beany flavor of soybeans still present in the final product (Park et al., 2005).

3.3 Stability during the refrigerated storage

pH, acidity, syneresis, and WHC

Susceptibility to syneresis, an undesirable property in yogurt products, is the effect of liquid separating from the yogurt curds (Ranadheera et al., 2012; Aryana & McGrew, 2007). The syneresis index was not influenced ($p > 0.05$) by the refrigerated storage time (Table 4). This behavior was also observed by Guven et al. (2005) in yogurts supplemented with inulin and by Aryana & McGrew (2007) in yogurts without any supplementation. CT presented a constant WHC up to 21 days of storage, whereas FB showed an increase in WHC after one week, followed by a decrease from the third week. Significant differences ($p < 0.05$) were observed between the samples for syneresis index and WHC, where the fermented beverage containing WSSE and inulin presented lower syneresis and higher WHC values. These results can be related to the addition of inulin in FB as this prebiotic ingredient when in an aqueous medium is able to form a tri-dimensional network of insoluble sub-micron crystalline inulin particles that immobilize large amounts of water to assure its physical stability (Franck, 2002). Furthermore, inulin acts as a thickener that forms complexes through hydrogen bridges, with the yogurt proteins, contributing to a lower syneresis index (Rinaldoni et al., 2012; Aryana & McGrew, 2007). Furthermore, the high WHC can be related to the gelling properties of soy proteins which are capable to form gels with semi-solid characteristics, when the medium is acidified (Donkor et al., 2007). Park et al. (2005) observed that partial substitution of bovine milk by WSSE in the manufacture of fermented beverages led to a reduction in syneresis index values.

Increased acidity of the samples was observed during the storage period. Over- acidification is one of the main problems in yogurts and *L. bulgaricus* is generally recognized as the microorganism responsible for the excessive production of lactic acid during storage (Hutkins, 2006; Ranadheera et al., 2012). Milder acidification was observed in FB, presenting higher values of pH and lower values of titratable acidity when compared to TC. This result may be explained by the buffer capacity of soy proteins which allows for obtaining fermented beverages with mild acidity (Rinaldoni et al., 2012). Proteins in caprine milk present low buffer capacity, making the yogurt more susceptible to over-acidification during storage (Martín-Diana et al., 2003).

Table 2. Physicochemical composition of the fermented beverages. Results are expressed as mean ± standard deviation.

Parameter	Fermented beverages	
	FB	CT
Dry matter ($g \cdot 100\ g^{-1}$)	$17.98^{a} \pm 0.05$	$16.23^{b} \pm 0.42$
Protein ($g \cdot 100\ g^{-1}$)	$3.15^{a} \pm 0.20$	$2.31^{b} \pm 0.35$
Fat ($g \cdot 100\ g^{-1}$)	$2.57^{a} \pm 0.21$	$2.83^{a} \pm 0.21$
Ash ($g \cdot 100\ g^{-1}$)	$0.63^{b} \pm 0.01$	$0.76^{a} \pm 0.01$
Lactose ($g \cdot 100\ g^{-1}$)	$4.64^{b} \pm 0.12$	$5.97^{a} \pm 0.26$
Calcium ($mg \cdot 100\ g^{-1}$)	$84.00^{b} \pm 4.00$	$122.67^{a} \pm 2.31$

FB: fermented beverage containing WSSE and inulin; CT: whole yogurt made from caprine milk. a, b: different lowercase letters in the same line mean a significant difference by the Tukey test at 5% of probability.

Table 3. Sensorial evaluation of the fermented beverages. Results are expressed as mean ± standard deviation.

Attribute	Fermented beverages	
	FB	CT
Color	$6.51^{a} \pm 1.54$	$6.65^{a} \pm 1.65$
Appearance	$6.73^{a} \pm 1.45$	$6.62^{a} \pm 1.40$
Flavor	$5.78^{b} \pm 1.96$	$7.24^{a} \pm 1.40$
Texture	$6.92^{a} \pm 1.91$	$7.05^{a} \pm 1.56$
Taste	$5.62^{b} \pm 2.38$	$7.43^{a} \pm 1.95$
Overall acceptability	$6.19^{b} \pm 1.90$	$7.38^{a} \pm 1.46$

a, b: different lowercase letters in the same line mean a significant difference by the Tukey test at 5% of probability.

Table 4. Syneresis index, WHC, pH, and titratable acidity during the shelf-life. Results are expressed as mean ± standard deviation.

Parameter	Storage time (days)	Fermented beverages	
		FB	CT
Syneresis ($g \cdot 100\ g^{-1}$)	1	$35.87^{aB} \pm 1.42$	$47.89^{aA} \pm 0.63$
	7	$36.21^{aB} \pm 1.93$	$48.48^{aA} \pm 2.00$
	14	$35.14^{aB} \pm 0.08$	$49.34^{aA} \pm 0.63$
	21	$37.41^{aB} \pm 1.99$	$50.94^{aA} \pm 0.52$
	28	$36.89^{aB} \pm 0.57$	$49.23^{aA} \pm 0.60$
WHC ($g \cdot 100\ g^{-1}$)	1	$89.86^{bA} \pm 0.62$	$56.01^{abB} \pm 1.06$
	7	$92.07^{aA} \pm 0.36$	$56.71^{aB} \pm 0.59$
	14	$90.88^{abA} \pm 0.41$	$54.66^{abB} \pm 2.12$
	21	$86.29^{cA} \pm 1.03$	$54.23^{abB} \pm 0.67$
	28	$86.38^{cA} \pm 1.13$	$52.62^{bB} \pm 1.44$
pH	1	$4.29^{aA} \pm 0.01$	$4.27^{aA} \pm 0.04$
	7	$4.28^{aA} \pm 0.01$	$4.23^{abB} \pm 0.01$
	14	$4.25^{bA} \pm 0.00$	$4.20^{bB} \pm 0.00$
	21	$4.19^{cA} \pm 0.01$	$4.20^{bA} \pm 0.01$
	28	$4.18^{cA} \pm 0.01$	$4.13^{cB} \pm 0.01$
Acidity ($g \cdot 100\ g^{-1}$ of lactic acid)	1	$0.70^{aB} \pm 0.05$	$0.78^{cA} \pm 0.02$
	7	$0.69^{aB} \pm 0.01$	$0.87^{bA} \pm 0.02$
	14	$0.72^{aB} \pm 0.02$	$0.86^{bA} \pm 0.02$
	21	$0.72^{aB} \pm 0.03$	$0.86^{bA} \pm 0.01$
	28	$0.75^{aB} \pm 0.03$	$0.91^{aA} \pm 0.01$

WHC: water-holding capacity; FB: fermented beverage containing WSSE and inulin; CT: whole yogurt made from caprine milk. a, b, c: different lowercase letters in the same column mean significant difference for each treatment along the shelf-life by Tukey's test at 5% of probability. A, B: different uppercase letters in the same row mean significant difference between the treatments by Tukey's test at 5% of probability.

Rheological characterization

Flow curves ($\tau = f(\gamma)$) demonstrated that the manufactured fermented beverages presented a non-linear behavior characteristic of non-Newtonian fluids (Figure 1). The models of Herschel-Bulkley and Mizrahi-Berk showed high goodness of fitting for all samples tested, however, these rheological models exhibited negative yield stress values ($\tau0$ e K_{OM}), which are meaningless physically and were thus considered inadequate to represent the rheological behavior of the samples. Negative values for yield stress were reported previously when the model of Herschel-Bulkley was used to describe the rheological behavior of fermented dairy beverages (Penna et al., 2001; Oliveira et al., 2002). The Casson model did not exhibit negative values for yield stress, however, data fitted better when Ostwald-de-Waelle (Power law) model was used showing higher determination coefficients. Therefore, as has been observed in many studies with dairy fermented beverages, the Power law model best fits the experimental data, thus being considered the most adequate rheological model to describe the rheological behavior of these products (Jumah et al., 2001; Aportela-Palacios et al., 2005; Park et al., 2005).

The flow behavior index is considered as a measure of the deviation from Newtonian behavior and values lower than 1 indicate a pseudoplastic behavior (Benezech & Maingonnat, 1994; Park et al., 2005). The fermented beverages evaluated in this research showed a pseudoplastic behavior in ascending curves (Table 5 and Figure 1). Rheological studies in yogurts and soymilk fermented beverages have demonstrated that these products are characterized as pseudoplastic fluids showing a shear-thinning effect which results in the reduction of apparent viscosity values as a function of a shear rate increase (Aportela-Palacios et al., 2005; Rinaldoni et al., 2012; Oliveira et al., 2002; Gauche et al., 2009; Donkor et al., 2007).

According to Horne (1998), diminishing values for apparent viscosity as a function of the shear rate increase may be a result of a rupture in interaction forces among molecules that form the curd. Along the flow curves, the presence of some peaks was observed (Figure 1). This behavior is probably due to the presence of some beads in the samples, which originated from aggregates formed from interactions between whey proteins and casein particles (Sodini et al., 2005).

A thixotropic effect was observed in both samples as a hysteresis effect was verified and characterized by the area between ascendant and descendant flow curves (Figure 2). This result was previously reported in fermented beverages made with milk or WSSE and is due to the rupture of the curd structure as a function of the shear applied (Rinaldoni et al., 2012; Penna et al.,

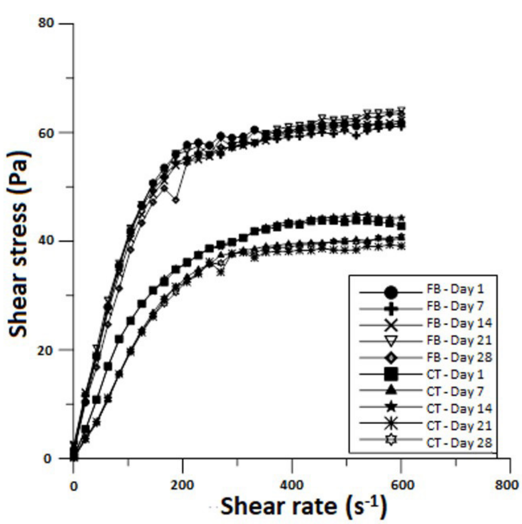

Figure 1. Ascending flow curves of shear stress *versus* shear rate for FB and CT at different times during the refrigerated storage.

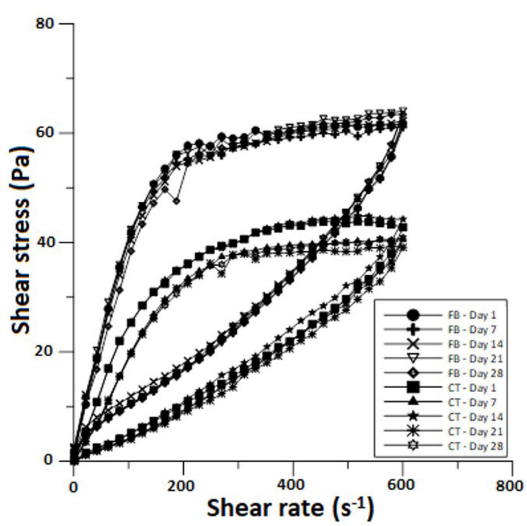

Figure 2. Thixotropic behavior: hysteresis effect between up and down cycles.

Table 5. Rheological modeling of the fermented beverages, according to the experimental data of the ascending curves after 1 day of storage (5 °C).

Treatment	Model						
	Ostwald-de-Waelle: $\tau = K(\gamma)^n$			Herschel-Bulkley: $\tau = \tau0 + K(\gamma)n$			
	K (Pa.s^n)	n	R^2	$\tau0$ (Pa)	K (Pa.s^n)	n	R^2
FB	9.641	0.307	0.865	-63.853	59.112	0.129	0.902
CT	4.441	0.374	0.918	-20.563	16.464	0.223	0.941
	Casson: $\tau^{0.5} = k_{OC} + k_C \cdot \gamma^{0.5}$			Mizrahi-Berk: $\tau^{0.5} = k_{om} + k_{m} \cdot \gamma^n$			
	k_{OC}	k_C	R^2	K_{OM}	K_M	n	R^2
FB	4.572	0.158	0.734	-17.864	19.763	0.044	0.920
CT	3.340	0.154	0.827	-12.718	13.498	0.059	0.943

2001). Descending curves were characterized by the reduction in consistency index values and by changes in the flow behavior index where the samples presented a dilatant behavior ($n > 1$) (Table 5). This result was also observed by Penna et al. (2001) in fermented dairy beverages from commercial brands.

The good fit of experimental data to the Ostwald-de-Waelle model can be observed by the high determination coefficients (R^2) found (Table 5). By using this model, it was possible to evaluate the rheological parameters consistency index (K) and flow behavior index (n) in up and down cycles for the fermented beverages during their storage. The fermented beverage containing WSSE and inulin showed higher values for consistency index and lower values for flow behavior index (n) when compared to the control (Table 6). This result is possibly due to the higher content of total solids and proteins in BF, which are factors acknowledged to improve rheological properties in these products (Rinaldoni et al., 2012; Jumah et al., 2001). The consistency index and flow behavior index measured in the ascending curves did not present significant changes during the storage ($p > 0.05$), for both treatments.

Microbiological evaluation

The lactic acid bacteria population in both treatments was above 8 log $CFU{\cdot}mL^{-1}$ during the storage time (Figures 3-4). These values are in accordance with those established by the Brazilian regulation, which requires a minimum of 6 log $CFU{\cdot}mL^{-1}$ in fermented milk beverages during the shelf-life (Brasil, 2007). Enumerations of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* did not show differences ($p > 0.05$) between samples, suggesting that partial substitution of caprine milk by WSSE and inulin addition did not influence on lactic acid bacteria viability. Oliveira et al. (2009) evaluate the effect of inulin addition at different concentrations (0, 1, 2, and 4 $g{\cdot}100\ g^{-1}$) on the growth of a lactic culture composed of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* and observed that the prebiotic ingredient did not influence on *S. thermophilus* viability while *L. delbrueckii* subsp. *bulgaricus* viability was influenced, and

Table 6. Rheological parameters of the fermented beverages according to the power law model.

Time	Sample	Ostwald-de-Waelle: $\tau = K(\gamma)^n$					
		Ascending curve			Descending curve		
		$K(Pa.s^n)$	n	R^2	$K(Pa.s^n)$	n	R^2
Day 1	FB	9.641^{aA}	0.307^{bA}	0.865	0.045^{aA}	1.116^{bA}	0.984
	CT	4.441^{bA}	0.374^{aA}	0.918	0.012^{bAB}	1.260^{aAB}	0.993
Day 7	FB	9.734^{aA}	0.305^{bA}	0.877	0.043^{aA}	1.128^{bA}	0.985
	CT	3.037^{bA}	0.424^{aA}	0.896	0.010^{bAB}	1.298^{aAB}	0.997
Day 14	FB	8.973^{aA}	0.306^{bA}	0.903	0.074^{aA}	1.055^{bA}	0.978
	CT	4.215^{bA}	0.385^{aA}	0.928	0.015^{bA}	1.237^{aB}	0.996
Day 21	FB	9.496^{aA}	0.315^{bA}	0.897	0.036^{aA}	1.158^{bA}	0.983
	CT	3.137^{bA}	0.416^{aA}	0.891	0.007^{bB}	1.332^{aA}	0.997
Day 28	FB	7.266^{aA}	0.353^{bA}	0.912	0.040^{aA}	1.139^{bA}	0.985
	CT	2.828^{bA}	0.434^{aA}	0.908	0.008^{bB}	1.325^{aA}	0.997

a, b, c: different lowercase letters in the same column mean a significant difference between FB e CT ($p < 0.05$). A, B: different uppercase letters in the same column mean a significant difference ($p < 0.05$) for each treatment during the storage.

higher values were obtained by using an inulin concentration of 4 $g{\cdot}100\ g^{-1}$.

Salmonella sp. absence and a most probable number per milliliter ($MPN{\cdot}mL^{-1}$), for total and thermotolerant coliforms, lower than 3 were observed during the shelf-life of both treatments. These values are also in accordance with the Brazilian regulation for fermented milk beverages (Brasil, 2007).

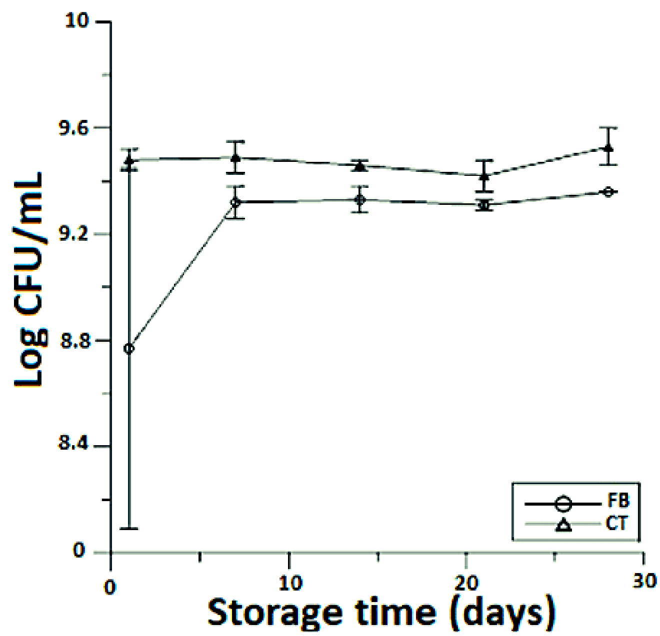

Figura 3. Enumeration of *S. thermophlilus* (log $CFU{\cdot}mL^{-1}$) during the refrigerated storage period at 5 °C.

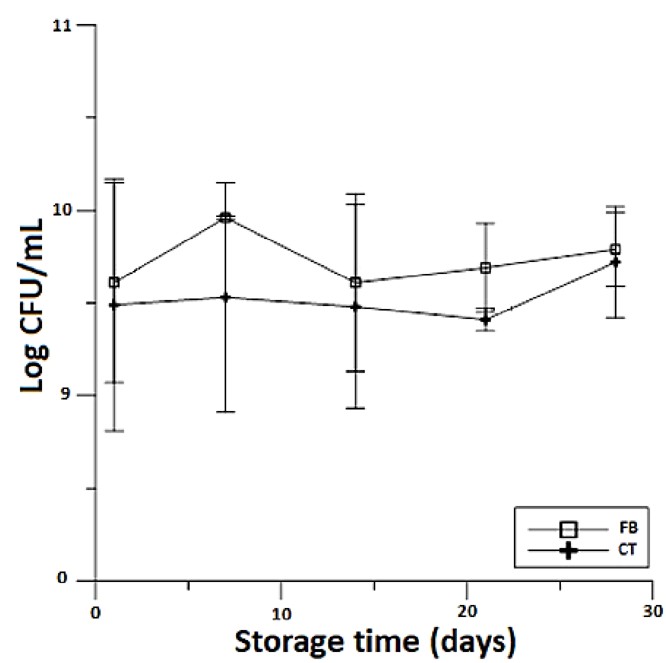

Figure 4. Enumeration of *L. delbrueckii* subsp. *bulgaricus* (log $CFU{\cdot}mL^{-1}$) during the refrigerated storage at 5 °C.

4 Conclusion

The fermented beverage evaluated in this study is an innovative product, manufactured from ingredients that have acknowledged functional properties. Partial substitution of caprine milk by WSSE and inulin supplementation led to positive aspects in the final product, such as desirable physical and physicochemical properties, showing a lower syneresis index, higher water holding capacity, lower post-acidification, and higher consistency. A negative influence was observed on the sensorial acceptance of the product, possibly due to the beany flavor characteristic of soy-based products, suggesting that future studies must be carried out in order to improve sensorial acceptance of the product by consumers.

Acknowledgments

The authors would like to thank the Coordination for the Improvement of Higher-Level Personnel (CAPES) for financial support and the Center for Humanities, Social and Agrarian Sciences, Federal University of Paraíba (CCHSA/UFPB), for supplying the caprine milk used to prepare the yogurt-like beverages used in this study.

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