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Effects of Frozen Storage on the Physical Properties and Sensory Acceptability of Goat's Milk Yoghurt

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Abstract

The effects of frozen storage of goat's milk on the physicochemical, physical properties, and sensory attributes of goat's milk yoghurts were evaluated. Four yoghurts were made from goat's milk stored at 4℃ overnight, and at -6, -20, or -35℃ for 1 month. Goat's milk yoghurts were stored at 6℃ for 21 days. Protein and lipid contents in all the yoghurts were insignificantly different, however, the total solids content, including the added sugar in the yoghurts made from frozen goat's milk, significantly increased in comparison with that in the yoghurt made from chilling goat's milk. The water holding capacity (WHC) and viscosity for all the yoghurts at any period of cold storage were statistically different. No significant differences in pH or titratable acidity for all the yoghurts were observed after 1 day of cold storage; however, these physicochemical properties for the yoghurts after 7 days of storage were significantly different. All the yoghurts after 21 days of storage received similar scores for appearance and texture, but significantly different scores for color, odor, flavor, and overall acceptability.

Keywords

Goat's milk, goat's milk yoghurt, frozen storage, physical properties, sensory acceptability

Introduction

Goats rank fifth among domestic animal populations in Vietnam after buffalo, cattle, pigs, and poultry. It was estimated that the number of milk goats was 204 heads in 2014 and markedly grew in both small households and industries because of the increase in the consumption of goat's milk and goat's milk products (Thu, 2017). The production of goat's milk amounts to approximately 2.4% of the total milk for human consumption in the world and ranks third after cow's and buffalo's milks (FAOSTAT, 2016). In recent years, interest in goat's milk and goat's milk based products has increased

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because of their high quality nutrients and health benefits (Turkmen, 2017).

In general, the total solids, protein, fat, lactose, mineral, and vitamin contents in goat's milk are similar to those in cow's milk (Domagała, 2009), however, there are several significant differences in individual components and their roles in food processing and human health benefits (Turkmen, 2017). Goat's milk is highly digestible and can be consumed by people with cow's milk allergies and gastrointestinal disorders; therefore, it can be used as a healthy substitute for cow's milk products (Abrahamsen & Holmen, 1981; Bruzantine *et al*., 2016). It has been reported that the ratio of β- to α_{s1}-casein in goat's milk is higher than that of cow's milk. In addition, the curd of goat's milk is softer and finer than that of cow's milk (Nurliyani *et al*., 2015) As a result, goat's milk protein is more digestible than cow's milk protein (El-Agamy, 2007).

Yoghurt is a popular dairy product around the world and is commonly made from cow's milk. In recent years, many customers in Vietnam have developed a preference for yoghurt made from goat's milk, and therefore, the demand for this dairy product is increasing. However, the production of goat's milk yoghurt throughout the year can be limited because of low animal productivity and a short period of lactation (about 8 months). In addition, small or medium-sized farms hinder production of yoghurt for this growing industry.

The frozen storage of milk is a simple process widely used to extend the shelf life of goat's milk (Nurliyani *et al*., 2015). However, this process probably causes disturbances of the fat emulsion (Nurliyani *et al*., 2015), aggregations of proteins, the development of off-flavor, and changes in the bacteriological status after defrosting (Katsiari *et al*., 2002). These defects mainly depend on the freezing rate, and frozen storage temperature and duration (Katsiari *et al*., 2002; Tribst *et al*., 2018).

Several studies have shown that the frozen storage of sheep's milk for up to 6 months insignificantly affected the composition and characteristics of resultant yoghurts (Katsiari *et al*., 2002). To date, few investigations have evaluated the effect of the frozen storage of goat's milk on the quality of goat's milk yoghurt.

The objective of this study was to investigate the effect of the frozen storage of goat's milk on the physicochemical, physical properties, and the sensory attributes of goat's milk yoghurt during cold storage. These results would be of great interest to dairy manufacturers that produce goat's milk yoghurt from frozen milk.

Materials and Methods

Materials and Chemicals

Goat's milk was collected in June 2018 from Saanen goats at the Centre for Goat and Rabbit Research (Sontay, Hanoi, Vietnam) and poured into 1.5-L sterilised plastic bottles. The bottles of milk were placed in a foam box with ice and delivered to the laboratory. Upon arrival, one bottle was stored at 4°C overnight and the three others were stored at -6, -20, or -35°C for 1 month before being used for the preparation of yoghurt. The yoghurt starter cultures were YO-MIX™ 187 LYO containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* spp. *lactic* (Danisco, France).

Preparation of yoghurt

Frozen goat's milk was thawed at room temperature until completely liquified and then mixed with 5% (w/v) of refined sugar. After being pasteurised at 90°C for 5min, the goat's milk was homogenized at 16,000rpm for 1min × 3 using an Ultra Turrax. The milk was cooled to 42°C, followed by inoculation with 0.02% (w/v) of the yoghurt starter cultures YO-MIX™ 187 LYO. The inoculated milk was placed in sterilised plastic containers with caps and incubated at 42°C until the pH reached 4.5 and then stored at 6°C for 21 days. The yoghurt samples were identified as follows: yoghurts produced from goat's milk stored at 4°C overnight, and stored at -6°C, -20°C, or -35°C for 1 month were called YG4 (control sample), YG-6, YG-20, and YG-35, respectively.

Chemical Analysis

Total solids were analysed according to ISO 6731:2010 (IDF 21:2010). Protein was

determined using the Kjeldahl method (ISO 8968 1:2014 (IDF 20-1:2014)). Fat was determined using the Gerber method (ISO 2446:2008 (IDF 226:2008)). The pH was measured using a pH meter (ORION 230A+). Titratable acidity was analyzed by titrating 100mL of a sample thinned with 2 parts distilled water, with 0.1 N NaOH, using phenolphthalein as the indicator. Titratable acidity was expressed as ºT. The analyses were carried out in triplicate.

Physical properties

Water holding capacity

The water holding capacity (WHC) was measured according to Isanga & Zhang (2009) with minor modifications. In brief, 2.0 grams of yoghurt were placed into centrifugal tubes and immediately spun at 3000 × g for 10min at 6°C. The supernatants were carefully removed and the centrifugal tubes were weighed. The WHC was defined as the ratio of the pellet weight after centrifugation to the initial weight of the yoghurt, expressed as a percentage (%). The assay was performed after 1, 7, 14, and 21 days of cold storage in triplicate.

Viscosity measurement

Viscosity was measured at about 6°C using a Brookfield viscometer (Dv+I Brookfield, USA) according to Nguyen *et al*. (2009). Yoghurt samples were thoroughly stirred with a spoon and immediately placed into a tube. Viscosity measurements were performed using a spindle S64 at a speed of 12rpm for 60s. Viscosity was expressed in mPa.s. The assay was performed after 1, 7, 14, and 21 days of cold storage in triplicate.

Sensory evaluation

Sensory acceptability of the yoghurts was assessed according to Öztürk *et al*. (2018). Ten experienced panellists used a five-point hedonic scale (1-unacceptable; 2-slightly acceptable; 3-acceptable; 4-very acceptable; 5-excellently acceptable) to determine the appearance and texture, flavor, color, and odor acceptability of yoghurt samples after 21 days of storage.

Data analysis

Data were analyzed using one-way ANOVA to identify significant differences among the frozen storage temperatures and periods of storage. All data were expressed as a mean ± standard deviation of the three replicates. The means were compared using the Tukey test at a 95% confidence.

Results and discussion

Chemical composition of milk and yoghurt

The composition of goat's milk stored at different temperatures and the resultant yoghurts is shown in **Table 1**. As can be seen, the frozen storage did not affect the composition of goat's milk ($P > 0.05$). The total solids contents in the frozen samples were slightly higher than the control sample, meanwhile the protein and lipid contents in all the samples remained nearly constant. During frozen storage, lactose crystallizes slowly as a monohydrate and consequently, the amount of free water in the milk is reduced (Fox *et al*., 2015), probably leading to an increase in the total solids content in the frozen milk. **Table 1** also shows that there was a considerable increase in the total solids content of the yoghurts made from samples of frozen milk in comparison with that of the control sample yoghurt ($P \leq 0.05$). However, the differences in protein and lipid contents in all the yoghurts at 21 days of cold storage were not found to be statistically significant ($P > 0.05$).

pH and titratable acidity

The pH and titratable acidity of the yoghurts are shown in **Table 2**. After 1 day of storage, the pH values for all the yoghurts were insignificantly different, with values ranging from 4.42 to 4.52. However, the differences in pH values for all the yoghurts after 7, 14, and 21 days of storage were found to be statistically significant ($P \leq 0.05$) (**Table 2**). This finding indicates that during milk freezing, more H^+ ions were probably released from micelle calcium phosphate, which caused the reductions of pH for the yoghurts. The pH values for the yoghurt samples made from frozen milk, except in the

Table 1. Composition of goat's milk and goat's milk yoghurts after 21 days of storage

Storage temperature (℃)	Milk			Yoghurt (21 days of storage)		
	Total solids (%)	Lipid (%)	Protein (%)	Total solids (%)	Lipid (%)	Protein (%)
4	12.47a ± 0.56	4.73a ± 0.05	2.33a ± 0.18	17.56b ± 0.33	3.47a ± 0.15	1.90a ± 0.19
-6	13.42a ± 0.56	4.42a ± 0.17	2.53a ± 0.49	19.32a ± 0.38	4.00a ± 0.26	2.21a ± 0.13
-20	13.68a ± 2.40	4.43a ± 0.11	2.38a ± 0.27	19.35a ± 0.27	4.13a ± 0.05	2.15a ± 0.07
-35	13.41a ± 1.90	4.53a ± 0.05	2.40a ± 0.24	19.43a ± 0.20	3.93a ± 0.15	2.11a ± 0.22

Note: Mean value ± standard deviation (n = 3). Means with different superscripts in the same column are significantly different (P≤ 0.05).

Table 2. pH and titratable acidity of goat's milk yoghurt during cold storage

Sample	pH				Acidity			
	1 day	7 days	14 days	21 days	1 day	7 days	14 days	21 days
YG4	4.52Ca ± 0.04	4.73Aa ± 0.04	4.56BCa ± 0.04	4.69ABa ± 0.07	87.0Ba ± 2.0	91.0ABb ± 2.6	95.0Aa ± 2.0	80.7Cc ± 2.3
YG-6	4.48ABa ± 0.04	4.59Ab ± 0.03	4.41BCb ± 0.07	4.61Aa ± 0.04	90.3Aa ± 4.0	94.3Aab ± 1.2	98.0Aa ± 4.0	92.0Ab ± 3.0
YG-20	4.46Aa ± 0.14	4.46Ac ± 0.05	4.38Ab ± 0.03	4.38Ab ± 0.03	92.3Aa ± 4.6	96.0Aab ± 1.7	98.7Aa ± 3.1	98.3Aab ± 3.5
YG-35	4.42Aa ± 0.10	4.38ABc ± 0.01	4.26ABc ± 0.02	4.31Bb ± 0.01	94.0Ba ± 1.7	99.3ABa ± 2.3	103.7ABa ± 6.8	104.7Aa ± 2.5

Note: Mean value ± standard deviation (n = 3). Means with different small letters in the same column are significantly different (P≤ 0.05). Means with different capital letters in the same row are significantly different (P≤ 0.05).

YG4: Yoghurt produced from goat's milk stored at 4℃ overnight (control sample).

YG-6: Yoghurt produced from goat's milk stored at -6℃ for 1 month.

YG-20: Yoghurt produced from goat's milk stored at -20℃ for 1 month.

YG-35: Yoghurt produced from goat's milk stored at -35℃ for 1 month.

YG-6 treatment, slightly decreased during cold storage. This finding was similar to the study of Katsiari *et al*. (2002) who reported about yoghurt made from frozen sheep's milk.

As shown in **Table 2**, the frozen storage of milk significantly affected the titratable acidity of the yoghurts. The data indicated that there were increases in the acidity values for the yoghurts made from milk which had been previously stored at lower frozen temperatures. During cold storage, the titratable acidity values for the yoghurts, except YG4, increased from the 1st day to the 21st day of storage.

Water holding capacity

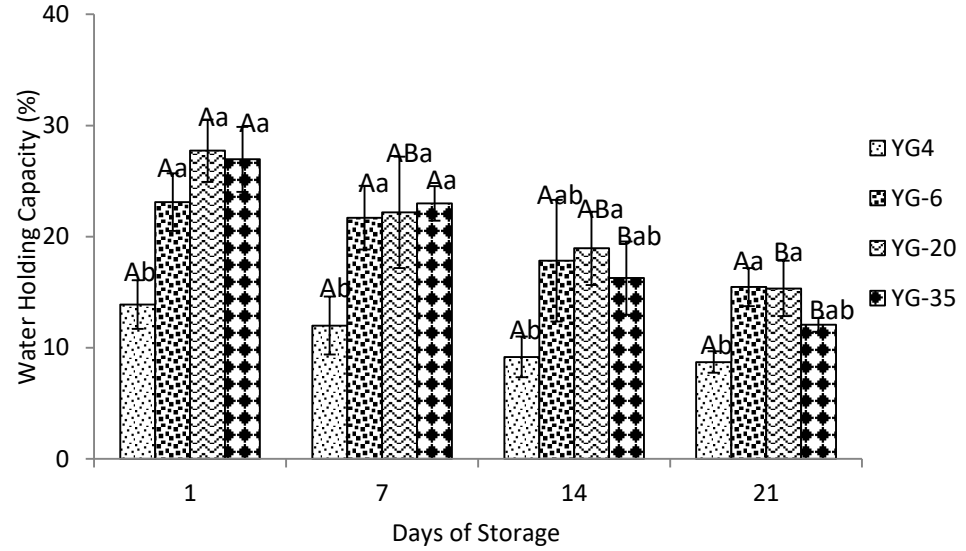
Figure 1 shows the WHC for the goat's milk yoghurts made from different types of milk after 1, 7, 14, and 21 days of storage. As indicated, the frozen storage of milk strongly influenced the WHC for the goat's milk yoghurts ($P \leq 0.05$). The WHC for all the goat's milk yoghurts made from frozen goat's milk was much higher than that for the goat's milk yoghurt made from goat's milk stored at 4℃; however, no statistical differences were observed among the YG-6, YG-20, and YG-35 samples. The WHC of the yoghurt reflects the syneresis of yoghurt gel, which is dependent on a number of variables, such as type of milk, total solids content, protein content, concentration of calcium, fat content, pH of the milk, preheat treatment of the milk, and stabilizers (Domagala, 2009). In the present study, the total solids content and protein content in the frozen milk samples were slightly higher than that in the refrigerated sample (**Table 1**). These factors could lead to increases in the WHC of the goat's milk yoghurt made from frozen milk. As shown in **Figure 1**, the WHC for all the goat's milk yoghurts made from frozen milk stored at -25℃ and -35℃ significantly decreased during cold storage. This finding is similar to the results reported by Domagała (2009). Thus, the decrease in the WHC during cold storage could be associated with the hydrolysis of a part of the proteins by bacteria derived proteases during fermentation, leading to the disruption of the protein network that weakened the gel structure, or the accommodation of the protein network during storage, leading to expulsion of the whey, which was initially retained in the protein chains (Tribst *et al*., 2018).

Viscosity

The viscosity for all the goat's milk yoghurts is shown in **Figure 2**. As indicated, the frozen storage of goat's milk before yoghurt making affected the viscosity of the goat's milk yoghurts. After 1 day of yoghurt storage, the same viscosity was observed among three samples (YG4, YG-6, and YG-20), but the viscosity for these yoghurts was much lower than that of the YG-35 sample. During the frozen storage of milk, the casein system is destabilized due to a decrease in the pH and an increase in the Ca2+ concentration (Fox *et al*., 2015). This probably led to an increase in the coagulation degree of the milk caseins when making yoghurt. Similar results for the yoghurts stored for 7 and 21 days were also found. On the other hand, it was observed that the viscosity of all the yoghurts significantly increased during cold storage and approximately doubled after 21 days of storage.

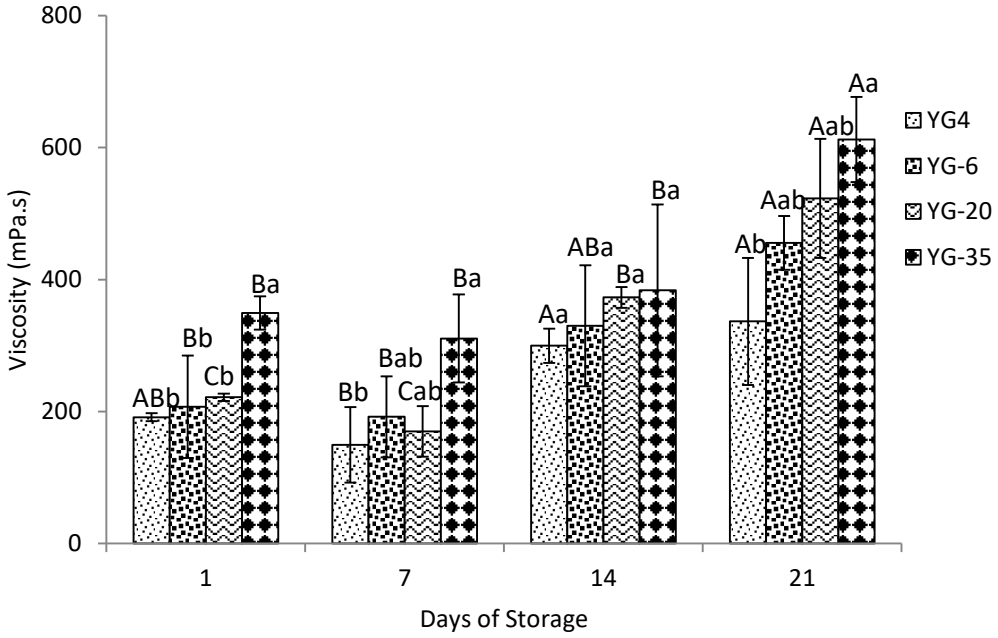
Sensory evaluation

The sensory attributes of the yoghurts after 21 days of storage are shown in **Table 3**. The frozen storage of milk before the manufacturing of yoghurt resulted in significant variations in the panellists' preferences for color, odor, and flavor ($P \leq 0.05$). Although the appearance and texture rating was equally assessed by the panellists ($P > 0.05$), the score for this attribute was the highest for the yoghurt made from milk stored at -35℃ (**Table 3**). **Table 3** shows that four attributes of the yoghurt made from milk stored at -35℃ were the most acceptable. Therefore, yoghurts made from frozen goat's milk, especially at -35℃, were of a good quality. This finding is in agreement with the results of Antifantakis *et al*. (1980) who observed that yoghurt made from stored frozen sheep's milk was generally acceptable.



Note: Yoghurts were made from goat's milk stored at 4℃ overnight (YG4), or at -6℃ (YG-6), -20℃ (YG-20), and -35℃ (YG-35) for 1 month. The bars with different small letters in the same day are significantly different (P≤ 0.05). The bars with different capital letters in the same frozen storage treatment are significantly different (P≤ 0.05).

Figure 1. Effect of frozen goat's milk on the water holding capacity of yoghurts during cold storage



Note: Yoghurts were made from goat's milk stored at 4℃ overnight (YG4), or at -6℃ (YG-6), -20℃ (YG-20) and -35℃ (YG-35) for 1 month. The bars with different small letters in the same day are significantly different (P≤ 0.05). Means with different capital letters in the same frozen storage treatment are significantly different (P≤ 0.05).

Figure 2. Effect of frozen goat's milk on the viscosity of yoghurts during cold storage

Table 3. Sensory acceptability properties of goat's milk yoghurts after 21 days of storage

Yoghurt sample	Appearance and texture	Color	Odor	Flavor	Overall acceptability
YG4	$2.6^{a} \pm 0.84$	$2.4^{b} \pm 0.96$	$3.3^{ab} \pm 0.48$	$2.9^{ab} \pm 0.56$	11.2
YG-6	$2.2^{a} \pm 0.78$	$2.2^{b} \pm 0.42$	$2.7^{b} \pm 0.67$	$2.1^{c} \pm 0.73$	9.2
YG-20	$2.8^{a} \pm 0.63$	$2.8^{ab} \pm 0.63$	$3.1^{ab} \pm 0.84$	$2.6^{bc} \pm 0.66$	11.3
YG-35	$3.0^{a} \pm 0.66$	$3.4^{a} \pm 0.63$	$3.6^{a} \pm 0.69$	$3.5^{a} \pm 0.52$	13.5

*Note: * Mean value ± standard deviation (n = 3). Means with different superscripts in the same column are significantly different (P≤ 0.05).*

YG4: Yoghurt produced from goat's milk stored at 4℃ overnight (control sample).

YG-6: Yoghurt produced from goat's milk stored at -6℃ for 1 month.

YG-20: Yoghurt produced from goat's milk stored at -20℃ for 1 month.

YG-35: Yoghurt produced from goat's milk stored at -35℃ for 1 month.

Conclusions

The present study demonstrated that the frozen storage of goat's milk strongly affected the physical characteristics and sensory quality of yoghurt. The yoghurts made from goat's milk stored at -20 and -35℃ for 1 month had pH, titratable acidity, WHC, viscosity, and sensory acceptability values that were better than those of yoghurts made from chilling milk and milk stored at -6℃. These results may assist small dairy companies producing goat's milk yoghurt throughout the year to ensure milk supply and yoghurt quality.

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