Comparative study on the heat stability of goat milk and cow milk

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ABSTRACT

We investigated differences between goat and cow milk by exploring the factors influencing milk stability by testing the heat coagulation time. Heat-stable milk samples were characterized by a higher pH, a lower heating temperature, a lower calcium concentration, a higher concentrations of EDTA-2Na, phosphate and citrate. However the sucrose concentration caused different patterns of heat stability. The heat stability of milk increased as the sucrose concentration increased from 10% to 30%, then decreased as it rose above 30%. Compared with cow milk, goat milk is less stable to heat treatments being affected by pH, heating temperature, and the addition of calcium chloride, disodium EDTA, disodium hydrogen phosphate, and sucrose. After adding sodium citrate, the heat stability of goat milk was better than that of cow milk, with ANOVA results indicating a statistically significant difference.

Key words: Cow milk, Goat milk, Heat stability, Heat coagulation time, Influencing factors.

INTRODUCTION

Goat milk is a complete food with perceived health advantages now that the ‘goaty’ flavor has gradually been reduced in a cost-effective way by adding α- and β-cyclodextrins (GFW, 2004; Sallies, 2002; Young, et al., 2012). Heat treatments can affect milk in several ways such as changes in the acidity and pH of milk due to the loss of CO₂, the transfer of calcium and phosphate to the colloidal state and the degradation of lactose (Laleye, et al., 2008; Sanchez-Macias, et al., 2013). It has also been reported that thermal processes can change the mineral equilibrium of milk, especially calcium and phosphate. Above all, heating processes such as ultra-heat treatment (UHT) can cause the modification of proteins so that whey proteins will coagulate with casein proteins and complex compounds will be formed between casein and lactose by the Maillard reaction, leading to organoleptic changes in the milk (Chen, et al., 2012; Morgan et al., 2000).

The heat stability of cow milk has been comprehensively studied and reported (On-Nom, et al., 2012; Sikand, et al., 2010; Singh, 2004). However, there have been relatively few studies comparing the heat coagulation time (HCT) of goat milk with that of cow milk at their natural pH. Therefore, the objectives of this study are: to compare the heat stability of goat milk with cow milk and investigate any differences, to control the factors that influence HCT and to explain the mechanism of heat stability for goat milk.

MATERIALS AND METHODS

Fresh goat milk was collected from the Tai’an San Xi Goat Farms (http://sxsyn.com/) and cow milk was donated by the dairy farm of the Shandong Academy of Agricultural Sciences, Shandong Province, China. The samples of mixed raw milk were stored at -18 °C until used for the experiments. The samples were thawed in a water bath at 4 °C before the experiments. Deionized water was used for the preparation of all solutions.

Hydrochloric acid and sodium hydroxide solution were added to milk samples to change the pH of the milk samples to values from 6.0 to 7.0 in 0.1 increments. The additives in this study, disodium EDTA, disodium hydrogen phosphate, sodium citrate, calcium chloride and sucrose solution, were used at concentrations of 0.02, 0.04, 0.06, 0.08 and 0.1M. Three replicated trials were performed to measure the heat coagulation time (HCT) (Chen et al., 2012).

Each experiment was carried out three times under the same conditions. The data were analyzed using SPSS 16.0 software (SPSS Inc., Chicago, IL, USA). One way ANOVA was used to determine whether the mean values of parameters from samples of goat milk and cow milk were significantly different at p ≤ 0.05 and p ≤ 0.01.

RESULTS AND DISCUSSION

As the total acidity of the milk increased, the thermal stability decreased and the milk solidified more easily, thus influencing the production and quality of any resulting dairy products. The differences in the
physicochemical properties between goat milk and cow milk are shown in Table 1. The value of pH in the goat milk was slightly higher than in the cow milk. The titration acidity of goat milk was much higher than that of cow milk.

The results of the alcohol test showed that goat milk exhibited a markedly lower ethanol stability than cow milk. The goat milk produced a much flocculated precipitate but the cow milk produced no flocculated precipitate. Compared with cow milk, the higher content of ionic calcium of goat milk could have been partly responsible for the greater instability of goat milk shown by the alcohol test.

The effect of pH on the heat stability of milk samples is shown in Figure 1. In general, as higher pH values increase the heat stability, the goat milk did not precipitate at pH values above 6.7, while the cow milk did not precipitate at pH values above 6.6. As shown in Figure 1, at pH 6.0 and 6.3, the stability of the goat milk and cow milk was significantly different (p < 0.05), and at pH 6.5, the difference was very significant (p < 0.01). This showed that goat milk and cow milk were significantly different in terms of their heat stability with the pH value having an important effect. Nevertheless, milk from small ruminants are frequently not stable at their natural pH, which might confirm the results of the present study.

The effect of heating temperature on the heat stability of goat milk and cow milk is shown in Figure 2. In general, higher temperatures decreased the heat stability of both goat milk and cow milk. At 100 °C, there was a significant difference between goat milk and cow milk but there no significant difference at higher temperatures (110, 120, 130, and 140 °C). The time that the cow milk resisted high temperatures was longer than for goat milk. This finding can be observed more clearly in Figure 2. Thus, the heating temperature played a very important role in the heat stability of milk.

There was no difference between goat milk and cow milk at different concentrations of calcium chloride (Figure 3). It can be seen that the calcium content had a negative impact on the heat stability of milk. This agreed with Morgan et al. (2000) who reported that heat-stable milk samples were characterized by a lower soluble calcium concentration. Calcium content and the state of balance of ionized calcium, colloidal calcium and calcium binding with protein were also shown to be of vital importance for the stability of milk. Ionic calcium was considered to be a significant determinant of casein micelle stability. Omoarukhe et al., also showed that adding soluble calcium salts could reduce the pH of milk leading to a reduction in heat stability.

The effect of disodium EDTA on the heat stability can be clearly observed in Figure 4. Adding disodium EDTA before UHT can improve the resistance of milk to thermal treatment with a positive relationship between the concentration of disodium EDTA and the heat stability of milk. At disodium EDTA concentrations of 0.04, 0.06 and 0.1 mol/L, there were very significant differences between

### Table 1: Physicochemical properties of goat milk and cow milk

<table>
<thead>
<tr>
<th>Item</th>
<th>Goat milk</th>
<th>Cow milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color and luster</td>
<td>White</td>
<td>White with shallow yellow</td>
</tr>
<tr>
<td>Smell</td>
<td>A slight mutton odor</td>
<td>A slight fragrance</td>
</tr>
<tr>
<td>pH (30 °C)</td>
<td>6.45±0.0058</td>
<td>6.42±0.0058</td>
</tr>
<tr>
<td>Titration acidity (°T)</td>
<td>12.7950±0.3546</td>
<td>12.3691±0.2925</td>
</tr>
</tbody>
</table>

Fig 1: Effect of pH on the heat stability of goat milk and cow milk

Note: * denotes significant difference (p<0.05); ** denotes very significant difference (p<0.01).

Fig 2: Effect of heating temperature on the heat stability of goat milk and cow milk

Fig 3: Effect of calcium chloride on the heat stability of goat milk
the heat stability of goat milk and cow milk (p < 0.01). This might be explained by disodium EDTA combining with calcium, which decreased the calcium activity. Thus it can be seen that all these factors contributing to decreasing the calcium activity might increase the heat stability of milk.

The effects of disodium hydrogen phosphate on the heat stability of goat milk and cow milk are shown in Figure 5. Figures 4 and 5 show that a similar effect may be produced by concentrations of disodium EDTA and disodium hydrogen phosphate in the same range from 0.02 to 0.1 mol/L. The differences between goat milk and cow milk were significant at disodium hydrogen phosphate concentrations of 0.06 and 0.08 mol/L (p < 0.05) and were very significant at 0.1 mol/L (p < 0.01). This was because phosphate can also combine with calcium and reduce calcium activity. Although heating treatment decreases the pH of milk adding phosphate inhibited the reduction in pH during pasteurization treatment or before UHT treatment. This agreed with a previous study (Boumpa, et al. 2008). Therefore, adding inorganic phosphate could increase the buffering capacity.

The effects of sodium citrate on the heat stability of goat milk and cow milk are shown in Figure 6. This shows that sodium citrate improved the heat stability of milk, especially goat milk. Compared with cow milk, the heat stability of goat milk is significantly better (p < 0.05) at a sodium citrate concentration of 0.04 mol/L. There were also very significant differences at sodium citrate concentrations of 0.06 and 0.08 mol/L (p < 0.01). Like the effects of other additives, a similar argument to explain the results can be presented for sodium citrate. In a similar way to phosphate, citrate might combine with calcium, which could thus limit the pH decrease and increase the buffering capacity. The amount of citrate is also an important parameter that governs the ionic calcium level. In addition, the proteins did not precipitate at a sodium citrate concentration of 0.1 M, which suggests that citrate plays an important role in increasing the heat stability of milk.

The effects of sucrose on the heat stability of goat milk and cow milk are shown in Figure 7. This shows that there is a special relationship between the concentration of sucrose and the heat stability of milk. The heat stability of milk increased as the sucrose concentration increased from 10% to 30%, but decreased at sucrose concentrations above 30%. The differences between goat milk and cow milk were also significant at sucrose concentrations of 10% and 30% (p < 0.05) and very significant at a concentration of 20% (p < 0.01). Therefore, the best concentration for adding sucrose to increase the heat stability of goat and cow milk was 30%.
CONCLUSION

Thermal treatment affects the heat stability of milk tremendously. It can be concluded that pH, with its positive correlation, is the most important factor influencing heat stability. The alcohol test indicated that goat milk exhibited a markedly lower ethanol stability than cow milk. The heating temperature also plays a vital role in affecting heat stability: the higher the heating temperature, the poorer the heat stability. In addition, some additives added before UHT treatment can also change the heat stability of milk. The application of calcium had a negative effect on the heat stability of milk, while the concentrations of EDTA-2Na, phosphate and citrate were positively correlated with heat stability. Moreover, the results showed a special relationship between heat stability and sucrose concentration. The heat stability of milk increased as the sucrose concentration increased from 10% to 30%, but decreased as the concentration of the sucrose increased above 30%. In the present study, the influence of all these factors except for sodium citrate confirmed that goat milk is less stable after heat treatment than cow milk. For sodium citrate, the heat stability of goat milk was better than cow milk, with ANOVA results indicating that the difference was statistically significant. This phenomenon revealed that cow milk was more sensitive to the effect of sodium citrate than goat milk. This finding has not been reported in other studies so needs to be elucidated by further research.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests regarding the publication of this paper.

REFERENCES


