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INFLUENCE OF DIFFERENT FACTORS ON THE CURDLING OF CAMEL MILK FROM THE TURKESTAN REGION

Abstract: *The production of cheese from camel milk represents a significant sector within the food industry, particularly in regions where camel breeding has been extensively developed. A distinctive chemical composition is exhibited by camel milk. These properties render it a valuable raw material for the development of functional foods, including cheeses with increased biological value. The curdling process inherent to the production of camel milk necessitates a multifaceted approach, one which is informed by the distinctive characteristics of this raw material. Achieving optimal curdling conditions necessitates the judicious modulation of critical factors such as temperature, enzyme activity, pH level, and the utilisation of a suitable starter culture. This paper explores the impact of various factors on camel milk curdling. It was observed that a reduction in active acidity (pH) to 5.8-5.6 units resulted in a significant decrease in coagulation time to 35-40 minutes, accompanied by a favourable trend in the textural indices of the clots during gelation. The findings indicate that a clotting temperature of 35 °C is optimal for the fermentation process, and the increase in calcium chloride concentration also has a significant impact on reducing clotting time. Furthermore, the results of this study demonstrated that heat treatment significantly influenced the firmness of the clots. The coagulation of raw milk exhibited a firmness of 250.08±10.3 g, while at 63-65°C, it reduced to 177.5±6.08 g, at 72-74°C, it decreased to 90.35±15.73 g, and at 80-85°C, pasteurisation of milk resulted in the lowest hardness of 55.45 ± 2.58 g. The cheese yield varied from 20.90 to 10.34 depending on heat treatment*

Key words: *camel milk, coagulation time, active acidity (pH), firmness, cheese, heat treatment.*

Introduction

Camel milk is a unique raw material due to its high nutritional, vitamin and mineral composition, which makes it a valuable product for both domestic and foreign markets [1, 2]. The consumption of camel milk in raw or fermented form is much more widespread than its use in processed products such as cheese [3]. Given the significance of this fact, the question of developing new areas of processing, such as cheese production, is raised. The process of coagulation and gel formation is pivotal in the production of cheese from camel milk and necessitates a bespoke approach to technological development [4].

The Turkestan region has witnessed a consistent annual increase in the camel population, reaching approximately 45 thousand heads as of 2024 [5]. The primary utilisation of camel milk is the production of traditional shubat, in addition to its processing into milk powder. Despite the high potential for development in this sector, there is a lack of enterprises specialising in the processing of camel milk into cheese. The primary challenges identified pertain to the absence of technologically advanced solutions and methodologies that are tailored to the distinctive characteristics of the local raw materials. However, there is a growing interest among entrepreneurs in developing this sector, which presents opportunities for the establishment of production facilities in proximity to farms.

The present study aims to investigate the influence of various factors on the coagulation of camel milk from the Turkestan region, including active acidity (pH), coagulation time, textural parameters, temperature, and calcium chloride concentration.

Research methods. Raw camel milk obtained in a private household in the village ‘Kyziltu’ of Turkestan region was used for research. The experiments were conducted in the research laboratory ‘Food biotechnology’ of NP JSC *"M.Auezov South Kazakhstan University*".

Determination of clotting time of camel milk. The objective of this study was to determine the clotting time of camel milk. In this study, a specific volume of milk and (or) calcium chloride solution was amalgamated, after which a solution of milk curdling enzyme was introduced. The mixture was then subjected to constant temperature on a water bath, whilst simultaneously a stopwatch was initiated. The clotting time was determined by recording the time between the addition of the enzyme solution and the initial detection of flocculation on the walls of the test tube. [6, 7].

HANNA pH meter (**pHep HI 98108**) was used to determine active acidity (pH).

The measurement of clot firmness texture parameters was conducted through the utilisation of a texture profile analysis (TPA) apparatus (Stable Micro Systems Ltd., UK). The samples were subjected to mechanical compression and back extruded across four cycles, employing a 35-mm diameter cylindrical probe at speeds of 1.0 mm/s, 2.0 mm/s, and 10.0 mm/s, respectively. The depth of indentation of the sample was 20 mm. The volume of all samples was 100 ml.

Results and discussion. Milk coagulation and rennet gel (coagulate) formation represent the most significant and sensitive process in the production of various cheese varieties [8]. This process is primarily characterised by the action of numerous factors that regulate both biochemical and physicochemical processes during coagulation, thereby directly influencing the rheological characteristics of the rennet casein gel.

The present study investigates the effect of varying values of active acidity (pH) on coagulation time (Table 1).

Table 1 – Effect of active acidity (pH) on milk coagulation

Active acidity (pH)	Coagulation time, min
6,6±0,2	85,5±0,5
6,03±0,1	50,0±0,5
5,8±0,1	40,5±0,5
5,6±0,1	35,5±0,5

As demonstrated in Table 1, it can be deduced that decreasing the active acidity (pH) of camel milk reduces its coagulation time. In a study where the pH was reduced from 6.6±0.2 to 5.6±0.1 and the enzyme was added, a reduction in coagulation time from 85.5±0.5 minutes to 35.5±0.5 minutes was observed, respectively. The findings of this study are consistent with the existing body of literature, which demonstrates that lowering the pH during cheese processing enhances the action of rennet enzyme, helps to neutralize the charge of colloidal calcium phosphate (CCP), and improves calcium solubility [9,10]. The decline in active acidity has also been demonstrated to influence the firmness of the clots (Figure 1).

From figure 1, it follows that the samples of clots obtained from camel milk, with decreasing active acidity there was a positive effect on the firmness of the clots. Clots with pH 5.8±0.1 and 5.6±0.1 were more gelatinous. Although firmness of the clots at active acidity of 5.6 was higher, in this work, the optimum value was taken as 5.8, as further reduction in active acidity may lead to less favourable quality characteristics of the finished soft cheese.

In addition, the effect of coagulation time of camel milk at varying temperature regimes, as illustrated in Figure 2, was investigated.

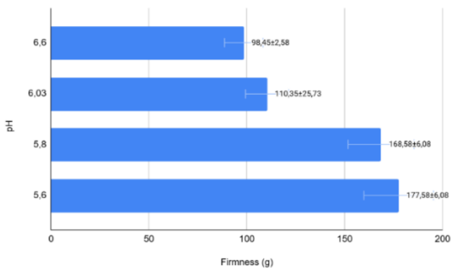

Figure 1 – Firmness of curd made from camel milk using different active acidity (pH)

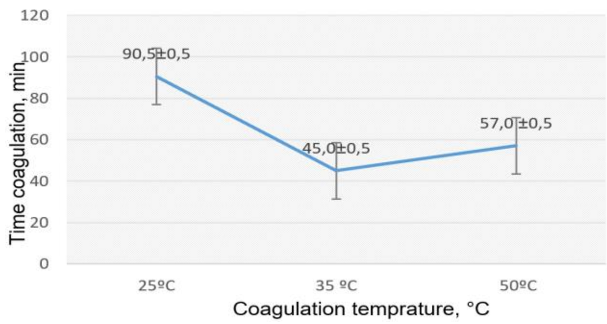

Figure 2 – Dependence of camel milk coagulation time on coagulation temperature

Figure 2 shows that when the coagulation temperature is increased from 25°C to 35°C, the coagulation time decreases significantly from 90.5 to 45.0 minutes, indicating faster fermentation. However, when the temperature is further increased to 50°C, the coagulation time increases to 57.0 minutes, possibly due to thermal denaturation of proteins or decreased activity of coagulating enzymes. These results emphasize the importance of selecting the optimal curdling temperature to ensure an efficient coagulation process and to obtain a quality cheese clot.

Milk coagulation can be thought of as a two-step process that involves a primary phase, i.e., limited hydrolysis of κ-casein, and a secondary phase where micelles of hydrolysed casein cross-link in the presence of Ca2+ to form a gel.

Hence, we studied the effect of calcium chloride concentration at a coagulation temperature of 35±0.1°C on the coagulation time of camel milk. Figure 3 shows a graph that depicts the dependence of milk coagulation time on calcium chloride concentration ($CaCl_2$).

As demonstrated in Figure 3, an increase in the concentration of $CaCl_2$ has been shown to reduce coagulation time. When the concentration of $CaCl_2$ was increased from 0 to 30 g/100 l, a reduction in coagulation time from 45.0±0.5 to 28.0±0.5 minutes was observed. This finding suggests that the addition of $CaCl_2$ accelerates the milk coagulation process. The initial decrease in coagulation time between 0 and 10 g/100 l is negligible (approximately 1.5 minutes), which may be due to the minimal effect of added calcium on coagulation at low concentrations. A more significant reduction in time is observed when the concentration is increased to 20 and 30 g/100 l (by 8.5 and 7 minutes, respectively), which improves the aggregation of casein micelles and accelerates clot formation.

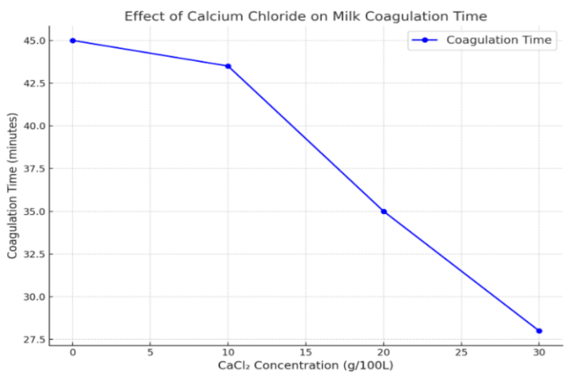

Figure 3 – Dependence of milk coagulation time on calcium chloride concentration ($CaCl_2$)

Furthermore, the impact of pasteurisation temperature on camel milk, both with and without calcium chloride addition, on clotting time was investigated (Figure 4).

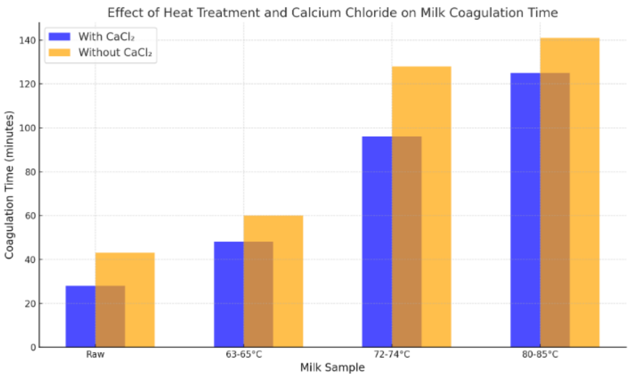

Figure 4 – Dependence of milk coagulation time on temperature treatment and presence of calcium chloride ($CaCl_2$)

As demonstrated in Figure 5, the coagulation time increases significantly with increasing processing temperature, from 43 minutes for raw milk to 141 minutes for milk treated at 80-85°C. This phenomenon can be attributed to the denaturation of whey proteins (e.g., β-lactoglobulin), which have the capacity to interact with casein, thereby impeding the clot formation process. The addition of $CaCl_2$ has been shown to result in a substantial reduction in coagulation time for all samples examined.

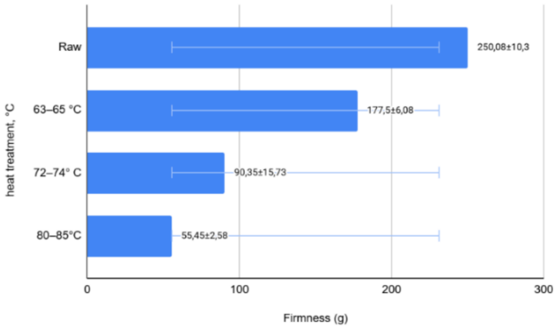

Figure 5 – Firmness of curd made from camel milk using different heat treatments

For instance, for raw milk, the coagulation time is reduced from 43 minutes to 28 minutes, and for milk treated at 80-85°C, from 141 minutes to 125 minutes. The addition of calcium chloride has been shown to restore the balance of free calcium in milk, thereby improving the aggregation of casein micelles and accelerating clot formation, even at elevated temperatures. The greatest reduction in coagulation time due to the addition of $CaCl_2$ is observed for raw milk, with a 15-minute reduction in coagulation time. Conversely, in high temperature treated milk (80-85°C), the effect of $CaCl_2$ is less pronounced, which may be attributable to strong protein denaturation, reduced calcium availability, and alterations in micelle structure. It is evident that the coagulation time increases with an increase in treatment temperature, both in the presence and absence of $CaCl_2$. This finding aligns with the observations reported by Hailu et al. (2016), who posited that increasing the coagulation temperature and decreasing the pH of camel milk can enhance its coagulation [11].

Further, textural indices of clot firmness when calcium chloride was added with an active acidity of 5.8 were studied in raw milk, and pasteurised at 63-65°C, 72-74°C and 80-85°C.

As demonstrated in Figure 6, the results indicated that camel milk clots prepared from raw milk exhibited significantly higher firmness (250.08±10.3) in comparison to pasteurised milk clots at 63-65°C (177.5±6.08) and 72-74°C (90.35±15.73), respectively. Conversely, the clots derived from pasteurised milk at temperatures ranging from 80 to 85°C exhibited a significantly lower level of firmness (55.45 ± 2.58) in comparison to the values above.

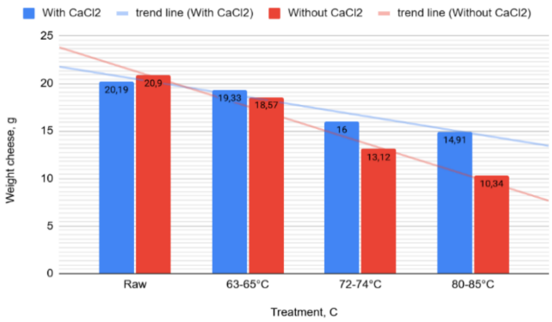

Figure 6 – Dependence of the yield on heat treatment and calcium chloride

The yield of cheese was found to vary according to the type of heat treatment applied. Specifically, the cheese yield from raw milk was 20.19-20-90g with and without calcium chloride, respectively, while pasteurization of the milk at 63-65°C resulted in a yield of 19.33-18.57g. Furthermore, at 72-74°C, the cheese yield with and without calcium chloride was -16-13.12, and at 80-85°C, the yield was 14.91-10.34.

Conclusions

The research indicates that the clotting process of camel milk in cheese production can be enhanced by manipulating various factors. Specifically, it has been observed that reducing the active acidity to 5.8 units, maintaining a clotting temperature of 35°C, and increasing the concentration of calcium chloride ($CaCl_2$) from 20 to 30 g/100L are pivotal in achieving this. These adjustments have been shown to reduce the coagulation time, thereby optimising the clotting process. Furthermore, an increase in temperature results in a decrease in the difference between treated and untreated milk in terms of coagulation time. The utilisation of the proposed optimised technologies is expected to result in a reduction of waste, ensure high yields, and guarantee the safety of the final product for consumers.

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ВЛИЯНИЕ РАЗЛИЧНЫХ ФАКТОРОВ НА СВЕРТЫВАНИЕ ВЕРБЛЮЖЬЕГО МОЛОКА ТУРКЕСТАНСКОЙ ОБЛАСТИ

Производство сыра из верблюжьего молока представляет собой значительный сектор пищевой промышленности, особенно в регионах, где широко развито верблюдоводство. Верблюжье молоко отличается особым химическим составом. Эти свойства делают его ценным сырьем для разработки функциональных продуктов питания, в том числе сыров с повышенной биологической ценностью. Процесс свертывания, присущий производству верблюжьего молока, требует многогранного подхода, учитывающего отличительные особенности этого сырья. Достижение оптимальных условий свертывания требует разумного регулирования таких критических факторов, как температура, активность ферментов, уровень pH и использование подходящей заквасочной культуры. В данной работе изучается влияние различных факторов на свертывание верблюжьего молока. Было замечено, что снижение активной кислотности (pH) до 5,8-5,6 единиц привело к значительному сокращению времени свертывания до 35-40 минут, что сопровождалось благоприятной тенденцией изменения текстурных показателей сгустков в процессе гелеобразования. Полученные данные свидетельствуют о том, что температура свертывания 35 °C является оптимальной для процесса ферментации, а увеличение концентрации хлорида кальция также оказывает значительное влияние на сокращение времени свертывания. Кроме того, результаты исследования показали, что тепловая обработка существенно влияет на упругость сгустков. При свертывании сырого молока его твердость составила 250,08±10,3 г, при 63-65°C она снизилась до 177,5±6,08 г, при 72-74°C – до 90,35±15,73 г, а при 80-85°C пастеризация молока привела к наименьшей твердости – 55,45±2,58 г. Выход сыра варьировался от 20,90 до10,34 в зависимости от тепловой обработки.

Ключевые слова: *верблюжье молоко, время свертывания, активная кислотность (pH), упругость, сыр, термическая обработка.*

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ТҮРКІСТАН ОБЛЫСЫ ТҮЙЕ СҮТІНІҢ ҰЮЫНА ӘРТҮРЛІ ФАКТОРЛАРДЫҢ ӘСЕРІ

Түйе сүтінен ірімшік өндіру – әсіресе түйе шаруашылығы кең таралған аймақтарда тамақ өнеркәсібінің маңызды бағыты. Түйе сүті ерекше химиялық құрамымен ерекшеленеді, бұл оны функционалды тағам өнімдерін, соның ішінде биологиялық құндылығы жоғары ірімшіктерді өндіру үшін бағалы шикізат етеді. Түйе сүтінің ұю процесі бұл шикізаттың өзіндік қасиеттеріне негізделген кешенді тәсілді талап етеді. Коагуляцияның оңтайлы шарттарына қол жеткізу үшін температура, ферменттердің белсенділігі, pH деңгейі сияқты маңызды параметрлерді мұқият реттеп, қолайлы ашытқы дақылдарын таңдау қажет. Бұл мақалада түйе сүтінің коагуляциясына әсер ететін әртүрлі факторлар қарастырылған. Зерттеу нәтижелері көрсеткендей, белсенді қышқылдылықтың (pH) 5,8-5,6 дейін төмендеуі коагуляция уақытын едәуір қысқартып, оны 35-40 минутқа дейін азайтады. Бұл, өз кезегінде, гел түзілу процесінде ұю құрылымының қолайлы динамикасымен сипатталады. Алынған мәліметтер коагуляция температурасының 35°C деңгейінде оңтайлы болатынын, сондай-ақ кальций хлориді концентрациясының жоғарылауы коагуляция уақытын қысқартуға айтарлықтай әсер ететінін дәлелдеді.

Сонымен қатар, бұл зерттеудің нәтижелері жылулық өңдеудің сүт ұйындысының қаттылығына елеулі әсер ететінін көрсетті. Шикі сүт коагуляцияланған кезде оның қаттылығы 250,08±10,3 г құраса, 63-65°C температурада бұл көрсеткіш 177,5±6,08 г-ға дейін, 72-74°C температурада 90,35±15,73 г-ға дейін төмендеді. Ал 80-85°C температурада пастерленген сүт ең *төменгі қаттылық мәнін көрсетті – 55,45±2,58 г. Ірімшіктің өнімділігі термиялық өңдеуге байланысты 20,90-дан 10,34-ке дейін өзгерді.*

Түйін сөздер: *түйе сүті, ұю уақыты, белсенді қышқылдылық (pH), қаттылық, ірімшік, жылулық өңдеу.*

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ЖҰМСАҚ ІРІМШІК ӨНДІРУ ТЕХНОЛОГИЯСЫНДА ӨСІМДІК ТЕКТЕС ШИКІЗАТТЫ ПАЙДАЛАНУДЫҢ ЕРЕКШЕЛІКТЕРІ

Аңдатпа: *Ірімшік – сүтті ұйыту және оны жетілдіру нәтижесінде алынған, ақуыз мөлшері жоғары тамақ өнімі. Ірімшікке қосымша дәм мен хош иіс беру үшін әртүрлі өсімдік тектес қоспалар қосу әдістері жеткілікті. Ұсынылып отырған мақалада жұмсақ тұзды ірімшікті өсімдік шикізаттарымен байыту арқылы олардың коректік және биологиялық құндылығын арттыру мүмкіндігін зерттейді. Ақжелкен ұнтағы мен грек жаңғағы сияқты табиғи ингредиенттерді қосу тұзды жұмсақ ірімшіктің құрамындағы С дәрумені мен тағамдық талшықтардың мөлшерін едәуір арттырады. Зерттеу нәтижесінде, № 3 үлгісінде ақжелкен мен грек жаңғағы қосылған ірімшіктің құрамында С дәруменінің мөлшері 6 есе көбейіп, тағамдық талшықтар 0,86 г дейін артқаны*