

Effects of traditional and modern processing techniques on the texture properties of goat milk curds

ÁDÁM LŐRINCZ* , JÓZSEF CSANÁDI, DIÁNA BÁNÁTI and
BALÁZS P. SZABÓ

Institute of Food Engineering, Faculty of Engineering, University of Szeged, Szeged, Hungary

ORIGINAL RESEARCH PAPER

Received: April 23, 2025 • Accepted: September 22, 2025

Published online: October 14, 2025

© 2025 The Author(s)



ABSTRACT

Compared to cow milk, goat milk curd typically has a softer structure and lower whey retention capacity, which presents challenges in cheese production. Previous studies have shown that homogenization and ultrasound treatment (sonication) improve the curd properties of cow milk, yet limited data are available regarding their effects on goat milk. The aim of this study was to investigate the effects of these two technologies – individually and in combination – on acid- and rennet-induced goat milk curds.

During our experiments, a portion of the samples was homogenized at 12 MPa, while others were sonicated for 15–60 min. Two combinations of treatments were also applied. We evaluated syneresis, viscosity, firmness, and stickiness of the resulting curds.

Our findings revealed that no single technology consistently outperformed the other across all parameters. However, 30-min sonication and the 6 MPa + 15-min combined treatment resulted in improved curd textures in multiple aspects. These results suggest that sonication is a promising alternative to traditional methods in goat milk processing.

KEYWORDS

goat milk, sonication, homogenization, curd texture

* Corresponding author. E-mail: lorincz@mk.u-szeged.hu

INTRODUCTION

In our study, we aimed to improve the properties of curds made from goat milk. Goat milk curds tend to be softer and have lower water-holding capacity compared to those made from cow milk (Joon et al., 2017). Such weak and overly soft curds are disadvantageous in cheesemaking, as they lead to excessive curd shattering during cutting (Riddell-Lawrence and Hicks, 1989) and exhibit slower syneresis. These properties reduce yield (Balatoni and Ketting, 1981; Everard et al., 2008) and result in higher whey expulsion, which consumers may perceive as a quality defect (Marinaki et al., 2016). These differences are largely attributable to the compositional variations between cow and goat milk (Sanz Ceballos et al., 2009; Jenness, 1980).

It is well-established that homogenization improves the curd properties of cow milk (Thomann et al., 2008; Paskov, 2010). Similarly, ultrasound treatment (sonication), a modern technique, has also been shown to positively influence curd texture (Wu et al., 2000; Kenari Razavi, 2021). These favourable effects have also been observed for goat milk curds (Delgado, 2020; Ragab, 2020).

Studies have further demonstrated the beneficial effects of microfiltration on rennet-induced curds (Thomann et al., 2008) and of microbial transglutaminase in increasing product viscosity (Romeih and Walker, 2017). Although our experiment excluded additive use, stabilizers and emulsifiers are also known to enhance texture (Lal et al., 2006).

Our goal was to examine the impact of homogenization and sonication—both separately and in combination—on various types of goat milk curds under specific treatment parameters.

MATERIALS AND METHODS

Milk

The milk used in the study was a mixed sample from goats kept in Southern Hungary. The herd consisted of Alpine and local parlagi tincses breeds and their crossbreeds. The sample was a mixture of the herd.

Enzyme

For rennet-induced coagulation, we used a commercial chymosin enzyme preparation (Maxiren 600, 100% chymosin), provided by a dairy company (Sole-Mizo). The enzyme is preserved in saline solution and stored at +4 °C. The standard dosage was 9 g per 100 L, which was proportionally adjusted to the volume of milk used. Measurements were performed using an automatic pipette.

Starter culture

For the production of acid-curd, we used a yogurt starter culture (YC-X11, FD-DVS type) from Christian Hansen, containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. The culture was rehydrated in distilled water and divided up into 2 mL sterile Eppendorf tubes, then stored at −18 °C. Each tube was sufficient to inoculate 5 L of milk.

Experimental design

Freshly collected and cooled (4 °C) raw milk was divided into six portions then the samples were treated. All samples were kept refrigerated until treatments were started. The treatments included homogenization (12 MPa, cold at 4 °C, using a Gaulin Lab 60 homogenizer) – H12 sample, sonication (15, 30, and 60 min using a Hielscher UP100H device at 100 W, 30 kHz) – S15 sample, S30 sample, S60 sample – and two combinations (6 MPa homogenization + 15 min sonication, 3 MPa homogenization + 45 min sonication) – H6+S15 sample and H3+S45 sample. During sonication, samples were cooled continuously and stirred every 5 min for 1 min. The samples were sonicated in a 2 L beaker, and a laboratory thermostat was used for keeping the samples at 4 °C. Sonication started at the temperature of 4 °C. Sonication for a longer period can cause the rise of temperature, therefore to counteract it the samples were continuously cooled. The samples were stirred with a hand held blender on maximum level for optimal mixing. Two litres of milk were sonicated in a single batch.

Four repetitions were performed. In every measurement the 12 MPa homogenized milk was used as control sample, since it is the traditional method. For ANOVA statistical analysis the IBM SPSS Statistics 29 program was used.

Acid coagulation

For acid-induced curd formation, the milk samples were heated to 42 °C and inoculated with the starter culture. The inoculated milk was dispensed into 100 mL sample containers and incubated at 42 °C in a laboratory incubator until a pH of 4.6 was reached. One of the original samples was separated so that the pH change could be tracked. This was necessary so as not to disturb the curd formation. For syneresis measurements samples were coagulated in 100 mL centrifuge tubes with the other samples. After fermentation, the curds were cooled and stored at 4 °C for up to 7 days prior to analysis.

Rennet coagulation

For rennet-induced coagulation, the enzyme was added at a concentration of 9 g/100 L. Coagulation was carried out at 36 °C in a water bath for 30 min, after the coagulation their texture was measured. For syneresis measurements, samples were coagulated in 100 mL centrifuge tubes in a 36 °C water bath, likewise for 30 min. After coagulation they were put in the centrifuge.

MEASUREMENTS

Texture analysis - rennet curd

Texture measurements were performed using a Brookfield CT3 Texture Analyzer with a TA11/1000 probe, operating in a penetrometer mode. The probe was pressed into the curd to a depth of 20 mm at a speed of 0.5 mm s⁻¹, repeated in two cycles.

Texture analysis - acid curd

Due to their low firmness, acid curds were tested using a Brookfield DV-I Prime rotational viscometer with spindle type 2 at 10 RPM.

Syneresis

Syneresis was evaluated for both types of curd by centrifugation. Samples (100 mL) were coagulated, then centrifuged at 5000 RPM for 15 min (RCF = 4053). The amount of separated whey was expressed as a percentage.

pH measurement

The pH development during acidification was monitored using a Thermo Orionstar 4 pH meter equipped with a bulb electrode.

RESULTS

Syneresis - acid curd

Lower syneresis indicates better water-holding capacity, which is desirable. Results are shown in Fig. 1. The sample homogenized at 12 MPa – H12 – exhibited the lowest whey separation (54.81%), significantly differing from the others. (H12-S15 $P < 0.001$, H12-S30 $P < 0.001$, H12-S60 $P = 0.002$, H12-H3+S45 $P < 0.001$, H12-H6+S15 $P = 0.001$) The second-best result (65.47%) was obtained from the sample treated with 6 MPa homogenization plus 15 min of sonication – H6+S15. This result was not significantly different from the 60-min sonicated sample – S60 (70.25%). The highest syneresis (81.90%) was observed after 15 min of sonication – S15.

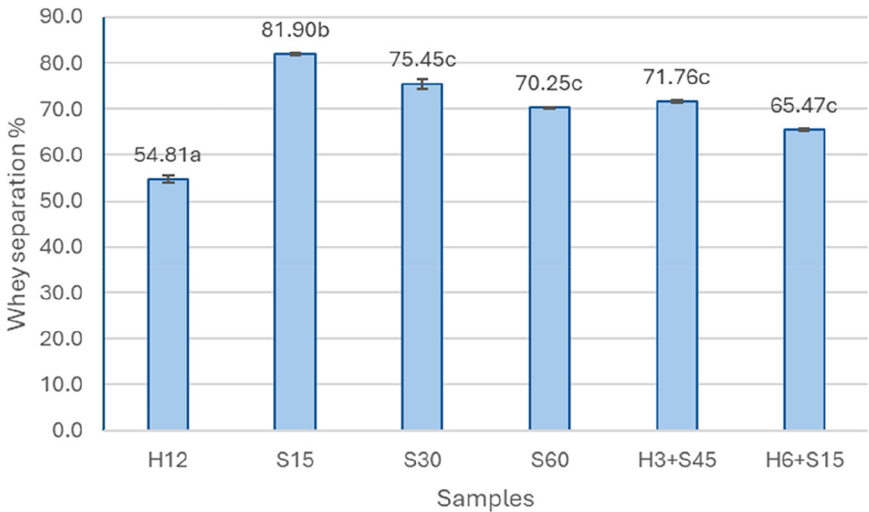


Fig. 1. Acid curd whey separation average results with standard deviation. Different letters indicate significant differences between means ($P < 0.05$)

Syneresis – rennet curd

In rennet curds, higher syneresis is often preferred for firmer structure. Results are shown in Fig. 2. The highest whey separation (86.42%) was found in the 30-min sonicated sample – S30. The 15-min – S15 – and 60-min – S60 – sonicated samples showed almost similar results (85.74% and 86.38%, respectively) to the 30 min – S30 – result. The combinations were significantly different from S15–S30–S60 and the homogenized sample. (H3+S45-S15 $P < 0.001$, H3+S45-S30 $P < 0.001$, H3+S45-S60 $P = 0.003$, H6+S15-S15 $P < 0.001$, H6+S15-S30 $P < 0.001$, H6+S15-S60 $P = 0.002$). The 12 MPa homogenized sample –H12 – showed the lowest whey separation (82.15%). (H12-S15 $P = 0.013$, H12-S30 $P < 0.001$, H12-S60 $P < 0.001$, H12-H3+S45 $P < 0.001$, H12-H6+S15 $P < 0.001$).

Texture - acid curd

The most viscous acid curd was achieved with 60-min sonication – S60 (1,640 mPas), followed by the 12 MPa homogenized sample – H12 (1,401 mPas). The 15-min sonicated – S15 sample – had very low viscosity and was not measurable. (Because of that it was not shown on the graph.) No statistically significant differences were found among treatments. Results are shown in Fig. 3.

Texture – rennet curd

Sonicated samples (S15, S30, S60) yielded the firmest rennet curds (237, 236.67, and 237 mN). These did not differ significantly from each other. The 12 MPa homogenized -- H12 – sample showed significantly lower firmness (H12-S15 $P = 0.024$, H12-S30 $P < 0.001$, H12-S60 $P = 0.038$), and the combined treatment groups showed intermediate firmness values, not significantly different from the homogenized groups. (H3+S45-S15 $P = 0.023$, H3+S45-S30

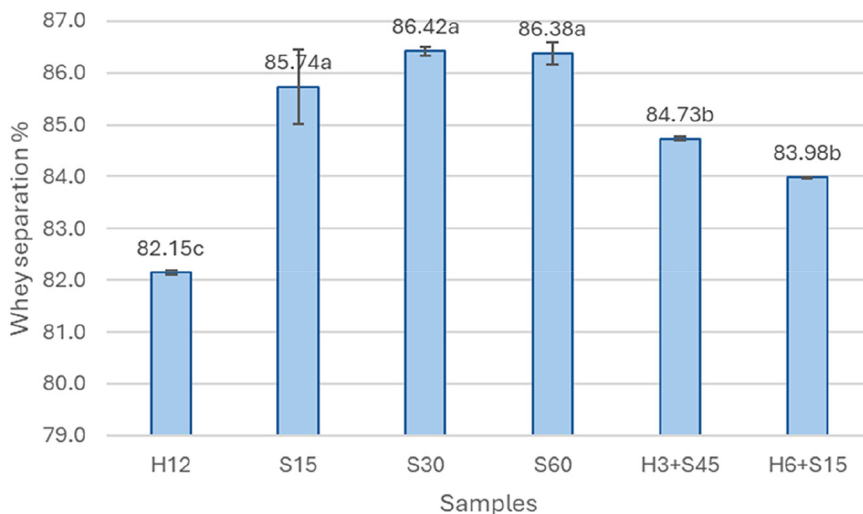


Fig. 2. Rennet curd whey separation average results with standard deviation. Different letters indicate significant differences between means ($P < 0.05$)

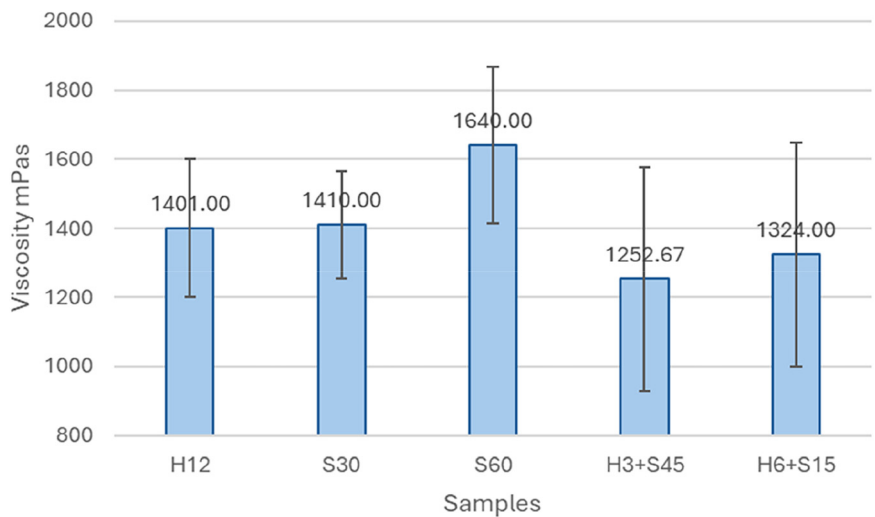


Fig. 3. Acid curd viscosity average results with standard deviation

$P < 0.001$, H3+S45-S60 $P = 0.038$, H6+S15-S15 $P = 0.038$, H6+S15-S30 $P = 0.008$, H6+S15-S60 $P = 0.049$) Results are shown in Fig. 4.

Adhesiveness – rennet curd

Lower adhesiveness is desirable to reduce curd shattering. Results are shown in Fig. 5. The lowest adhesiveness was observed in the 30-min sonicated sample – S30 –, significantly

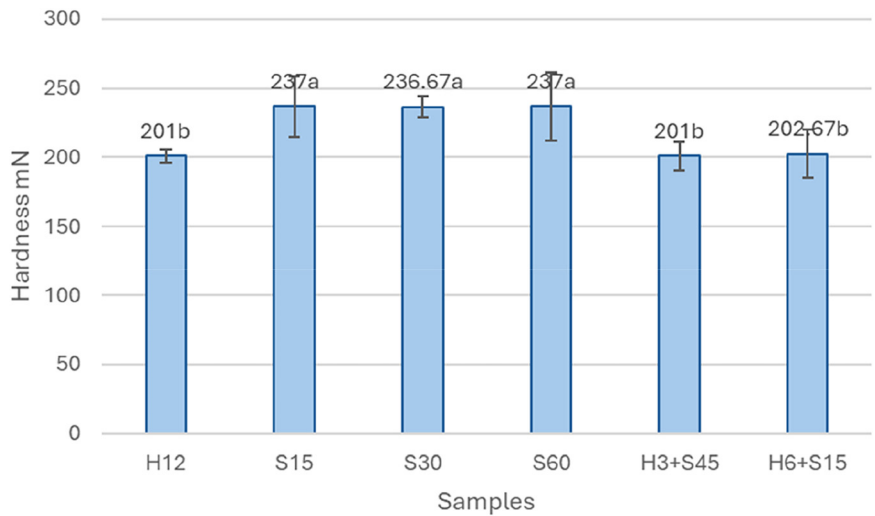


Fig. 4. Rennet curd hardness average results with standard deviation. Different letters indicate significant differences between means ($P < 0.05$)

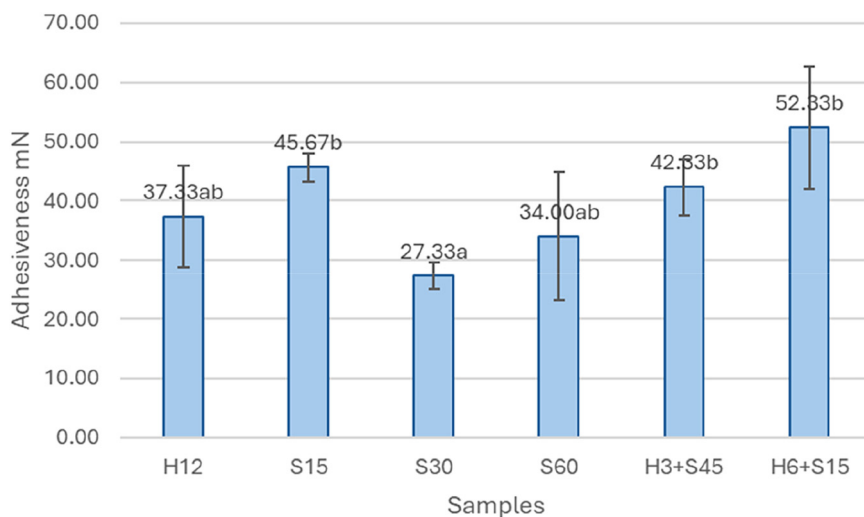


Fig. 5. Rennet curd adhesiveness average results with standard deviation. Different letters indicate significant differences between means ($P < 0.05$)

lower than S15 ($S30-S15 P < 0.001$) and H3+S45 ($S30-H3+S45 P < 0.001$) H6+S15 ($S30-H6+S15 P = 0.002$), except for the 60-min sonicated – S60 – and the 12 MPa homogenized samples – H12. However, the 60-min sonicated – S60 – and the 12 MPa homogenized samples – H12 showed higher standard deviations, which may explain the overlap.

DISCUSSION

Previous studies (Wu et al., 2000) have shown that ultrasound treatment can increase both viscosity and water-holding capacity in yogurts. Our results support the observed increase in viscosity; however, in our case, whey separation increased in sonicated samples compared to homogenized ones. Our results cannot be compared with theirs because in this study they used cow milk (we used goat milk) and also they changed the power level of the sonicator not the time of treatment. In the study by Choudhary and Rawson (2021), longer sonication resulted in better water retention, from a three dimensional graph we could read that the shortest treatment time caused around 55% water holding capacity while the longest treatment times resulted over 65% water holding capacity. Our results contradict this, as prolonged sonication led to higher syneresis.

Regarding firmness, our findings showed that longer sonication slightly increased the firmness of rennet-induced curds, although the differences were not statistically significant. Similar trends were observed in the work of Liu et al. (2014). In their experiment sonicated samples showed 13.9 Pa maximum curd firmness while non sonicated samples showed only 6.6 Pa.

The contradictory results may be due to differences in milk composition, or processing parameters. Further investigations are necessary to clarify these effects and to identify optimal sonication conditions for goat milk processing.

CONCLUSION

The study tested a limited number of treatment combinations. While the results were mixed, several findings emerged. In rennet coagulation, sonication performed best for syneresis: S30 sample performed best (86.42%) but S15 and S60 samples showed very close results (85.74% and 86.38%). In the case of rennet coagulation firmness also sonication performed best. The results of S15, S30 and S60 samples were very close. For acid coagulation, homogenization resulted in the least whey separation (54.81%), but a combined 6 MPa + 15 min treatment – H6+S15 – also performed well (65.47%). Sonication yielded firmer rennet curds, while acid curds responded well to both technologies. Overall, 30-min sonication – S30 – appears promising and is recommended due to its contribution to curd firmness.

Further studies are needed to confirm these findings and explore broader parameter ranges.

REFERENCES

- Balatoni, M. and Ketting, F. (1981). *Tejipari kézikönyv*. Mezőgazdasági Kiadó, Budapest.
- Choudhary, P. and Rawson, A. (2021). Impact of power ultrasound on the quality attributes of curd and its fermentation/gelation kinetics. *Journal of Food Process Engineering*, 44(7): e13698.
- Delgado, K., et al. (2020). Different ultrasound exposure times influence the physicochemical and microbial quality properties in probiotic goat milk yogurt. *Molecules*, 25(20): 4638.
- Everard, C.D., et al. (2008). Effects of cutting intensity and stirring speed on syneresis and curd losses during cheese manufacture. *Journal of Dairy Science*, 91(7): 2575–2582.
- Jenness, R. (1980). Composition and characteristics of goat milk: review 1968–1979. *Journal of Dairy Science*, 63(10): 1605–1630.
- Joon, R., et al. (2017). Instrumental texture and syneresis analysis of yoghurt prepared from goat and cow milk. *The Pharma Innovation Journal*, 6(7): 971–974.
- Kenari, R.E. and Razavi, R. (2021). Effect of sonication conditions: time, temperature and amplitude on physicochemical, textural and sensory properties of yoghurt. *International Journal of Dairy Technology*, 74(2): 332–343.
- Lal, S.N.D., O'Connor, C.J., and Eyres, L. (2006). Application of emulsifiers/stabilizers in dairy products of high rheology. *Advances in Colloid and Interface Science*, 123–126: 433–437.
- Liu, Z., et al. (2014). Ultrasound improves the renneting properties of milk. *Ultrasonics Sonochemistry*, 21(6): 2131–2137.
- Marinaki, E., et al. (2016). Probiotic yogurt production with *Lactobacillus casei* and prebiotics. *Current Research in Nutrition and Food Science*, 4(Special Issue October), [online], <https://doi.org/10.12944/CRNFSJ.4.Special-Issue-October.07>
- Paskov, V., Karsheva, M., and Pentchev, I. (2010). Effect of starter culture and homogenization on the rheological properties of yoghurts. *Journal of the University of Chemical Technology and Metallurgy*, 45(1): 59–66.
- Ragab, E.S., et al. (2020). Ultrasound improves the rheological properties and microstructure of rennet-induced gel from goat milk. *International Dairy Journal*, 104: 104642.
- Riddell-Lawrence, S. and Hicks, C.L. (1989). Effect of curd firmness on stirred curd cheese yield. *Journal of Dairy Science*, 72(2): 313–321.

- Romeih, E. and Walker, G. (2017). Recent advances on microbial transglutaminase and dairy application. *Trends in Food Science & Technology*, 62: 133–140.
- Sanz Ceballos, L., et al. (2009). Composition of goat and cow milk produced under similar conditions and analyzed by identical methodology. *Journal of Food Composition and Analysis*, 22(4): 322–329.
- Thomann, S., Schenkel, P., and Hinrichs, J. (2008). Effect of homogenization, microfiltration and pH on curd firmness and syneresis of curd grains. *LWT - Food Science and Technology*, 41(5): 826–835.
- Wu, H., Hulbert, G.J., and Mount, J.R. (2000). Effects of ultrasound on milk homogenization and fermentation with yogurt starter. *Innovative Food Science & Emerging Technologies*, 1(3): 211–218.

Open Access statement. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited, a link to the CC License is provided, and changes – if any – are indicated. (SID_1)