An Insight into Preparation of Goat Milk-Based Cheese Using Various Technological Interventions

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Milk and dairy products from animals like cows, buffalo, goats, sheep, donkeys, camel etc are well-known among different age groups as they provide calories (energy), proteins, fat, carbohydrates, vitamins, and minerals as these components are important for our wellbeing. Apart from cow milk, an upward growth in demand and consumption of goat milk and goat milk-based products has been observed. In 2020, goat milk production across the globe was around 20.6 million tonnes whereas in India it was around 5.8 million tonnes. In India, goat milk contributes approximately 3% to the total milk production (FAOSTATS, 2020). Goats have been integral to the livestock sector in developing countries. Goats are one of the oldest domesticated small ruminants, dated 8000 B.C. in Mesopotamia (Middle East) for their milk, meat, skin, hair and fibre products to meet the needs of people in rural areas. Goats are well-known for their easy adaptability towards climatic changes, diverse management practices and geological in arid and semi-arid environments (Hatziminaoglou & Boyazoglu, 2004; Park and Haenlein, 2010). Consequently, goat milk and goat milk-based products have played a significant role socioeconomic development of under-developed and developing countries.

Goat milk is different from cow or human milk for its higher buffering capacity (higher β-casein), easy digestibility (average fat globule size of cow milk fat ~ 4.5 µm whereas goat milk fat globule size ~ 2.5 µm), distinct alkalinity and better therapeutic properties. The easy digestibility of goat milk is mainly attributed to the lower amount of αs1 casein protein and small fat globule size (Haenlein, 2004; Park, 2007; Yangilar, 2013). The detailed composition of goat milk in comparison with cow milk has been depicted in Table 1.

Apart from providing nutrition, goat milk has nutraceutical properties which include the bioactive peptides released upon hydrolysis having potent immunostimulatory, anticarcinogenic, antithrombic, ACE inhibitory, antioxidant, and antimicrobial activities. Hence, with an increase in awareness about the health benefits of goat milk, especially lower allergenicity, several attempts have been made to convert goat milk into goat milk products such as cheese, yoghurt, ice-creams, etc with better bio-functional properties. Among different, goat milk products, cheese second most widely produced and consumed after liquid milk consumption.

In 2017, the global cheese production was around 565,075 tonnes where the majority of produce was soft or unripened cheese varieties (Chevre, Blue cheese, White mold, Feta, Robiola de Capra etc. The low preference towards goat milk-based products was mainly attributed to its 'goaty flavour' which can be overcome to a certain extent by a fermentation process using lactic acid bacteria (LAB). The hard or semi-hard varieties are manufactured in lower quantities due to various known challenges that are faced during its production such as lack of availability of milk, perishable nature of cheese due to high moisture content, lower fat content, difficulty for rennet coagulation, limited start growth, soft-curd formation, lack of firmness in cheese texture, lower cheese yield and increased hardness during storage etc.

Table 1. Proximate compositional comparison between cow milk and goat milk

Constituent	Goat Milk	Cow Milk
Fat (%)	3.8	3.6
Protein(%)	3.5	3.3
Lactose(%)	4.1	4.6
Ash(%)	0.8	0.7
Solid not Fat(%)	12.1	12.2
Total Solids(%)	12.2	12.3
Calories (Cal)	70	69
Acid value	0.47	0.48
Iodine value	30.44	27.09
Polenske value	1.80	7.06
Saponification value	228.6	232.3
Reichert Meissl value	29.16	24.02
Refractive index	1.450	1.451
Unsaponifiable matter (milk fat)	0.41%	0.41%
Titratable Acidity (% Lactic acid)	0.11	0.13
pH	6.5-6.9	6.4-6.6
Viscosity (cP)	~1.5	~2.0
Freezing Point (°C)	-0.580	-0.547
Calcium (mg)	134	122
P (mg)	121	1119
Se (µg)	1.33	0.96
Vitamin A (IU)	185	126
Vitamin D (IU)	2.3	2
Total n-6	1.78	2.83
Total n-3	0.44	0.56
Saturated Fatty Acid	68.79	68.72
Mono Unsaturated Fatty Acid	24.48	27.40
Poly Unsaturated Fatty Acid	3.70	4.05
ω-6/ωs-3	5.00	6.01

Hence, advances in techno-functional interventions can be used to overcome the stated challenges such as membrane processing (ultrafiltration, microfiltration), enzymatic modification, non-thermal and thermal processing like high-pressure processing, ultrasound, pulsed electric field etc (Lai *et al.*, 2020).

Recently, technological and biotechnological alternatives to promote ripening, and improve yield and flavour have been explored, which include the application of ultrafiltration, rennet substitutes/alternatives, the addition of exogenous enzymes such as transglutaminase, non-starter lactic culture, high-pressure processing etc (Khattab *et al.*, 2019). Technological development has given an opportunity to standardize milk and improve the yield and textural properties intended for cheese making at the industrial level for certain types of cheese.

Among many membranes processing, ultrafiltration (UF) processing is the most widely used membrane technology for cheese making. UF is a pressure-driven process using a semi-permeable membrane to separate macromolecules or colloids from liquids. Based on molecular weight cut-off (1–200K Da), UF permeates lactose, vitamins, soluble minerals, and non-protein nitrogen and retains fat, colloidal salts, and total protein. This resulted in the application of UF in the production of different cheeses where it has increased yield and improved the textural characteristics (Mistry and Maubois, 2017). The level of UF concentration plays a key role, the concentration can be up to 2-5 folds. The 2 folds concentration has been shown to improve cheese yield in cheeses like mozzarella, cheddar and cottage mainly due to the retention of whey proteins (Guinee *et al.*, 2006; Lipnizki, 2010; Kethireddipalli & Hill, 2015). A reduced-fat Cheddar cheese was prepared using exopolysaccharide-producing LAB, which resulted in cheese with improved texture, viscoelastic behaviour, melt characteristics, water-holding capacity, and reducing certain cheese defects (Agrawal and Hassan, 2007) and in cow milk Cheddar cheese, UF resulted in increasing total solids concentration, retention of whey proteins and calcium, yield (↑ 6-8 %) (Bintis and Papademas, 2018). When the concentration was rising above 2 folds up to 5 folds, it also resulted in similar outcomes however this medium concentration was of not much commercial interest (Kelly *et al.*, 2008; Lipnizki, 2010). Further increase in concentration above 6 and 7 folds, which is pre-cheese where whey proteins were completely trapped and only heat-treated cheese milk was acceptable to manufacture semi-hard and hard varieties (Banks, 2007; Fox *et al.*, 2017). Hence, based on studies, it can be concluded that lower concentration retentate up to 3 folds was acceptable in terms of texture and yield only when heat treatment was given e.g., feta cheese (Hannon *et al.*, 2009). Hence, as a thumb rule, using UF to manufacture cheese needs a detailed analysis of physico-chemical properties to interpret the cheese quality and consumer acceptance and give the expected profitability.

Further, using enzymes such as microbial transglutaminase is a protein-glutamine cross-linker, known as Amine γ-glutamyl transferase (EC: 2.3.2.13) (mTG) which is most commonly found in nearly all prokaryotes and eukaryotes cells. This enzyme catalyses the transfer of the acyl group between the γ-carboxamide group of peptide-bound glutamine residues and several primary amines, including the ε-amino group of protein lysine residues resulting in the formation of inter- and intramolecular isopeptide bonds within and between proteins (Zhu *et al.*,1995; Kuraishi *et al.*, 2001; Jaros *et al.*, 2006). As this enzyme forms cross-links in and within the protein structure, it enhances the functional properties in products such as viscosity, water-holding capacity, texture and rheological characteristics without compromising the nutritional quality. Cohort studies have focused on the application of transglutaminase (TG) to improve the functional properties in cow milk-based products and only limited data is available regarding its application in goat milk-based products (Lauber *et al.*,2000; Bönisch *et al.*,2007). However, few studies related to the application of TG in goat milk certain cheeses like halloumi type, goat milk whey cheese, fresh goat cheese, and cheddar have been shown to improve the yield and texture of cheese.

In addition, mTG can be added at different stages of cheese production such as (1) TG could be added to previously pasteurization milk, and thus, the enzyme TG will be inactivated when the coagulant is added; (2) after the curd cutting; and (3) simultaneously with the coagulant. The addition of TG at the above-stated steps has its advantages and disadvantages but the key benefit of adding TG is that it retains whey protein due to cross-linking with curd protein by enhancing nutritive and textural attributes in goat milk Cheddar cheese. However, this depends on various factors like pH, temperature, concentration of enzyme, pretreatment given to milk, presence of any other enzymes, cofactors etc. The main advantage of using TG is that it is calcium-independent, works well at a wide range of pH (5-7) and temperature range between 40-50 °C but loses activity at 70 °C at pH 6 and it has obtained GRAS status from FDA since 1998 (Ando *et al.*,1989; Yokoyama *et al.*, 2004; Jaros *et al.*, 2006). An experiment conducted by Hu and co-workers (2013) to produce low-fat Cheddar cheese (LFT) from cow milk (0.12 % fat) and outcomes of the study were that when transglutaminase was added yield increased from around 6.5 (LFT) to ~8.7 (TG added LFT) and compositional low-fat TG added Cheddar cheese has higher protein and fat recovery (%) than the LFT i.e ~64.2 & ~71.7, and ~83.4 & ~71.2, resp. The textural-rheological properties of TG-addedLFC showed that with an increase in time hardness and cohesiveness were increasing and springiness was decreasing slowly but in the case of LFC, Hardness was decreasing, and springiness & cohesiveness were increasing.

Hence, using UF and mTG intervention singly or in combination, a goat milk-based cheese can be developed with better retention of whey proteins, improved yield along rheological properties and better textural characteristics. However, research in this direction of manufacturing hard-variety cheese resulted in limited success. Hence, further investigations are required to develop hard variety cheese using novel approaches singly or in combination with treatments and investigating the effect of these interventions on cheese during ripening and respective metabolite profiling to identify various biomarkers using targeted or untargeted approaches.

References

Agrawal, P., & Hassan, A. N. (2007). Ultrafiltered milk reduces bitterness in reduced-fat Cheddar cheese made with an exopolysaccharide-producing culture. Journal of dairy science, 90(7), 3110-3117.

Ando, H., Adachi, M., Umeda, K., Matsuura, A., Nonaka, M., Uchio, R., ... & Motoki, M. (1989). Purification and characteristics of a novel transglutaminase derived from microorganisms. Agricultural and biological chemistry, 53(10), 2613-2617.

Ballabio, C., Chessa, S., Rignanese, D., Gigliotti, C., Pagnacco, G., Terracciano, L., & Caroli, A. M. (2011). Goat milk allergenicity as a function of αS1-casein genetic polymorphism. Journal of Dairy Science, 94(2), 998-1004.

Banks, J. M. (2007). Ultrafiltration of cheesemilk. Cheese problems solved, 30.

Fahmi, A. H., Sirry, I., & Safwat, A. (1956). The size of fat globules and the creaming power of cow, buffalo, sheep and goat milk. Indian J. Dairy Sci, 9, 80-86.

FAOSTAT, 2020. http://faostat.fao.org/default.aspx

Fox, P. F., Guinee, T. P., Cogan, T. M., & McSweeney, P. L. (2017). Fundamentals of cheese science (pp. 121-183). New York: Springer US.

Guinee, T. P., O'Kennedy, B. T., & Kelly, P. M. (2006). Effect of milk protein standardization using different methods on the composition and yields of Cheddar cheese. Journal of Dairy Science, 89(2), 468-482.

Haenlein, G. F. W. (2004). Goat milk in human nutrition. Small ruminant research, 51(2), 155-163.

Hannon, J. A., Lortal, S., Tissier, J. P., & Famelart, M. H. (2009). Limited ripening of low-fat UF-cheese due to CaPO4 barrier. Dairy science & technology, 89(6), 555-568.

Hatziminaoglou, Y., & Boyazoglu, J. (2004). The goat in ancient civilisations: from the Fertile Crescent to the Aegean Sea. Small Ruminant Research, 51(2), 123-129.

Hu, Y. N., Ge, K. S., Jiang, L., Guo, H. Y., Luo, J., Wang, F., & Ren, F. Z. (2013). Effect of transglutaminase on yield, compositional and functional properties of low-fat Cheddar cheese. Food science and technology research, 19(3), 359-367.

Jaros, D., Partschefeld, C., Henle, T., & Rohm, H. (2006). Transglutaminase in dairy products: chemistry, physics, applications. Journal of texture studies, 37(2), 113-155.

Kelly, A. L., Huppertz, T., & Sheehan, J. J. (2008). Pre-treatment of cheese milk: principles and developments. Dairy Science and Technology, 88(4-5), 549-572.

Kethireddipalli, P., & Hill, A. R. (2015). Rennet coagulation and cheesemaking properties of thermally processed milk: Overview and recent developments. Journal of Agricultural and Food chemistry, 63(43), 9389-9403.

Khattab, A. R., Guirguis, H. A., Tawfik, S. M., & Farag, M. A. (2019). Cheese ripening: A review on modern technologies towards flavor enhancement, process acceleration and improved quality assessment. Trends in Food Science & Technology, 88, 343-360.

Kuraishi, C., Yamazaki, K. and Susa, Y. 2001. Transglutaminase: its utilization in the food industry. Food Rev. Int. 17:221-246

Lai, G., Pes, M., Addis, M., & Pirisi, A. (2020). A cluster project approach to develop new functional dairy products from sheep and goat milk. Dairy, 1(2), 154-168.

Lipnizki, F. (2010). Cross-flow membrane applications in the food industry. Membrane Technology: Membranes for food applications, 3, 1-24.

Miller, B. A., & Lu, C. D. (2019). Current status of global dairy goat production: An overview. Asian-Australasian journal of animal sciences, 32(8), 1219.

Mistry, V. V., & Maubois, J. L. (2017). Application of membrane separation technology to cheese production. In Cheese (pp. 677-697). Academic Press.

Park, Y.W. and Haenlein, G.F.W. (2010) Milk production, in Goat Science and Production (ed. S. Solaiman), Wiley-Blackwell Publishing, New York, pp. 275–292.

Park, Y.W., 2007. Hypoallergenic and therapeutic significance of goat milk. Small Ruminant Research

Yokoyama, K., Nio, N., & Kikuchi, Y. (2004). Properties and applications of microbial transglutaminase. Applied microbiology and biotechnology, 64(4), 447-454.

Zhu, Y., Rinzema, A., Tramper, J., & Bol, J. (1995). Microbial transglutaminase—a review of its production and application in food processing. Applied microbiology and biotechnology, 44(3), 277-282.

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