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Effect of heat treatments on the physicochemical and structural properties of goat milk

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10 **Abstract:** In modern dairy industry, thermal processing is applied for safety concern of microbial risk during goat milk (GM) processing, which would concern the stability of milk proteins. In this paper, we studied the outcomes of thermal treatments (pasteurization, spray drying and ultra-high temperature (UHT)) commonly practiced in the milk industries on the denaturation of protein structure and physicochemical properties of GM. Confocal scanning microscopy illustrated that high heat treatments

- 15 strengthened the milk fat globules size (MFGs) of GM. The results from circular dichroism and fluorescence spectroscopy presented that spray drying and UHT both treatments made significant transformations in protein structure of GM. Moreover, these treatments also decreased the total sulfhydryl concentration and zeta potential in milk proteins, while surface hydrophobicity increased significantly indicating that thermal treatment had a great impact on GM proteins. Whereas,
- 20 pasteurization had the least effect on serum proteins compared to raw milk serum. This study provided a great understanding of physicochemical and structural changes of GM underlying commercial thermal treat ments.

Key words: goat milk; serum protein; heat treatment; physicochemical properties; structural analysis

25 **0 Introduction**

Milk is a nutritional and completely digestible food, which is rich in protein and also provides many bioactive compounds to neonate such as immunoglobulins, hormones, chemokines, antimicrobial, and growth factors^[1,2]. Due to its perishable nature, milk is typically consumed by animals just after production^[3]. In contrast to bovine milk, GM has increased in popularity among consumers due to its low level of lactose content, high calcium content and high protein. Although, no major difference was identified in protein content between cow and GM, a significantly lower amount of α_{s1} -CN only existing in the casein micelle and a higher concentrate of β -CN + κ -CN in the serum portion were found in GM than bovine milk^[4, 5]. Moreover, Goat MFGs and membrane proteins are also different from bovine milk^[6]. Membrane of fat globule in milk can stabilize fat particles in the serum phase and provides many biological functions^[7].

Because of the nutritional and commercial importance of dairy products, milk processing has been conducted to preserve the freshness of milk after its first production. In dairy chemistry, heating impact on the milk is an important consideration as heat processing is regularly applied in the manufacturing of almost all milk products. When milk is preserved to prolong the shelf-life of

40 milk products using heating conditions, a numerous change can happen to the milk. Moreover, thermal treatments have a major impact on milk fat and may decrease the size and surface area of MFGs in milk^[8,9].

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The most possible change in milk during heating is protein denaturation, which can alter the functional and nutritious properties of milk proteins. The denaturation method can be reversible, mainly depend on the physicochemical forms of milk, where limited unfolding of the whey proteins can occur with a significant loss of different secondary structure. In contrast, irreversible denaturation might be happened where aggregation of proteins can take place including sulfhydryl (–SH)/disulfide (S–S) interchange reactions^[10]. In general, whey protein aggregation involves the interaction of a free –SH group with the S–S bond of cystine-containing proteins such as κ -casein, β -Lg, α -La, and BSA via –SH/S–S interchange reactions^[11]. In addition, the three major whey proteins, β -lactoglobulin, α -lactalbumin, and bovine serum albumin mostly denature at around 78, 62, and 64 °C, respectively^[12, 13].

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Now, it is well developed for bovine milk that milk treating at high temperature, especially UHT and spray drying, is the main fact for modifications of milk proteins. So far, there are less information reported about the changes in GM proteins and MFGs after thermal treatments. As reported, heat processing could change physicochemical properties of proteins in food, including surface hydrophobicity, zeta potential, emulsifying activity, emulsion stability, protein solubility, reducing viscosity, and improving gelling properties^[14, 15]. However, previous researches have mostly observed the effect of heat processing on GM serum protein and fat globule at lower than 100 °C, and limited information is accessible on the protein changes of GM protein after UHT and spray drying.

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Hence, it is necessary to determine how thermal processing affects denaturation and the subsequent changes in the structural and chemical properties of serum protein from GM. Therefore, this study aims to determine the extent of thermal processing on physicochemical and structural properties of GM serum protein after commercial heat processing.

1 Materials and Methods

1.1 Preparation of heat-treated sample

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Milk was transported to our laboratory from dairy farm in Zhejiang (Hangzhou province, China) using an ice box within 4 h. Then the raw milk was appropriately divided into four portions. The first portion served by means of the control sample. The remaining three were treated by different heat process including pasteurization, UHT, and spray drying. The heating conditions were 65 $\$ for 30 min in pasteurization, and 135 $\$ for 5 sec in UHT (Power Point International, Toda-Shi, Japan). For the spray drying, the preheating was done for 15 sec at 95 $\$. Milk from preheating was then concentrated to 20% at 45 $\$ using evaporator. Afterward, the concentrated milk was dried in a Mini Spray Dryer B-290 (Buchi Laboratorums-Technik AG, Switzerland) at 165 \pm 5 $\$ and 80 \pm 5 $\$ as inlet and outlet temperature respectively. The 10 g SDM powder was reconstituted in 100 mL warm water (at 45 $\$) with continuous stirring for one hour.

1.2 Separation of milk Serum

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To remove milk fat, milk was first centrifuged at 1500 \times gravity for 15 min at 10 $^{\circ}$ C temperature (Beckman Coulter Avanti J-26 XP Centrifuge). Then, the obtained skimmed milk was shifted to ultracentrifuge tubes for ultracentrifugation and centrifugation was accomplished at 100,000 \times gravity for 1.50 h at 25 $^{\circ}$ C (Beckman L-60, rotor 70Ti). Three layers appeared inside the ultracentrifuge tubes. Milk fat and casein pellet were separated on the topmost and underneath

side respectively. The transparent liquid obtained in the middle was milk serum.

85 **1.3 Particle size**

The MFGs distributions of raw and heated milk was measured with a Microtrac S3500 size analyzer (Microtrac instrument, US). An EDTA buffer solution (35 mM, pH 7.0) was inserted to the sample tube at 1:1 (v/v) ratio to isolate the casein micelles. The refractive index was fixed at 1.33 and 1.46 for water and milk fat respectively. The mean MFGs distribution was studied by the volume-weighed mean diameter $d_{4,3} (d_{4,3} = \Sigma n_i d_i^4 / \Sigma n_i d_i^3)$.

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1.4 Microstructure analysis

Confocal laser screening microscope (CLSM) was fitted to monitor the micrograph of MFGs by a confocal microscope (Carl Zeiss AG, Germany). The method was applied with modifications as described by a previous study^[16]. Sample and Nile red (1 mg mL⁻¹) were mixed together at a ratio of 1:100 (v/v) to stain the sample. After mixing, the sample was placed in a dark chamber for 20 min. The stained sample was then deposited on a microscopic glass slide, and a coverslip was applied immediately to ensure no air trap. An objective (63×1.4 oil immersion) was set to capture the micrographs.

1.5 Zeta potential

100 Zeta potential of milk serum was determined at 25 $^{\circ}$ C using a nano Zetasizer (Nano omni Brookhaven Instruments, US). The concentration of milk serum was diluted at a protein concentration of 0.5 mg mL⁻¹, then pH was adjusted to 7.0 with hydrochloric acid (0.1 N). The dispersion of sample was then filtered in a syringe membrane filter (0.45 µm) (Millipore Corp., MA, USA) prior to the analysis.

105 **1.6 Sulfhydryl group (-SH) measurement**

The sulfhydryl groups in serum solutions was determined by utilizing Ellman's reagent (4 mg mL⁻¹) as reported by previous study^[17]. Briefly, concentration of samples was diluted at 1 mg mL⁻¹ with buffer (PBS, 7.4). Afterwards, 500 μ L of serum solution was mixed with 2.5 mL of Tris buffer (8 M urea, pH 8.0). Ellman's reagent (20 μ L) was then added into the mixture. The solution was incubated at 25 °C in dark for 15 min, and absorbance was examined at 412 nm with a UV–vis spectrophotometer (UV- 2700, Shimadzu, Tokyo, Japan).

1.7 Surface hydrophobicity (SH)

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1-Anilinonaphthalene-8-Sulphonic acid solution (ANS) was used to measure surface hydrophobicity in serum proteins of GM by a spectrophotometer (F-7000, Hitachi, Japan). The method was used with modifications as reported by previous study^[18]. At first, serum solution was diluted with PBS buffer (pH 7.4), and the concentration was ranged from 0.5 to 3.5 mg mL⁻¹. Then 5 ml of protein sample was reacted with a 25 μ L aliquot of ANS solution (8 mM in 0.1 M phosphate buffer, pH 6.0) at 25 °C for 20 min in dark. Finally, the intensity was acquired at 374 and 485 nm excitation and emission wavelength respectively.

120 **1.8** Circular dichroism (CD) spectroscopy

The CD spectrum was recorded between 190 and 260 nm on a Chirascan V100 CD spectrometer (British Applied Photo Physics, United Kingdom) at 25 °C. Spectra from serum proteins were obtained at a concentration of 0.50 mg mL⁻¹ in a pathlength of 1 mm cuvette. On average, eight scans were taken and filtered to remove the noise. The operating scan speed was at 50 nm per min, 0.125 sec as of response time. The analysis of secondary protein structure was carried out via CDNN.

1.9 Fluorescence analysis

Fluorescence intensity spectra of serum protein was observed by a Spectro-fluorometer
F-4500 (Hitachi, Japan). At first, all samples were dissolved to a concentration of 0.5 mg mL⁻¹ in
ultrapure water. Afterwards, each sample spectrum was monitored from 280–400 nm of emission wavelengths at 25 ℃ temperature with 5.0 nm excitation slit, and at 295 nm as excitation wavelength.

1.10 Statistical Analysis

One-way ANOVA analysis of observed data were carried by GraphPad Prism (version 8.3.1, 135 GraphPad software Inc, CA, US). Values were expressed as the means \pm SD. Difference were regarded as statistically significant if $P \le 0.05$.

2 Results

2.1 Size distribution and confocal laser screening microscope of MFGs

Structural changes of different types of processed MFGs during different heating process 140 could be assessed by CLSM. Figure 1(A-D) shows the CLSM images of raw, pasteurized, UHT and spray dried milk, which were stained with Nile red to label the TAG. From the CLSM micrograph of raw and pasteurized milk, a regular shape and size were monitored in both samples without any remarkable changes, whereas milk fat was formed large particles in UHT sample. In case of spray drying, some small and large particles were remarked in figure 1 D rather than 145 dispersed evenly through the aqueous phase.

Figure 1E showed that UHT MFGs had the largest size with the average $d_{4,3}$ 6.21±0.04 µm, following by spray dried MFGs with average $d_{4,3}$ 4.91±0.02 µm, Pasteurized MFGs with average $d_{4,3}$ 4.32±0.03 µm, and raw MFGs had the smallest size with average $d_{4,3}$ 4.09±0.03 µm. UHT and spray drying both showed polydispersity and bimodal size distribution. UHT MFGs had two peaks at 4.62 and 18.50 µm, while spray dried MFGs showed peaks at 0.409 and 5.50 µm.

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Fig. 1 CLSM images of MFGs from raw milk (A), pasteurized milk (B), UHT milk (C) and spray dried milk (D).

Size distribution of MFGs (1E)

2.2 Zeta potential and surface hydrophobicity (SH)

Hydrophobic interactions perform a significant role in conformation, stability and physical properties of proteins. Figure 2 showed that heat treatment significantly increased the SH of serum proteins in heated GM (P < 0.05). SH of serum proteins from heat treated GM increased according to the applied heating intensity on milk.

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Zeta potential of serum proteins heated and unheated GM were appeared in Figure 3. The Zeta potential of spray drying and UHT milk serum was significantly decreased than the control and pasteurized milk serum indicating that zeta potential of serum decreased with increase in heating intensity. However, Zeta potential of all samples was within unstable range.



Fig. 2 Surface hydrophobicity of GM serum after different heat treatments



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2.3 Sulfhydryl group content

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The total - SH content is well established method to analyze the effects of different thermal and ionic treatment on the covalent relations of proteins in milk. Figure 4 shows that significant (P < 0.05) reduction occurred in total -SH content of serum proteins in heat treated GM samples. The total SH group content deceased from 22.78 \pm 0.76 to 12.71 \pm 0.78 µmol SH/g in serum proteins after the UHT treatment compared to raw milk sample.



Treatments

Fig. 4 Total -SH content from raw, pasteurized, spray drying and UHT treated GM serum.

175 2.4 Circular dichroism spectroscopy

Figure 5 shows that raw and pasteurized milk serum proteins possessed similar CD spectral shape, and showed a maximum spanning from 205 to 215 nm. Whereas, UHT and spray drying treatments showed a marked shift of peaks at 202 and 201 nm with a negative ellipticity, suggesting that there was considerable secondary structural loss in serum protein of spray dried and UHT treated milk. Table 1 presents secondary structure compositions calculated by CDNN. Our result revealed that there was negligible variance in protein compositions loss between raw and pasteurized milk serum whereas, UHT showed a gross loss in both β -sheet and α -helix contents, and an increase in β -turn and random coil structure. Moreover, spray dried serum proteins had the similar pattern of structure loss with the UHT treatment.

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Fig. 5 Far-UV CD spectra of GM serum proteins from raw, pasteurized, spray dried and UHT milk.

Tab. 1 Secondary structural analysis (%) from far-UV CD spectra of GM serum protein from raw, pasteurized,

Sample	a-Helix	Antiparallel beta sheet	Parallel Beta sheet	Beta-Turn	Random. Coil
Raw	16.8	32.6	5.0	19.4	33.5
Pasteurization	12.1	28.9	4.3	21.2	32.1
Spray drying	8.3	26.6	3.2	24.5	37.1
UHT	7.3	18.3	2.6	28.2	42.9

spray dried and UHT milk.

2.5 Fluorescence spectroscopy

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In our study, we used fluorescence spectroscopy to characterize the changes in serum protein conformation by analyzing the modification of tryptophan residue. The relative fluorescence intensity of GM serum treated with different heat treatments were shown in Figure 6. The wavelength of raw and pasteurized serum samples remained constant, whereas fluorescence intensity was slightly higher in pasteurized serum than the raw serum. In contrast, the relative 195 intensity of spray dried and UHT serum protein samples decreased markedly compared to raw and pasteurized serum protein samples.



Fig. 6 Fluorescence spectra of GM serum from raw, pasteurized, spray dried and UHT treated milk.

Discussion 3

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The changes in MFGs after different thermal treatments were in steady with former reports^{[6}, ^{19]}. In addition, the CLSM images were also in accordance with the findings of size dispersal of the MFGs (Figure 1E) which suggested that heat treatment had a significant effect on MFGs of GM. These changes were commonly assigned to the fusion of MFGs during heat treatment. MFGs can be increased due to the denaturation of protein and coalescence of the fat globules after the heat treatment^[20]. Moreover, coalescence of fat globules might be in relation with the protein-lipid interactions in the MFGM^[19].

For the native milk serum, residues of the hydrophobic site were concealed in center of the protein molecules; after thermal treatment, the limited unfolding of GM serum proteins could bring these residues to the surface, causing in the increase of hydrophobicity^[21]. Our study also 210 found high SH in thermally treated milk samples, which suggested that the solubility of protein also decreased in heat treated samples. Effect of thermal conditions on SH was also reported for other proteins where heat treatments increased the hydrophobicity of pea proteins and soy proteins^[22, 23]. Furthermore, researchers were also confirmed that the free hydrophobic residue induced during protein denaturation led to a high content of surface hydrophobicity in protein sample^[18].

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In our study, spray drying and UHT treated sample showed increase in net negative charge of zeta potential, even though it was within unstable range for all samples. The modifications in surface potential of protein particles in milk serum under different treatment could be due to the differences in the degree of hydrophobic or hydrophilic exposure of milk serum caused by

220 different heat treatments^[24]. Schmitt et al.^[25] also noted that the increased negative charge of zeta potential could induce whey protein aggregation. In contrast, -SH content in protein samples reduced gradually with increase in thermal treatment. The measured decrease in total -SH content in heat treated milk might be due to the fact of protein denaturation that increased with an escalation in heating intensity. Alternatively, disulfide bonds development might be the main reason in decrease of total -SH content in heated milk serum. Reporters^[24] also found similar trend in polymerized WPI and WPC after heat treatment.

CD spectra analysis revealed that protein structure of serum from spray drying and UHT treated GM were changed remarkably by heat treatment. This might have happened because of the denaturation and unfolding of GM proteins throughout the heat treatments. Studies found similar changes of protein structure in milk serum protein treated by high temperature short time pasteurization and UHT^[14, 15].

In addition, we analyzed fluorescence spectroscopy to investigate the protein conformational changes. In our study, the wavelength of control and pasteurized samples remained constant, where fluorescence intensity was slightly higher in pasteurized milk serum than the raw milk serum. Researchers also found similar trend in polymerized WPC and WPI, and noted that the increase in intensity has been connected with the disclosure of more hydrophobic residues which located in the center of the protein molecules caused by protein unfolding and aggregation^[24]. Moreover, there was also a 5 and 1 nm red shift in emission wavelength of spray drying and UHT treatment, respectively, suggesting that denaturation and unfolding of protein was pronounced in this two sample through thermal treatments. Moreover, the red shift also indicated that occlusion or microenvironment of tryptophan residues were changed throughout the heating process^[26, 27].

4 Conclusion

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The structural and physicochemical properties of serum proteins from GM treated with thermal treatments were evaluated successfully to facilitate the production of dairy products. The results in this study suggested that pasteurization showed no remarkedly effect on GM serum protein and MFG size compared to raw milk serum, whereas spray drying and UHT treatment had high influence on denaturation of serum protein structure and also on MFGs. In addition, the total -SH content and zeta potential decreased with the increase in heating intensity. This study provided supervision on the selection of mild processing conditions for GM processing.

250 Acknowledgement

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References

[1] GROSVENOR C E, PICCIANO M F, BAUMRUCKER C R. Hormones and Growth Factors in Milk [J]. Endocrine Reviews, 1993, 14(6): 710-728.

260 [2] BALLARD O, MORROW, A L. Human milk composition: nutrients and bioactive factors [J]. Pediatric clinics

of North America, 2013, 60(1): 49-74.

[3] CHEN D, ZHAO X, LI X, et al. Milk compositional changes of Laoshan goat milk from partum up to 261 days postpartum [J]. Animal Science Journal, 2018, 89(9): 1355-1363.

[4] LOU X, LI J, ZHANG X, et al. Variations in fatty acid composition of Laoshan goat milk from partum to 135
 days postpartum [J]. Animal Science Journal, 2018, 89(11): 1628-1638.

[5] ZHAO X, CHENG M, ZHANG X, et al. The effect of heat treatment on the microstructure and functional properties of whey protein from goat milk [J]. Journal of Dairy Science, 2020, 103(2): 1289-1302.
[6] MA Y, ZHANG L, WU Y, et al. Changes in milk fat globule membrane proteome after pasteurization in human, bovine and caprine species [J]. Food Chemistry, 2019, 279: 209-215.

- [7] ZANABRIA R, TELLEZ A M, GRIFFITHS M W, et al. The antiproliferative properties of the milk fat globule membrane are affected by extensive heating [J]. Dairy Science & Technology, 2014, 94(5): 439-453.
 [8] SHARMA P, OEY I, EVERETT D W. Interfacial properties and transmission electron microscopy revealing damage to the milk fat globule system after pulsed electric field treatment [J]. Food Hydrocolloids, 2015, 47: 99-107.
- [9] YANG Y, ZHENG N, ZHAO X, et al. Changes in bovine milk fat globule membrane proteins caused by heat procedures using a label-free proteomic approach [J]. Food Research International, 2018, 113: 1-8.
 [10] VASBINDER A J, de KRUIF C G. Casein-whey protein interactions in heated milk: the influence of pH [J]. International Dairy Journal, 2003, 13(8): 669-677.
 [11] WIJAYANTI H B, BANSAL N, DEETH H C. Stability of Whey Proteins during Thermal Processing: A
- [11] WIJATANTITH B, BANSAL N, DEETHTH C. Stability of Whey Proteins during Therma Processing: A
 Review [J]. Comprehensive Reviews in Food Science and Food Safety, 2014, 13(6): 1235-1251.
 [12] LIU G, ZHONG Q. Thermal aggregation properties of whey protein glycated with various saccharides [J].
 Food Hydrocolloids, 2013, 32(1): 87-96.
 [13] BRYANT C M, M cCLEMENTS D J. Molecular basis of protein functionality with special consideration of cold-set gels derived from heat-denatured whey [J]. Trends in Food Science & Technology, 1998, 9(4): 143-151.
- 285 [14] ZHANG Z, YANG Y, TANG X, et al. Effects of Ionic Strength on Chemical Forces and Functional Properties of Heat-induced Myofibrillar Protein Gel [J]. Food Science and Technology Research, 2015, 21(4): 597-605.

[15] GALLIER S, VOCKING K, POST J A, et al. A novel infant milk formula concept: Mimicking the human milk fat globule structure [J]. Colloids and Surfaces B: Biointerfaces, 2015, 136: 329-339.

- [16] QI P X, REN D, XIAO Y, et al. Effect of homogenization and pasteurization on the structure and stability of whey protein in milk [J]. Journal of Dairy Science, 2015, 98(5): 2884-2897.
 [17] SEGAT A, MISRA N N, FABBRO A, et al. Effects of ozone processing on chemical, structural and functional properties of whey protein isolate [J]. Food Research International, 2014, 66: 365-372.
 [18] KATO A, NAKAI S. Hydrophobicity determined by a fluorescence probe method and its correlation with
- surface properties of proteins [J]. Biochimica et Biophysica Acta (BBA) Protein Structure, 1980, 624(1): 13-20.
 [19] YAO Y, ZHAO G, YAN Y, et al. Effects of freeze drying and spray drying on the microstructure and composition of milk fat globules [J]. RSC Advances, 2016, 6(4): 2520-2529.
 [20] MILLQVIST-FUREBY A, ELOFSSON U, BERGENST ÅHL B. Surface composition of spray dried milk protein-stabilised emulsions in relation to pre-heat treatment of proteins [J]. Colloids and Surfaces B: Biointerfaces,

2001, 21(1): 47-58.
[21] CAO Y, XIA T, ZHOU G, et al. The mechanism of high pressure-induced gels of rabbit myosin [J].
Innovative Food Science & Emerging Technologies, 2012, 16: 41-46.
[22] PENG W, KONG X, CHEN Y, et al. Effects of heat treatment on the emulsifying properties of pea proteins
[J]. Food Hydrocolloids, 2016, 52: 301-310.

305 [23] REN C, XIONG W, PENG D, et al. Effects of thermal sterilization on soy protein isolate/polyphenol complexes: Aspects of structure, in vitro digestibility and antioxidant activity [J]. Food Research International, 2018, 112: 284-290.
 [24] JIANG S, ALTAF HUSSAIN M, CHENG J, et al. Effect of heat treatment on physicochemical and

[24] JIANG S, ALTAF HUSSAIN M, CHENG J, et al. Effect of heat treatment on physicochemical and emulsifying properties of polymerized whey protein concentrate and polymerized whey protein isolate [J]. LWT, 2018, 98: 134-140.

- 2018, 98: 134-140.
 [25] SCHMITT C, BOVAY C, ROUVET M, et al. Whey Protein Soluble Aggregates from Heating with NaCl: Physicochemical, Interfacial, and Foaming Properties [J]. Langmuir, 2007, 23(8): 4155-4166.
 [26] XIANG B Y, NGADI M O, OCHOA-MARTINEZ L A, et al. Pulsed Electric Field-Induced Structural Modification of Whey Protein Isolate [J]. Food and Bioprocess Technology, 2011, 4(8): 1341-1348.
- 315 [27] Tang C, Yang X Q, Chen Z, et al. Physicochemical and structural characteristics of sodium caseinate biopolymers induced by microbial transglutaminase [J]. Journal of food biochemistry, 2005, 29(4): 402-421.

热处理对羊奶理化和结构特性的影响

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摘要: 在现代乳品工业中,常采用热加工方式来提高山羊奶(GM)的微生物安全性,但这 往往影响其蛋白稳定性。本文研究了乳品工业中常用的热处理方式(巴氏杀菌、喷雾干燥和 超高温(UHT))对山羊奶蛋白结构变性和理化性质的影响。共聚焦扫描显微镜显示,高 热处理增加了山羊奶的乳脂球大小(MFGs)。圆二色谱和荧光光谱分析结果表明,喷雾干 燥和 UHT 处理均使山羊奶蛋白质的结构发生了显著变化。此外,这些处理还降低了乳蛋白 中的总巯基浓度和 Zeta 电位,但显著增加了表面疏水性,表明热处理对山羊奶蛋白的影响 很大。然而,巴氏杀菌对山羊奶血清蛋白的影响最小。本研究对进一步理解商业热处理下山

330 羊奶的理化和结构变化具有重要意义。关键词:山羊奶;血清蛋白;热加工;物化特性;结构分析中图分类号:TS252.1