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CHANGES IN TEXTURE OF YOGHURT FROM GOAT'S MILK MODIFIED BY TRANSGLU-TAMINASE DEPENDING ON pH OF THE MILK**

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Abstract: Set yoghurt from goat's milk with adjusted pH to 6,4, 6,3, 6,2 and 6,1 and than modified by microbial transglutaminase (TGase) were produced. Control yoghurt was produced from goat's milk of pH 6,4 but without modification by TGase. In yoghurt determined sensory quality, pH, texture parameters and syneresis. Modification of goat's milk by TGase caused an increase in apparent viscosity, hardness and adhesiveness of the yoghurt. The pH of the milk incubated with TGase in the range 6.4-6.1 has no influence on such texture parameters like viscosity, hardness, adhesiveness, extrusion force and syneresis. The pH and extrusion force of the stored yoghurts was significantly lower than the values of these parameters in fresh yoghurts.

Key words: goat's milk yoghurt, pH, texture, transglutaminase

Introduction and literature review

Transglutaminase (TGase) (EC 2.3.2.13) catalyses the formation of covalent cross-links between glutamine and lysine residues in many food proteins e.g. in casein. Crosslinking of food proteins by TGase modifies the hydration ability, the gelation, rheological and textural properties of food products as well as yoghurt. Optimum pH of microbial TGase is in the range of 6-7, however the enzyme is stabile at pH 5 – 9. Formation of cross-links in casein depends on pH of incubation with the enzyme and at pH 6.5 is negligible because of the electrostatic repulsion of the micelles (*Ajinomoto* 2000*, Schrosch et al.* 2000, *Domagała* 2001).

According to *Faergemand et al.* (1999) addition of TGase to cow's milk

enable the production of yoghurt with proper texture without addition of milk powder. *Lorenzen et al.* (2000) and *Lauber et al.*(2000*)* have found, that cross-linking of casein in milk by microbial TGase increase hardness and viscosity of cow's milk yoghurt gel and reduce syneresis.

TGase can be also used to improve the texture and rheological properties of goat's milk yoghurt, which is characterised by less firm gel and lower viscosity than cow's milk yoghurt. The aim of this work was to determine the influence of pH of goat's milk incubated with TGase on texture paarameters and syneresis of the yoghurt.

Materials and methods

Raw milk was obtained from Polish White Improved breed of goat's during the middle of lactation. Milk for yoghurt production was pasteurised at 85°C for 15 min., cooled down to 40°C and pH of the milk was adjusted using 10% solution of lactic acid to 6,4, 6,3, 6,2 and 6,1. Milk with regulated pH was incubated with microbial transglutaminase from Ajinomoto, Japan, given in the amount of 2 u (unit) per 1g protein for 2 hours at 40°C. After incubation the enzyme was inactivated at 80°C for 1 minute. Next the milk was cooled down to 44°C and inoculated with starter culture YC-180 from Chr. Hansen, Denmark. The starter was added at 5 u level to 25 litter of milk. The yoghurt was incubated at 44°C, until the pH 4.8 was reached. Then the products were cooled to 5-8°C, stored at this temperature for 14 h and 14 days and then analysed. Control yoghurt was produced from goat's milk with pH 6,4 but without modification by TGase. Total solids, total protein, casein, whey protein, non protein nitrogen, fat, lactose, ash content as well as density, viscosity, titratable acidity and pH were determined in goat's milk used for yoghurt production (*AOAC* 1995*, Budsławski* 1973*, PN-68/A-86122, Zmarlicki* 1981) For yoghurt the following analysis was done: sensory evaluation in 5-point scale performed by trained panel of 5 judges of verified sensory acuity, pH, texture using universal texture analyser TA-XT2 (Stable Micro Systems, UK). In texture analysis penetrometric test with plastic cylinder of 20 mm diameter, penetration rate of 1mm/s and penetration depth of 25 mm, and additionally extrusion force tests were performed. Syneresis was determined using drainage methode (*Dannenberg, Kessler* 1988) and centrifugal methode *(Pluta et al.* 1999), apparent viscosity using rotary viscometer Rheotest RV2 (VEB MLW Medingen. Germany).

Results of investigations and discussion

In table 1 is presented chemical composition and main physicochemical properties of raw goat's milk for yoghurt preparation. Total solids and total protein content in processed milk was lower than mean content of this component in goat's milk given in literature. According to *Pełczyńska* (1995) the total solids content in goat's milk ranged from 11,50 to 13,63% and total protein content from 2,9 to 3,76%. Also *Kudełka* (2001) has found that the mean total solid in goat's milk is 12.06% and total protein content 3,2%.

Table 1. Chemical composition and physicochemical properties of raw goat's milk for yoghurt preparation (mean values from three series ± standard error)

Parameter	Mean value ± standard error
Total solids [%]	10,74 ± 0,24
Total protein [%]	2,78 ± 0,07
Casein [%]	2,28 ± 0,07
Whey protein/ [%]	0,31 ± 0,02
Non protein nitrogen[%]	0,29 ± 0,02
Fat [%]	3,2 ± 0,06
Lactose [%]	4,72 ± 0,06
Ash [%]	0,82 ± 0,02
Density [g/cm^3]	1,0300 ± 0,000
Viscosity [mPa·s]	1,87 ± 0,02
Acidity [°SH]	6,5 ± 0,06
pH	6,61 ± 0,02

The mean content of main components in analysed goat's milk was also generally lower than the mean content of these components in goat's milk given by *Ziarno and Truszkowska* (2005).

In table 2 are presented the results of sensory evaluation, texture analysis and syneresis determinations of fresh and in table 3 of cold stored yoghurts from goat's milk with adjusted pH, modified by transglutaminase and of control yoghurt. Results of statistical analysis concerning effects of pH of goat's milk incubated with transglutaminase and time of storage on quality

properties of produced yoghurts are presented in table 4.

Table 2. Quality properties of fresh yoghurts from goat's milk with adjusted pH and modified by transglutaminase in comparison with control yoghurt

Parameter	Control yoghurt pH 6,4	Yoghurts from milk modified by transglutaminase/			
		pH 6,4	pH 6,3	pH 6,2	pH 6,1
Sensory evaluation [points]	3,83 ±0,06	3,82 ±0,21	3,97 ±0,02	3,76 ±0,20	3,82 ±0,09
pH	4,32 ±0,03	4,42 ±0,03	4,40 ±0,05	4,46 ±0,05	4,41 ±0,05
HardnessTPA [G]	$21,61^{A,a,b,c}$ ±1,81	$30,87^{A}$ ±2,14	$29,64^{a}$ ±0,59	$30,06^{b}$ ±1,74	$29,72^{c}$ ±2,12
Adhesiveness/TPA [G·s]	$17,74^{a,b,c}$ ±3,46	$37,37^{a}$ ±6,89	34,06 ±1,82	$42,22^{b}$ ±5,29	$38,71^{c}$ ±8,23
Extrusion force [G]	$50,03^{a}$ ±2,62	74,00 ±4,34	$108,98^{a}$ ±15,95	85,49 ±9,05	82,23 ±10,41
Apparent viscosity [Pa·s]	$0,30^{A.B.C.D}$ ±0,06	$0,53^{A}$ ±0,03	$0,58^{B}$ ±0,03	$0,51^{C}$ ±0,05	$0,50^{D}$ ±0,04
Syneresis 1) [%]	50 ±1	39 ±3	43 ±2	47 ±2	42 ±4
Syneresis 2) [%]	2,6 ±0,1	2,5 ±0,3	2,9 ±0,1	3,3 ±0,4	3,5 ±0,3

1) determined using drainage method; 2) determined using centrifugal method; $^{A-D}$ – statistically highly significant difference ($p \leq 0,01$) between means marked with the same letters in the rows; $^{a-c}$ – statistically significant difference ($p \leq 0,05$) between means marked with the same letters in the rows

Modification of goat's milk by microbial transglutaminase caused significant increase in apparent viscosity, hardness and adhesiveness of fresh yoghurt. After cold storage of the yoghurts these differences were high significant. According to *Faaergemand et al.* (1999), *Lauber et al.* (2000) and *Lorenzen et al.* (2000) modification of cow's milk by microbial Tgase increase the hardness and apparent viscosity of yoghurts. *Lorenzen et al.* (2000) have found, that hardness of yoghurt from cow's milk with addition of TGase was 2-fold higher, than hardness of yoghurt from cow's milk without addition of TGase. The values of measured parameters for yoghurts made from goat's milk incubated with TGase at pH in the range 6,4-6,1 were similar. Only in stored yoghurt adhesiveness were the highest in product from milk incubated with enzyme at pH 6,3, and the lowest in product

incubated at pH 6,1. Statistical analysis showed, that pH of milk incubated with TGase in the range of 6,4-6,1 has no influence on sensory quality, measured texture parameters, syneresis and rheological parameters calculated from used models. Time of storage significantly influenced only pH and extrusion force of analysed yoghurt. The pH and extrusion force of stored yoghurts was lower than of fresh yoghurts, only extrusion force of stored control yoghurt was higher than of fresh control yoghurt.

Table 3. Quality properties of yoghurts from goat's milk with regulated pH and modified by transglutaminase in comparison with control yoghurt after 14-days cold storage

Parameter	Control yoghurt pH 6,4	Yoghurts from milk modified by transglutaminase/			
		pH 6,4	pH 6,3	pH 6,2	pH 6,1
Sensory evaluation [points]	3,58 ±0,16	3,99 ±0,08	3,96 ±0,09	3,27 ±0,53	3,89 ±0,03
pH	4,25 ±0,03	4,3 ±0,02	4,21 ±0,03	4,22 ±0,02	4,22 ±0,01
Hardness TPA [G]	$22,37^{A,B,C,D}$ ±1,40	$32,40^{A}$ ±1,13	$31,81^{B}$ ±1,37	$31,12^{C}$ ±0,38	$31,88^{D}$ ±1,86
Adhesiveness TPA [G·s]	$12,52^{A,B,C,D}$ ±1,78	$39,36^{A}$ ±4,02	$43,32^{B,a}$ ±3,68	$32,94^{C}$ ±3,41	$30,35^{D,a}$ ±2,32
Extrusion force [G]	65,05 ±16,74	70,66 ±7,16	61,48 ±1,91	55,61 ±6,03	44,75 ±5,99
Apparent viscosity [Pa·s]	$0,28^{A.B.C.D}$ ±0,06	$0,52^{A}$ ±0,03	$0,53^{B}$ ±0,03	$0,49^{C}$ ±0,05	$0,49^{D}$ ±0,04
Syneresis 1) [%]	41 ±5	42 ±4	42 ±3	42 ±3	42 ±5
Syneresis 2) [%]	2,6 ±0,1	2,5 ±0,4	2,9 ±0,5	3,1 ±0,4	3,3 ±0,4

1) determined using drainage method; 2) determined using centrifugal method; $^{A-D}$ – statistically highly significant difference ($p \leq 0,01$) between means marked with the same letters in the rows; $^{a-c}$ – statistically significant difference ($p \leq 0,05$) between means marked with the same letters in the rows/

Table 4. Mean squares of deviation from variance analysis concerning effects of pH of goat's milk incubated with transglutaminase and time of storage on quality properties of yoghurt

Source of variation	1. pH of milk/	2. Time of storage/	Interaction 1x2/	Error/
Degrees of freedom	3	1	3	16
Sensory quality	0,2422	0,0267	0,1304	0,1455
pH	0,0016	0,2501**	0,0012	0,0039
Hardeness	1,3446	17,9920	0,4361	7,3495
Adhesiveness	21,5907	15,2641	117,7419	75,4804
Extrusion force	470,23	2650,41**	319,73	221,39
Apparent viscosity	4804,27	2799,79	359,63	2809,97
Syneresis 1)	0,1128	0,0417	0,1261	0,2950
Syneresis 2)	0,8747	0,0504	0,0282	0,4404

1) determined using drainage method; 2) determined using centrifugal method; ** – statistically highly significant difference ($p \leq 0,01$) of the effect of the study factor

Conclusions

1. Modification of goat's milk by TGase caused an increase in apparent viscosity, hardness and adhesiveness of fresh and storage yoghurt.
2. The pH of the milk incubated with TGase in the pH range 6.4-6.1 has no influence on such texture parameters like viscosity, hardness, adhesiveness, extrusion force and syneresis.
3. During cold storage of the yoghurt, the pH and extrusion force decreased significantly in comparison with the values of these parameters in fresh yoghurt.

PROMENE U STRUKTURI JOGURTA OD KOZIJEG MLEKA MODIFIKOVANOG TRANSGLUTAMINAZOM U ZAVISNOSTI OD pH MLEKA

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Rezime

Transglutaminaza (TGase) (EC 2.3.2.13) katalizuje stvaranje kovalentnih veza između glutamina i rezidua lizina u mnogim proteinima u hrani npr. Kazeinu. Međusobno povezivanje proteina u hrani pomoću TGase modifikuje sposobnost hidracije, želatinizaciju, reološke i strukturne osobine prehrambenih proizvoda pa i jogurta. Optimalna pH mikrobiološke TGase je u opsegu od 6-7, međutim, enzim je stabilan na pH 5 – 9. Formiranje međusobnih veza u kazeinu zavisi od pH inkubiranja sa enzimom I na pH 6.5 je zanemarljiva zbog elektrostatičkog odbijanja micela. Dodavanje TGase kravljem mleku omogućava proizvodnju jogurta adekvatne čvrstoće i viskoznosti i niske sinereze bez dodavanja mleka u prahu. TGase se može koristiti za poboljšanje structure i reoloških osobina jogurta od kozijeg mleka koje karakteriše manje čvrst gel i niža viskoznost nego kod jogurta od kravljeg mleka. Cilj ovog rada je bio određivanje uticaja pH kozijeg mleka inkubiranog sa TGase na parametre strukture i sinerezu jogurta. Proizvedeni su jogurti of kozijeg mleka sa prilagođenom pH na 6,4, 6,3, 6,2 i 6,1 i modifikovano korišćenjem mikrobiološke transglutaminaze (TGase) . Kontrolni jogurt je proizveden od kozijeg mleka pH vrednosti 6,4 bez modifikacije sa TGase. U jogurtu je određivan senzorni kvalitet, pH, parametri strukture i sinereze. Modifikovanje kozijeg mleka sa TGase izazvalo je povećanje očigledne viskoznosti, čvrstoće i prijanjanja, adhesivnosti jogurta. pH mleka inkubiranog sa TGase u opsegu 6.4-6.1 nije imao uticaj na ovakve parametre strukture kao što su viskoznost, čvrstoća, adhesivnost, ekstruziona snaga i sinereza. pH i ekstruziona snaga skladištenog jogurta su bili signifikantno niži od vrednosti ovih parametara kod svežeg jogurta.

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