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CHANGES IN TEXTURE OF YOGHURT FROM ULTRAFILTRATED GOAT'S MILK AS INFLUENCED BY DIFFERENT MEMEBRANE TYPES

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ABSTRACT

The influence of type of ultrafiltration membrane on yoghurt texture produced with ultrafiltrated (UF) milk was investigated. Goat's milk was concentrated with three membranes of the following pore sizes: 10 kDa, 30 kDa and 100 kDa. Ultrafiltration was carried out to complete 2-fold concentration (v/v) of milk. Concentrated milk was used for production of set yoghurt with Chr. Hansen starter culture YC-180. Yoghurt samples were also produced using unaltered milk. The ultrafiltration process had a significant effect on composition of retentates, sensory evaluation of yoghurts, their viscosity and most of their texture parameters. The type of membrane used influenced significantly dry matter, protein, fat and lactose levels as well as acidity of milk retentates. In consequence sensory evaluation scores, viscosity, hardness and cohesiveness of yoghurt gel were also influenced. The size of membranes had a significant effect on ultrafiltration rate. Goat's milk for yoghurt can be best concentrated with 30 kDa pore size membrane.

Key words: texture, ultrafiltration, ultrafiltration membranes, yoghurt

INTRODUCTION

Apart from flavour, quality of yoghurt and other fermented milks is largely dependent on its texture [6,11,12]. Texture is defined as a group of physical properties of food influenced by its structural elements and perceived by human senses. Similarly to flavour, texture is a multi-parameter property of food [13,16]. To achieve desirable texture properties, yoghurt is produced from milk enriched by adding dry matter. One of the ways of increasing dry matter content in milk for yoghurt is its ultrafiltration. Ultrafiltration is a membrane separation technique used to separate and concentrate substances containing molecules of size from 500 to 300 000 Da. Membrane pore sizes determine the type of molecules that can migrate by it. During milk ultrafiltration, retentate concentration of macromolecules larger than membrane pores, e.g. casein, whey proteins, and fat, increases as concentration of milk increases. Small molecules in soluble phase of milk such as lactose and minerals are removed via membrane to permeate solution. Protein concentrates produced by ultrafiltration have better nutritional value than concentrates produced with traditional methods. Application of appropriate ultrafiltration process parameters, including choice of suitable membrane, influence composition and functional properties of milk concentrates. These can be used to produce fermented milks and also cottage cheeses, soft cheeses and dairy deserts, eliminating the need for milk powder addition [5,14,19].

Although basic composition of goat's milk is similar to cow's milk, the physicochemical properties of both milks are significantly different. These differences are caused by different structure, composition and size of casein micelles, proportion of individual protein fractions and increased concentration of salts and non-protein nitrogen components in goat's milk [17].

The aim of this study was to determine the influence of membrane type on texture of yoghurt produced from goat's milk concentrated with ultrafiltration technique.

MATERIALS AND METHODS

Raw milk for the experiment was obtained from an improved Polish White breed of goats during the middle of lactation (June - September). Raw milk was heated to 50°C and submitted to 2-fold concentration with ultrafiltration (Amicon ultrafiltration unit, model CH2A). Three types of Amicon's Hollow Fiber membranes, with pore sizes 10 kDa, 30 kDa and 100 kDa were used. The goat's milk concentrates that were obtained were pasteurised at 85°C for 15 min., cooled down to 44°C and inoculated with Chr. Hansen yoghurt starter culture YC-180 using 2% addition of active culture. Incubation was carried out at 44°C until the cut off point of 4.8 pH (ca. 4-5hrs) was reached. Then the product was cooled down to 5°C and stored at this temperature for about 14hrs before analysis. The control samples were produced from unaltered goat's milk. Dry matter, 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 [9,18]. Yoghurt analyses involved: sensory evaluation on 5-point scale performed by trained panel of 6 judges of verified sensory acuity, viscosity measurement using Hoepler viscometer [19] and texture profile analysis using computerised Stable Micro Systems texture analyser TA-XT2. Texture analysis involved penetration test with plastic cylinder of 20 mm diameter, penetration rate of 1 mm/s and penetration depth of 25 mm. The following texture parameters were determined: hardness, adhesiveness, cohesiveness, gumminess, resilience [10]. The experiment was carried out in three independent replicates. Statistical analysis of the obtained results was carried out with one-way ANOVA and significance of differences between means was assessed with Duncan test.

RESULTS AND DISCUSSION

Ultrafiltration of milk for yoghurt production is one of several valuable techniques used to increase milk dry matter content, necessary to obtain compact coagulum and appropriate viscosity of yoghurt [15]. The main parameters of milk ultrafiltration process for each of 3 types of ultrafiltration membrane used, are presented in Table 1. The average time of reduction of 2 000 cm^3 of milk to 1 000 cm^3 retentate using 10 kDa membrane, was 64 min. Application of 30 kDa membrane reduced the time of ultrafiltration almost 2 fold – to 30 min, and the 100 kDa membrane to 19 min. The rate of ultrafiltration process, measured as an average speed of permeate outflow, was 15.6 cm^3/min for 10 kDa membrane, 34.2 cm^3/min and 51.9 cm^3/min for 30 kDa and 100 kDa membranes respectively. Both the time of the process and the rate of ultrafiltration were significantly influenced by the type of the ultrafiltration membrane.

Table 1. Main parameters of goat's milk ultrafiltration process

Type of membrane	Time of UF[min]	Rate of permeate outflow[cm^3/min]
	x ± s*	x ± s
10 kDa	64 ± 2 ^{A,B}	15.6 ± 0.5 ^{A,B}
30 kDa	30 ± 3 ^{A,a}	34.2 ± 2.9 ^{A,C}
100 kDa	19 ± 1 ^{a,B}	51.9 ± 2.3 ^{B,C}

* ± standard error
A-C – statistically highly significant differences between averages marked with the same letter in a column ($p \leq 0.01$)
a – statistically significant difference between averages marked with the same letter in a column ($p \leq 0.05$)

The mean content of main constituents and physicochemical properties of milk before concentration and in milk concentrated with three different types of membranes are shown in Table 2. The statistical analysis showed highly a significant influence of reduction process on all investigated milk components and physicochemical measure of its quality. Only the milk pH of untreated and UF milk was not significantly different. In the milk concentrates that were obtained, regardless of the type of membrane used, the dry matter, protein, fat and ash content as well as density, viscosity and acidity increased. The levels of lactose and non-protein nitrogen decreased.

Table 2. Composition and physicochemical properties of goat's milk: unconcentrated and 2-fold (v/v) concentrated using ultrafiltration on 3 various membranes

Type of milk		Total solids [%]	Total protein [%]	Non protein nitrogen [%]	Fat [%]	Lactose [%]	Ash [%]	Density [g/cm^3]	Viscosity [mPa·s]	Titratable acidity [°SH]	Active acidity pH
		x ± s*	x ± s	x ± s	x ± s	x ± s	x ± s	x ± s	x ± s	x ± s	x ± s
Unconcentrated		$12.50^{A,B,C}$ ± 0.26	$3.25^{A,B,C}$ ± 0.06	$0.29^{A,B,a}$ ± 0.01	$3.27^{A,B,C}$ ± 0.13	$4.86^{A,B,C}$ ± 0.03	$0.78^{A,B,C}$ ± 0.03	$1.0295^{a,b,c}$ ± 0.0003	$1.60^{A,B,C}$ ± 0.01	$6.8^{A,B}$ ± 0.1	6.63 ± 0.05
Membranes used concentration factor 2x (v/v)	10 kDa	$16.48^{A,D}$ ± 0.17	$5.49^{A,D}$ ± 0.06	0.20^{A} ± 0.01	5.20^{A} ± 0.11	$4.39^{A,D}$ ± 0.04	1.04^{A} ± 0.03	1.0342^{a} ± 0.0013	2.36^{A} ± 0.17	$7.6^{A,a}$ ± 0.1	6.58 ± 0.05
	30 kDa	$16.41^{B,E}$ ± 0.57	534^{B} ± 0.02	0.20^{B} ± 0.02	$5.40^{B,a}$ ± 0.09	$4.40^{B,E}$ ± 0.02	0.99^{B} ± 0.03	1.0335^{b} ± 0.0011	2.30^{B} ± 0.17	$7.0^{a,C}$ ± 0.1	6.65 ± 0.03
	100 kDa	$14.49^{C,D,E}$ ± 0.05	$5.22^{C,D}$ ± 0.02	0.22^{a} ± 0.02	$5.00^{C.a}$ ± 0.06	$3.62^{C,D,E}$ ± 0.06	1.02^{C} ± 0.04	1.0347^{c} ± 0.0012	2.53^{C} ± 0.07	$7.8^{B,C}$ ± 0.1	6.61 ± 0.03

* mean ± standard error
A-E – statistically highly significant differences between averages marked with the same letter in a column ($p \leq 0.01$)
a-c – statistically significant differences between averages marked with the same letter in a column ($p \leq 0.05$)

The type of membrane used significantly influenced dry matter, protein, fat and lactose content and titratable acidity of concentrates. Application of 10 kDa and 30 kDa membranes yielded higher increase in dry matter comparing to 100 kDa pore size membrane. It could be explained by migration of molecules larger than 10 kDa and 30 kDa respectively and smaller than 100 kDa through this membrane. In the concentrate obtained by ultrafiltration with 10 kDa, the significantly higher concentration of total protein than in that obtained with 100 kDa membrane was detected. On the other hand, fat content was higher in retentate obtained with 30 kDa membrane compared to that obtained with 100 kDa membrane. The 100 kDa retentate was also characterised by significantly smaller lactose content comparing to the other two retentates and untreated milk samples. Biliaderis et al. [4] and Abrahamsen and Holmen [1,2] observed similar changes in cow's and goat's milk components. The later, similarly to Becker and Puhan [3], detected an increase in lactose level after ultrafiltration of cow's and goat's milk, whereas this study showed decrease of lactose levels in retentate in comparison to milk before ultrafiltration. Żbikowska and Żbikowski [19] have shown that during ultrafiltration process, concentration of mineral salts in retentates increases, but to a lesser degree than the concentration of proteins. This is caused by a decrease of absolute content of mineral salts during ultrafiltration. Ultrafiltration removes calcium, magnesium, and phosphorus which are present in the soluble phase of milk. Minerals, which are bound to casein in the form of colloid calcium phosphate, remain in retentate and as the concentration of milk increases so do their levels.

The mean values of sensory evaluation scores, viscosity and texture analysis of yoghurt produced from different ultrafiltration and untreated milks are presented in Table 3. Overall, the 2-fold milk concentration with ultrafiltration significantly influenced the sensory evaluation scores for yoghurt, their viscosity and most of the texture parameters. The sensory profiles of UF milk yoghurt texture were similar to those of homogenised fromage frais, which suggests that 2-fold concentration of goat's milk for yoghurt production can be to high.

Table 3. Sensory evaluation and instrumental texture parameters of goat's milk yoghurt from unconcentrated and 2-fold (v/v) UF concentrated milk obtained with 3 different UF membranes

Type of milk		Sensory evaluation [points]	Viscosity [mPa·s]	Hardness TPA [G]	Adhesiveness TPA [Gs]	Gumminess TPA [G]	Cohesiveness TPA	Resilience TPA
		x ± s*	x ± s	x ± s	x ± s	x ± s	x ± s	x ± s
Unconcentrated		$3.17^{a,A,B}$ ± 0.05	$77.68^{A,B,C}$ ± 6.68	$20.51^{A,b,c}$ ± 3.43	$29.86^{a,b,c}$ ± 5.54	$15.81^{A,b,c}$ ± 2.51	0.70^{a} ± 0.07	0.19 ± 0.07
Membranes used concentration factor 2x(v/v)	10 kDa	$3.60^{a,C}$ ± 0.11	$538.31^{A,D,E}$ ± 20.55	$73.45^{A,d,e}$ ± 10.50	73.42^{a} ± 16.68	37.34^{A} ± 3.58	$0.50^{a,b}$ ± 0.04	0.09 ± 0.02
	30 kDa	$4.25^{A,C,D}$ ± 0.14	$420.68^{B,D,F}$ ± 20.44	$45.05^{b,d}$ ± 2.81	64.16^{b} ± 8.18	33.40^{b} ± 5.03	0.73^{b} ± 0.07	0.17 ± 0.06
	100 kDa	$3.70^{B,D}$ ± 0.03	$307.03^{C,E,F}$ ± 16.51	$50.25^{C,e}$ ± 5.63	81.42^{c} ± 8.15	28.94^{c} ± 2.92	0.55 ± 0.03	0.06 ± 0.01

* mean ± standard error
A-F – statistically highly significant differences between averages marked with the same letter in a column ($p \leq 0.01$)
a-c – stat

The type of ultrafiltration membrane significantly influenced results of sensory evaluation of yoghurts, their viscosity, hardness and cohesiveness of coagulum. The highest preference score was obtained for yoghurt produced from milk concentrated with 30 kDa. Significantly lower scores were received by other samples, both produced from UF and from untreated milk. This could be caused on the one hand by the fact that milk concentrated with 10 kDa membrane had high protein content and yoghurt produced from it had very compact gel and on the other hand lower dry matter content in 100 kDa caused by migration of some high molecular weight substances to the permeate.

Yoghurt produced from UF milk concentrated with 10 kDa membrane, was characterised by higher viscosity and hardness in comparison to other samples (Table 3). Amongst yoghurts produced from UF milk, the lowest viscosity was observed in samples obtained from 100 kDa UF milk, however its hardness was not different from hardness of yoghurt produced from 30 kDa UF milk concentrate. A significant difference was also found in yoghurt cohesiveness, which was different for 10 kDa and 30 kDa yoghurt samples. Yoghurts produced from concentrated milk with different membranes did not vary in gumminess. Also, resilience of yoghurts produced from untreated milk and from UF concentrated milk did not vary significantly between the samples.

According to Tamime and Muir [15], texture properties and structure of yoghurt gel is largely determined by dry matter content and especially protein content. Many authors reported significant improvement of yoghurt coagulum produced from UF milk [1,2,3,4,6,11,12]. However, in many of the papers there is no information on the type of membranes used and in the others the authors use only one type of filtration membrane. Abrahamsen and Holmen [1,2] reported that yoghurts produced from UF goat's milk with both continuous and batch methods received better sensory evaluation scores than yoghurt from milk concentrated with other methods. Cow's UF milk yoghurts, produced by the same authors were characterised by higher viscosity and hardness in comparison to yoghurts and yoghurts produced from milk concentrated with other methods. In their experiments, Biliaderis et al. [4] and Savello and Dargan [11,12] used ultrafiltration membranes of 10 kDa pore sizes, and Becker and Puhan [3] membranes of 20 kDa pore sizes. They reported, similarly to Lankes et al. [6], higher gel hardness and higher viscosity, after stirring in yoghurts produced from UF milk, than in yoghurts produced from milk with addition of milk powder. Savello and Dargan [11,12] underlined also that concentration of milk for youghurt with UF significantly diminishes susceptibility of yoghurt to syneresis. Mahdi et al. [7] and Ozer et al. [8] used UF with membranes of 50 kDa [7] and 25 kDa [8] pore sizes respectively, in production of "Labneh", i.e. concentrated yoghurt. In this case however, the yoghurt was subjected to ultrafiltration, not the milk itself. Both authors reported beneficial influence of UF on quality properties of final product.

CONCLUSIONS

1. Two-fold UF concentration of goat's milk for yoghurt changes milk composition and its physicochemical properties.
2. The type of UF membrane used influences the rate of ultrafiltration process, composition of retentates and texture of yoghurt produced from these retentates.
3. The membrane of 30 kDa pore size seems to be the most suitable for goat's milk used for yoghurt production. A membrane of 10 kDa pore sizes increases the time of ultrafiltration and a 100 kDa membrane loses significant amount of milk dry matter.

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