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PHYSICOCHEMICAL AND SENSORY CHANGES OF GOAT MILK PERMEATE FOLLOWING ITS FERMENTATION AND STORAGE

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Key words: permeate, goat milk, fermentation, storage time

The aim of the research project was to assess the quality parameters of goat milk permeate subjected to the fermentation process with the assistance of thermophilic cultures of traditional composition and enriched with probiotic strains. The fermented permeates were stored in refrigerated conditions for 6 weeks and during this period, changes in their active and titratable acidity were estimated, their colour parameters were measured instrumentally and their sensory profiles were examined. The type of the bacterial cultures applied did not affect the pH value of the permeates over the entire storage period. After the termination of the fermentation process, permeates treated with traditional cultures were characterised by the highest titratable acidity and this relationship did not change until the end of the storage period. Regardless of the type of the bacterial culture applied, the fermentation process resulted in a significant decrease of sample L* lightness and increase of their C* colour. After 6 weeks, values of the L* and C* coefficients of the fermented permeates decreased significantly, whereas the non-fermented permeats failed to exhibit any changes in the colour parameters in the course of their storage. The permeate fermented with the assistance of the traditional bacterial culture received the highest number of points for its overall desirability after 6 weeks of storage. During this period, the 'metallic' taste of the permeate disappeared and, simultaneously, we could observe an increase in the intensity of a refreshing taste and fresh smell.

INTRODUCTION

Processes of membrane separation are widely applied in milk processing technologies and recently they have been employed increasingly frequently to thicken goat milk [Mahdi *et al.*, 1990; Domagała & Kupiec, 2003]. The developed by-product of goat milk permeate provides a valuable supplement of pro-healthy food articles because of its nutritive value and assimilability. However, its wider application is limited by technological and economic aspects. Among factors restricting the processing value of the permeate is its low content of dry substance at its high proportion of lactose [Vyask & Tong, 2003]. One of the methods reducing the amount of lactose in the permeate is its fermentation. The permeate enriched by an addition of cultures of lactic fermentation bacteria, including those with probiotic properties, can be employed in the production technology of fermented beverages.

The objective of the research project was to assess changes in the physicochemical and sensory parameters of the permeate obtained as a result of a controlled process of fermentation of the examined permeate directly after its production and in the course of its further refrigerated storage.

MATERIALS AND METHODS

Goat milk permeate subjected to the process of fermentation and storage was utilised in the performed investigations. The goat milk permeate was obtained under industrial conditions. The reference material was selected goat milk of the highest hygienic and cytological quality [Danków *et al.*, 2003]. The milk was standardized, pasteurized and thereafter directed to the ultrafiltration module, where it was concentrated to 23% of the dry content. For separation, there were used drilled polypropylene diaphragms type PM-50 Romicon Corp. (Werbun, USA) with the total area of 2.4 m^2. The final pressure of diaphragms operation amounted to 1.8 MPa, temperature to 40°C, and the module's capacity to 870 dm^3/min. The permeate obtained was cultured with a thermophilous bacteria culture with the traditional strains *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus* type YC-180 and with probiotic cultures of *Lactobacillus acidophilus*, *Bifidobacteriun bifidum* and *Streptococcus thermophilus* type ABT 1 company Chr. Hansen A/S (Hørsholm, Denmark). The cultures were added in the form of lyophilised Direct Vat Set in the amount of 50 active units, which corresponds to 2% active working starter. The cultured permeate was incubated at a

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temperature of 43°C for 24 h until pH under 4 has been achieved. The permeate was stored for 56 days at a temperature of 4°C in tight packages of 0.25 dm^3 each. The experiment was based on 6 production lots. Four samples of the permeate (n=24) were taken from each lot for testing.

Determination of the proximate chemical composition of the permeate was carried out using standard methods [AOAC, 1990]. When determining total nitrogen content, the Kjetec System 1026 Distiling Unit Tecator Co. (Örebro, Sweden) device was used. The content of macroelements: Ca, Na and K, were determined using an atomic absorption spectrophotometer, type SP-2900 Pye Unicam Co. (Cambridge, UK), with the background correction in the flame system using adequate cathodic lamps [IDF/ISO, 1992]. The content of phosphorus was determined using the calorimetric method. Active acidity was measured using a pH-meter, type CP-315 Elmetron Co. (Zabrze, Poland), fitted with an integrated electrode, type ESAgP-301W Eurosensor Co. (Gliwice, Poland) consisting of a glass half-element and saturated chlorosilver half-element. The results of titration acidity were expressed in Soxhlet-Henkl (°SH) degrees [AOAC, 1990]. The colour of milk and permeate was measured on a reflection basis using a spectrophometer type U-3000 Hitachi Co. (Tokyo, Japan) with the layer thickness of 1 cm and C light source. To assess the colour in reflected light, the CIELAB system was used, where L* stands for brightness, whereas a* and b* are chromaticity coordinates. The temperature of the measured sample ranged from 22 to 24°C. Colour saturation was calculated on the basis of the formula: $C^*=(a^2 + b^2)^{0.5}$, [CIE, 1974]. The sensory quality of the permeate was tested using the descriptive quantitative analysis. A team of seven qualified and trained assessors tested the sensory profile of the permeate. While making preliminary evaluations, own source of terms describing the properties of the product tested was used. The intensity of each factor was marked on the 100 mm scale according to limit determinations: 0 – insensible, 10 – very intense [Mc Ewan, 1992].

The results obtained were subjected to a statistical analysis using Excel sheets and Statistica 6.0 software. Standard error (SE), linear regression using least squares method were calculated and the hypothesis was reviewed at a specific significance level of p=0.05 [Brandt, 1997].

RESULTS AND DISCUSSION

No significant impact of the fermentation process of goat milk permeate on its content of dry matter, fat and protein was observed on the basis of the investigations performed (Table 1). In the case of the permeate fermented with the use of traditional bacterial cultures (permeate l), 16.3% less lactose was determined than in the non-fermented permeate, while in the case of the permeate fermented with the assistance of probiotic cultures (permeate ll), the level of lactose was by lower 14%. Moreover, after the fermentation process, 6.5% less calcium and 5.4% less phosphorus were determined in the examined permeates in comparison with their levels before fermentation. The permeate samples fermented using the traditional bacterial cultures were characterised by over 6 times higher titratable acidity than before the fermentation process. In the same period of time, the titratable acidity of permeate ll increased over 5 times. The fermentation process resulted in significant changes of colour parameters evaluated instrumentally. In comparison with the non-fermented permeates, the lightness coefficient L* of the fermented samples decreased two-fold, while the degree of the colour saturation coefficient C* increased.

TABLE 1. The chemical composition and acidity of goat milk permeate before and after fermentation.

Components and physical and chemical properties	Sample type		
	non-fermented permeate	permeate after fermentation	
		traditional	probiotic
Total solids (%)	5.78^{a}	5.71^{a}	5.76^{a}
Fat (%)	0.09^{a}	0.08^{a}	0.08^{a}
Protein (%)	0.19^{a}	0.20^{a}	0.17^{a}
Lactose (%)	4.91^{c}	4.11^{a}	4.22^{b}
Calcium (mg/dm^3)	231^{b}	218^{a}	214^{a}
Sodium (mg/dm^3)	435^{a}	441^{a}	438^{a}
Potassium (mg/dm^3)	266^{a}	271^{a}	269^{a}
Total phosphorus (mg/dm^3)	391^{b}	372^{a}	368^{a}
Titratable acidity (oSH)	3.5^{a}	22.1^{c}	18.2^{b}
Lightness L*– value	24.03^{b}	12.70^{a}	12.35^{a}
Colour saturation C*	7.47^{a}	9.40^{b}	10.25^{b}

a–c – various small letters in the lines stand for statistically significant differences at p=0.05

Further significant changes of the parameters examined occurred during the 6-week period of sample refrigerated storage. Over the storage time, pH values of the fermented permeates were observed to decline, on average, by 0.42 units (Table 2). A difference in the pH values between permeate l and ll occurred only once after 28 days of storage. In the case of the non-fermented permeate, no significant changes in the pH values of the samples examined were observed during the entire storage period. In addition, also the value of the titratable acidity of this permeate remained unchanged for the period of 56 days (Table 3). The difference in the titratable acidity of the fermented permeates determined directly after the termination of the fermentation process did not change throughout the storage period. The values of the titratable acidity of permeate ll were, on average, by 22.1% lower than those of permeate l. The values of titratable acidity of permeate l after 4 and 6 weeks of storage were identical and higher (on average) by 38.5% than the values determined directly after the termination of the fermentation process. On the other hand, the increase in the titratable acidity of permeate ll after 6 weeks amounted to 32.3%.

TABLE 2. Changes in active acidity – pH of goat milk permeate during cold room storage.

Permeate	Storage time (weeks)			
	0	2	4	6
Non-fermented	6.62^{aB}	6.63^{aB}	6.62^{aC}	6.65^{aB}
Traditional fermentation	3.96^{cA}	3.91^{cA}	3.70^{bA}	3.52^{aA}
Probiotic fermentation	3.90^{bA}	3.86^{bA}	3.84^{bB}	3.50^{aA}

a–c; A–B – various small letters in rows and various capital letters in columns indicate statistically significant differences at p=0.05

TABLE 3. Changes in titratable acidity (°SH) of goat milk permeate during cold room storage.

Permeate	Storage time (weeks)			
	0	2	4	6
Non-fermented	3.5^{aA}	3.6^{aA}	3.6^{aA}	3.9^{aA}
Traditional fermentation	22.1^{aC}	24.7^{bC}	29.7^{cC}	31.4^{cC}
Probiotic fermentation	18.2^{aB}	20.1^{aB}	21.5^{bB}	24.1^{cB}

a–c; A–B – various small letters in rows and various capital letters in columns indicate statistically significant differences at p=0.05

Values of the lightness coefficients L* of the fermented permeates, in contrast to the values of the same colour parameter of the non-fermented permeate, underwent significant changes in the course of the storage period (Figure 1). After the storage period, the lightness of the experimental permeates, irrespective of the type of the bacterial culture applied during the fermentation process, was by over 1.5 times lower than that determined directly after the termination of the fermentation process. The values of the colour saturation coefficient C* of the fermented permeates decreased over 2 times along with storage time (Figure 2). However, the values of the colour saturation coefficient C* of permeates l and ll differed significantly after 4 weeks of storage. In the other periods of storage, the fermented

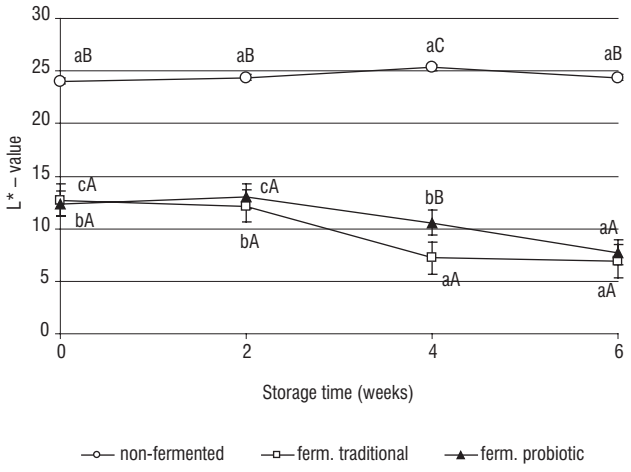

FIGURE 1. Changes in the values of the lightness coefficients L* of goat milk permeate during cold room storage.

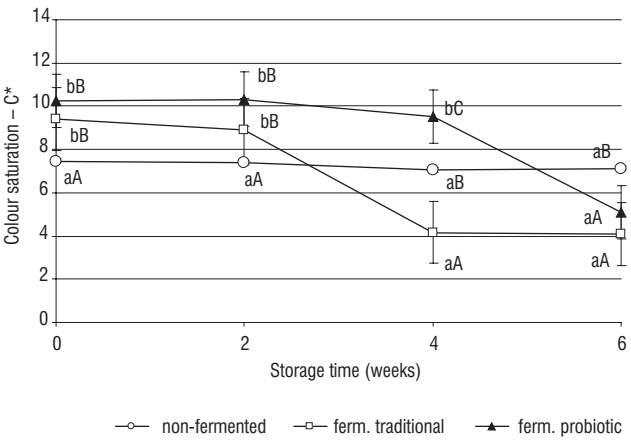

FIGURE 2. Changes in the color saturation C* of fermented goat milk permeate during storage cold room.

permeates were characterised by the same degree of colour saturation coefficient C*.

On the basis of the results obtained, it was concluded that the fermentation process of the permeates examined contributed significantly to the improvement of their sensory properties. Of the samples examined, the permeate fermented with the assistance of cultures with traditional bacterial composition turned out to have the most desirable sensory properties (Table 4). The overall desirability of this permeate increased along with storage time. In addition, it was demonstrated that the continued sensory estimated improvement of quality occurred in the course of storage (Figure 3). This effect was achieved as a result of the disappearance of the 'metallic' taste of permeate accompanied by the increase in the intensity of the refreshing and acid taste and fresh smell. After 6 weeks of storage, the permeate evaluated was characterised by increased turbidity and lower intensity of yellow colour in comparison with that assessed on the termination of the fermentation process.

The chemical composition of permeate is strictly dependant on the diaphragm operating conditions and the size of its pores. During ultrafiltration, the concentration of

TABLE 4. Sensory changes in overall acceptability of goat milk permeate during cold room storage.

Permeate	Storage time (weeks)				Σ
	0	2	4	6	
Non-fermented	4.1^{bA}	4.0^{bA}	4.2bA	3.5^{aA}	15.8
Traditional fermentation	6.5^{aB}	7.1^{bB}	8.9^{cC}	9.6^{dC}	32.1
Probiotic fermentation	6.7^{aB}	9.5^{cC}	7.3^{bB}	7.8^{bB}	31.3
Σ	17.3	20.6	20.4	20.9	

a–c; A–B – various small letters in rows and various capital letters in columns indicate statistically significant differences at p=0.05

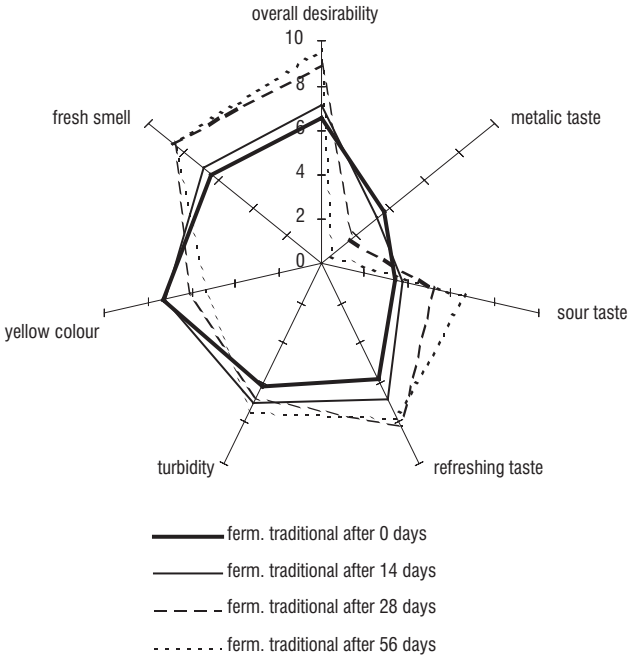

FIGURE 3. Sensory quality profile of fermented traditional permeate during cold room storage.

macromolecules larger than the pores of the ultrafiltration membrane, such as casein or whey proteins, increases proportionally to the increase in condensation level. Small molecules, such as lactose and mineral elements, are removed to the filtrate. However, some part of Ca, Mg and P combined with casein in the form of a colloidal calcium phosphate does not penetrate to the permeate, but remains in the concentrate. During infiltration conducted under neutral pH of milk at a temperature of 50°C, the condensation higher than 2-fold does not cause any significant changes in the absolute Ca content, while condensation higher than 3-fold does not cause any significant changes also in the absolute content of Mg and P in the concentrate [Barbano *et al.*, 1988; Premaratne Cousin, 1991; Srilaorkul *et al.*, 1991; Vyas & Tong, 2003]. The milk condensation level during ultrafiltration affects its buffer volume. It has been demonstrated that with the 5-fold milk condensation, the buffer's volume is determined in 54% by the amount of casein, in 10% by whey proteins and in 36% by mineral salts [Żbikowska & Żbikowski, 1996]. The change in the functional properties of milk proteins, Ca ions activity in the soluble phase and buffer properties of the solution determine the time of acid coagulation as well as the growth and activity of cultures introduced as inoculum during the fermentation processes. Therefore, the incubation period may be longer after culturing, before it attains active acidity at the level close to *e.g.* the acidity of milk fermented beverages, and during further storage the acidity increase may be less intensive. In yogurts stored under cold room conditions for 3 weeks, the pH values decrease on average by 0.3 units, while the titration acidity increases by 19% [Cais-Sokolińska *et al.*, 2002; Al-Kadamany *et al.*, 2003]. The course of the fermentation process, and particularly the activity of bacterial cultures, determine the level of lactose defermentation. In the opinion of Valera-Moreiras *et al.* [1992], after 4-h incubation of cultured milk at a temperature of 43°C, the quantity of dehydralized lactose reaches the level of 20–30%. On the other hand, Toba *et al.* [1983] detected further (by over 8%) drop of the quantity of lactose in fermented beverages stored for 10 days at a temperature of 10°C. Fermentation-induced changes in the colour and activity as well as proportions of smell-producing compounds as metabolites, determine the sensory properties of the product. Such properties may become more intense during further storage, due to various shelf lives of microflora occurring in the product [Biliaderis *et al*., 1992; Urbach, 1995].

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ZMIANY WYBRANYCH CECH FIZYKO-CHEMICZNYCH I SENSORYCZNYCH PERMEATU MLEKA KOZIEGO W WYNIKU JEGO UKWASZANIA I PRZECHOWYWANIA

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Celem pracy była ocena wyróżników jakości permeatu mleka koziego poddanego procesowi ukwaszenia przy udziale termofilnych kultur o tradycyjnym składzie i wzbogaconych w szczepy probiotyczne. Ukwaszone permeaty przechowywano przez 6 tygodni w warunkach chłodniczych. W tym okresie oceniono zmiany kwasowości czynnej i miareczkowej permeatów, zmierzono instrumentalnie parametry barwy i zbadano ich profil sensoryczny. Rodzaj zastosowanych kultur bakteryjnych nie miał wpływu na wartości pH permeatów w trakcie całego okresu przechowywania. Po zakończonej fermentacji największą kwasowością miareczkową charakteryzowały się permeaty ukwaszone kulturą tradycyjną. Zależność ta utrzymywała się do końca okresu ich przechowywania. Niezależnie od rodzaju zastosowanej kultury proces fermentacji spowodował istotne obniżenie jasności L* próbek oraz wzrost nasycenia ich barwy C*. Po 6 tygodniach wartości współczynnika L* i C* permeatów ukwaszonych istotnie obniżały się. Podczas przechowywania nie wykazano zmian parametrów barwy permeatu nieukwaszonego. Największą liczbę punktów za ogólną pożądalność uzyskał permeat ukwaszony kulturą tradycyjną po 6 tygodniach przechowywania. W tym okresie dochodzi do zanikania smaku metalicznego permeatu i jednocześnie wzrostu natężenia smaku orzeźwiającego i zapachu świeżego.