Dynamics of salt diffusion and yield of three types of goat's milk cheese

Sonja Srbinovska, Tihomir Čizbanovski, Vladimir Džabirski,
Sreten Andonov, Bone Palasevski

Original scientific paper - Izvorni znanstveni rad UDC:637.3:636.39

Summary

This paper studies the dynamics of salt diffusion during the ageing of three types of cheese from goat's milk: Mozzarella, White Brined and Pecorino. The salt concentration was consistently analyzed at the 72nd hour and on the 5th, 10th, 20th, 40th, 50th, 60th and 90th day of the cheese ageing period. The distribution of salt in the three layers of cheese – inner (I), middle (II) and outer (III) was also studied. The salt equilibration in the cheese mass of Mozzarella occurred on the 15th day, in the White Brined - on the 60th day, whereas in Pecorino the content of salt even on the 90th day was by 1% lower in the inner layer than in the two other layers of this cheese. The utilization rate of dry matter was 52.17% in Mozzarella, 50.64% in the White Brined and 48.32% in Pecorino. Accordingly, the yield of Mozzarella is 18.13±0.43%, of White Brined - 12.50±0.37% and the yield of Pecorino is 9.18±0.13%.

Key words: goat cheese, salt diffusion, cheese yield

Introduction

In the last few years in our country, there is an increasing popularity of the goat's milk and its products. The increased interest on the marketplace and the scientific community is consistent with the general trend and efforts for production of healthy food, since the goat's milk has been well known for its beneficial effects on human health. Taking into consideration the fact that the goat's milk cheese is more sensitive to salt, the study of the dynamics of salt diffusion in the cheese mass is of great significance for the processes that occur in the cheese as well for the cheese quality.

The results obtained by other researchers (Baltadzieva, 1985; Tomas, 1981; Sutherland, 1974; Kindstend et al., 1996; Morris et al., 1985) show

that there is an uneven distribution of salt and moisture during different processes in the cheese, which reflects on the rate of ageing and different taste of the cheese wheel. The salt penetrating in the cheese mass cause changes in the protein structure and their hydrophilic capacity. The cheeses of the Cheddar type that contain less salt have better adhesives and cohesiveness, acidity, bitterness and unpleasant flavour, accompanied by decreased hardness and salinity (Schroeder et al., 1988).

The yield is one of the most important economic factors in the production of cheese. The extent of distribution of the proteins and fats in the whey, as well as the percentage of whey dispersion, depend on numerous factors, the most important being: the thermal processing of the milk, the milk and whey acidity, the extent of cutting and chopping of the curd, the second heating, etc. (Scott, 1986). The share of coagulation proteins in the goat's milk is 70.9% in relation to the total nitrogen matter, and the remaining part of 20.4% is milk serum proteins while the inorganic nitrogen matter participate with 8.7%. (Lahaye, 1992).

The experiments conducted in Greece with the Feta cheese from pure sheep's and goat's milk or from mixture of both types of milk, demonstrate that the yield is much higher in the case of sheep's milk cheese (27.93 as opposed to 15.07 in the goat's milk types of cheese), the content of fat and proteins is also higher, but the texture of the pure goat's milk cheese is harder (Mallatou et al., 1994).

Materials and methods

The raw materials subject to the research were cumulative goat's milk, whereas the cheese was processed without standardization in the "Milk Way" Dairy Plant in the Republic of Bulgaria.

The composition of milk, cheese and whey were analyzed by using standard methods: total solids by drying to constant weight; protein - Kjeldahl method; lactose - Bertrand method; fat - Gerber method for milk and whey, and Gerber-Siegfeld method for cheese; ash with glowing on 550 $^{\circ}$C, pH with pH-meter Hanna Instruments, and titrametric acidity -Thorner method.

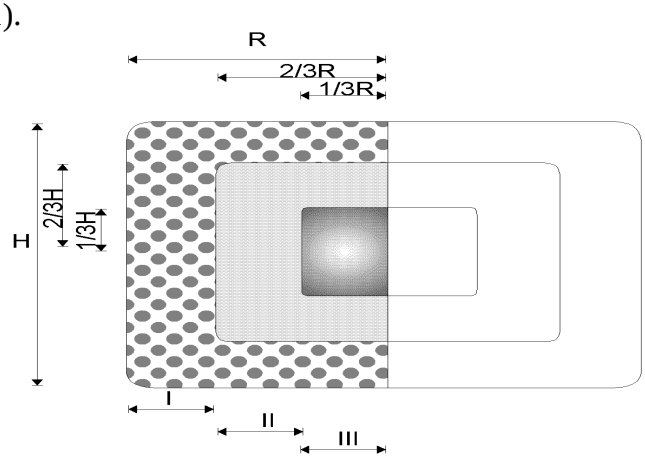
The cheese samples for Pecorino were taken with stainless steel knife with pointed blade; while the White cheese and Mozzarella were sampled by taking entire cheese.

Table 1: Processing steps of Mozzarella, White cheese and Pecorino from goat's milk
Tablica 1: Postupci proizvodnje Mocarela, Bijelog sira i Pekorino sira od kozjeg mlijeka

Processing steps Postupci proizvodnje	Mozzarella Mocarela	White brined cheese Bijeli sir u salamuri	Pecorino Pekorino
- Pasteurization	65-68 °C; 20 min.	72-74 °C; 20 min.	65-68 °C; 30 min.
- Milk ripening	/	/	Increase acidity with 1% *St. lactis*
- Starter culture	*St. thermophilus*	*St. lactis, Lb. casei*	*St thermophilus, Lb. helveticus, Lb. delbrueckii ssp. bulgaricus*
- Coagulation	t = 30-32 °C τ = 30 min.	t = 32-34 °C τ = 60 min.	t = 34-35 °C τ = 5 min.
- $CaCl_2$	20 ml/100 l 50% $CaCl_2$	0.015%	0.010 %
- Cutting the curd	hazelnut	2 x 2 cm; three times	Wheat seed
- Cooking the curd	39 - 40 °C and cheddaring the curd	/	45-46 °C 45-50 min.
- Hot water processing	78-80 °C	/	/
- Pressing	/	5 kg/kg curs mass	25 kg
- Salting	10-12% r-r NaCl 3 – 4 h t=10-15°C,pH=5.25	20-22% r-r NaCl 10–12 h, t=14-15 °C, pH=5,0	21%± 1 r-r NaCl 48 h, t = 12±1°C, pH = 5.10
- Cheese ripening	/	10-12 °C; 60 days	12-14 °C; 80-85 days
- Dry salt, manually	/	Light salting on the surface when putting cheese into cans	Until 30 days
- Storage	2 – 3 °C; 30 days	t = 4 - 6 °C	t = 2 – 4 °C

During the cheese-ripening phase, the distribution of salt in the three cheese layers was observed – inner (I), middle (II) and outer (III) layers. For

that purpose the cheese portions were divided on equal parts and than the layers were carefully removed. From the layers, an average sample was taken and the salt concentration was analyzed according to the Mooor method (Inihov 1971).



Picture 1: Layers of cheese for sampling
Slika 1: Slojevi sira uzetih za uzorkovanje

In order to determine the losses in the whey and the cheese yield, a chemical analysis of the cheeses and whey obtained during the production process was conducted, including the pressing of each type of cheese (Stamenova,1985). The cheese yield was calculated by the following formula (Baltadzieva, 1993):

$$Y = \left[\frac{DMM\% - DMW\%)}{DMC\%} x100 \right] - F$$

DMM% - percentage of dry matter in the milk;

DMW% - percentage of dry matter in the whey;

DMC_1% - percentage of dry matter in the cheese;

F - loss factor during processing. (the coefficients taken for this research were: Mozzarella 0.2; White Brined cheese 0.3 and Pecorino 0.6

Results and discussion

The average chemical composition of goat's milk used in cheese production is described in Table 2.

Table 2: Composition of goat's milk used in cheese production
Tablica 2: Sastav kozjeg mlijeka korištenog u proizvodnji sira

Parameters Parametri	$\bar{x}$ (n=30)
- Fat /%	3.84 ± 0.360
- Protein /%	3.21 ± 0.034
- Casein /%	2.49 ± 0.031
- Lactose /%	4.49 ± 0.077
- Ash /%	0.75 ± 0.027
- Total solids /%	12.64 ± 1.240
- Acidity - °T - pH	15.75 ± 1.410 6.65 ± 0.056
- Density	1.03143 ± 0.717

The comparable results for the composition of Mozzarella, White brined cheese and Pecorino from goat's milk are presented in table 3.

The research showed that the dynamics of the salt diffusion in the soft, brined and hard types of cheese from goat's milk examined in the three layers of the cheese (Tables 4, 5, and 6), depends on the moisture content in the cheese. The higher the moisture content of the cheese, the quicker the salt diffusion in the cheese (Eck, 1986).

The salt content in the third layer of the soft cheese becomes equal with half of the salt content in the first layer as early as at the 72nd hour, and the equilibrium of the salt in all three layers of the soft cheese occurs on the 15th day. In the White Brined and the hard types of cheese there is only 11% and 11.6% salt, respectively, in relation to the first layer. The differences in the salt concentration between the first and the second layer of the soft and brined types of cheese is 1%, whereas the same difference in the hard cheese is 4%.

Table 3: Composition of the three types of cheese made from goat's milk
Tablica 3: Sastav sireva dobivenih od kozjeg mlijeka

Parameters Parametri	Mozzarella Mocarela (30 days/ 30 dana)	White cheese Bijeli sir (60 days/ 60 dana)	Pecorino Pekorino (90 days/ 90 dana)
Water /%	65.3 ± 0.54	52.8 ± 0.39	39.80 ± 0.57
Total solids /%	34.7 ± 0.54	47.2 ± 0.39	60.20 ± 0.57
Acidity /^{o}T	168 ± 1.65	280 ± 1.20	196 ± 1.03
Lactic acid /%	1.51 ± 0.02	2.52 ± 0.20	1.76 ± 0.09
pH	5.06 ± 0.01	4.56 ± 0.02	5.36 ± 0.02
Fat /%	12.50 ± 0.61	22.74 ± 0.38	26.84 ± 0.21
Proteins /%	14.04 ± 0.21	17.10 ± 0.84	26.48 ± 0.44
Salt /%	2.40 ± 0.09	3.60 ± 0.42	4.60 ± 0.20

Table 4: Salt diffusion in Mozzarella cheese from goat's milk
Tablica 4: Difuzija soli u Mocarela siru dobivenom od kozjeg mlijeka

Layers Slojevi	Distribution of salt (%) in research intervals Raspodjela soli (%) u razdoblju ispitivanja		
	72^{nd} hour	5^{th} day	15^{th} day
I layer	3.0 ± 0.1	2.9 ± 0.4	2.5 ± 0.2
II layer	2.0 ± 0.3	2.5 ± 0.2	2.5 ± 0.4
III layer	1.5 ± 0.2	2.0 ± 0.6	2.5 ± 0.2

In the White Brined types of cheese the content of salt barely becomes equal, on the 60^{th} day with a difference of 0.3% in the third layer composed to the first and the second layer. In the hard types of cheese, regardless of the fact that the difference in the salt content in the layers is notably decreased, the salt content is still by 1% higher in the first and the second layer than in the third layer (Tab. 3).

Table 5: Salt diffusion in White Brined cheese from goat's milk
Tablica 5: Difuzija soli u Bijelom siru u salamuri dobivenom od kozjeg mlijeka

Layers Slojevi	Distribution of salt (%) in research intervals Raspodjela soli (%) u razdoblju ispitivanja						
	72nd hr	5th day	15th day	30th day	40th day	50th day	60th day
I layer	5.5 ± 0.3	5.3 ± 0.3	5.0 ± 0.2	4.8 ± 0.4	4.3 ± 0.2	4.0 ± 0.4	3.7 ± 0.2
II layer	4.5 ± 0.1	4.7 ± 0.4	4.8 ± 0.2	4.5 ± 0.3	4.0 ± 0.3	3.6 ± 0.3	3.7 ± 0.3
III layer	0.5 ± 0.2	0.5 ± 0.1	1.0 ± 0.1	1.5 ± 0.3	2.5 ± 0.2	3.2 ± 0.2	3.4 ± 0.5

Table 6: Salt diffusion in Pecorino hard cheese from goat's milk
Tablica 6: Difuzija soli u Pekorino tvrdom siru od kozjeg mlijeka

Layers Slojevi	Distribution of salt (%) in research intervals Raspodjela soli (%) u razdoblju ispitivanja						
	72nd hr	5th day	15th day	30th day	40th day	50th day	90th day
I layer	5.8 ± 0.2	6.5 ± 0.3	7.2 ± 0.2	6.8 ± 0.4	6.0 ± 0.3	5.5 ± 0.4	5.0 ± 0.4
II layer	1.8 ± 0.5	2.0 ± 0.4	2.5 ± 0.3	2.8 ± 0.3	3.3 ± 0.4	3.5 ± 0.3	4.8 ± 0.4
III layer	0.5 ± 0.6	0.7 ± 0.5	1.2 ± 0.1	1.4 ± 0.2	1.7 ± 0.3	2.0 ± 0.4	4.0 ± 0.3

Similar results on the salt distribution in Mozzarella were obtained by Kindstend et al. (1996). They link these results to the different moisture concentration in the cheese layers, i.e. after heating the cheese mass immediately undergoes cooling in the brine, so there is a quick movement of the moisture from the warm center towards the cool outer layer.

Comparing the salt diffusion in the Cheddar type of cheese which falls in the category of hard cheeses, Morris et al. (1985) found that the salt distribution in the layers was not achieved even after 24 weeks of ageing, which coincides with our results of the study on the salt distribution in the layers of the Pecorino hard cheese.

The particular quality of specific types of cheese is greatly dependent on the degree of the curd processing. At the same time, there is a smaller or higher loss of the dry matter content in the whey. The comparative

characteristics of the milk, the semi-hard and the hard types of cheese from goat's milk are based on the essential quality features of the produced types of cheese: Mozzarella, White Brined and Pecorino. According to the obtained results given in Table 7, it may be concluded that the losses of milk fat content in the soft cheese are 0.38% ± 0.05, whereas in the brined cheese are increased by 10.52%, and in the hard type of cheese (Pecorino) the loss increases by 42.11% compared to the soft types of cheese.

The loss of total proteins in the whey of the soft cheese is 0.58%±0.03, while in the brined cheese it is increased by 15.52%, and in the hard cheese – by 42.38%.

The increase of the dry matter losses in the whey progresses in the same way, i.e. the loss of dry matter in the whey during the production of soft cheese (Mozzarella) ranges 5.83±0.35%, in the White Brined cheese it is increased by 3.64% and in the hard cheese (Pecorino) – by 8.06%. The volume of obtained whey of Mozzarella compared to its milk quantity varies from 58.00±0.22%, whereas in the White Brined it is increased by 24.14%, and in Pecorino – by 46.89% in relation to the soft type of cheese.

In the production of hard cheese, among other factors, the degree of curd cutting and chopping is much more intensive in comparison to the semi-hard and soft types of cheese. Therefore, the dry matter losses as well as the percentage of dispersed whey are the highest. In addition, during the second heating, which is a typical process in the production of hard and some semi-hard types of cheese, the cheese cubes undergo mixing, so that the extended mechanical influence and the temperature effect result into a distribution of larger dry matter content in the whey.

A specific result of our research is that in the soft Mozzarella type of cheese, the loss is somewhat higher than in other types of soft cheese. It emerges from the cooking of the curd, which is a typical procedure in the technology of this particular type of cheese.

In order to determine the cheese yields, an analysis was conducted on the extent of dry matter utilization in the production of the three types of cheese from goat's milk. The obtained results are given in Table 8.

Table 7: Loss of dry matter in the whey
Tablica 7: Gubitak suhe tvari u sirutki

Indicators Pokazatelji	Mozzarella Mocarela	White Brined Bijeli sir u salamuri	Pecorino Pekorino
Fat /%	0.38 ± 0.05	0.42 ± 0.03	0.54 ± 0.04
Total protein /%	0.58 ± 0.03	0.67 ± 0.05	0.82 ± 0.06
Dry matter /%	5.83 ± 0.35	6.10 ± 0.41	6.30 ± 0.52
Whey / Milk /%	58.0 ± 0.22	72.0 ± 0.50	85.2 ± 0.67
% DM* / Milk %	72.26 ± 0.39	63.97 ± 0.48	55.97 ± 0.65

DM* - Dry matter

Table 8: Distribution of dry matter, proteins and fats in the production of some types of goat's milk cheeses
Tablica 8: Raspodjela suhe tvari, proteina i masti u proizvodnji nekih tipova sireva od kozjeg mlijeka

Type of cheese Tipovi sireva	Used DM* % Korištena suha tvar /%	Used fats /% Korištene masnoće /%		Used proteins /% Korišteni proteini %		Other used DM* /% Ostale korištene suhe tvari /%
		TF* %	TDM* %	TP* %	TDM* %	
Mozzarella	52.17	90.10	28.38	81.35	20.75	3.03
White Brined	50.04	89.06	28.05	78.45	20.01	1.98
Pecorino	48.32	85.93	27.08	73.63	18.79	2.45

DM* - Dry matter
TDM* - Total dry matter
TF* - Total fats
TP* - Total proteins

The results presented in Table 8 demonstrate that in the production of goat's milk cheese the fats are utilized to the highest extent which is 90.10% in Mozzarella, 89.06% in White Brined and 85.93% in Pecorino, i.e. the coefficient of transformation of the fats from the milk into the cheese is 0.901%, 0.8906% and 0.8593%, respectively. The used fats in the cheese of

Mozzarella type have a share of 28.38% in the total dry matter content and the loss rate is 3.12%. The degree of used fats in White Brined is 28.05% and 27.08% in Pecorino, whereas the loss is 3.45% and 4.42% respectively, in comparison to the total dry matter content of the milk.

The degree of utilization of the proteins is low. In Mozzarella it rates to 81.35%, in White Brined – 78.45% and 73.63% in Pecorino, which means that the degree of transformation is 0.8135%, 0.7845% and 0.7363%, respectively. The used proteins from the milk into the cheese of Mozzarella type have a share of 20.75% in the total dry matter content whereas the loss in the whey is 4.76%. The degree of used proteins from the milk into White Brined is 20.01% and 18.79% in Pecorino, and the loss is 5.49% and 6.73% respectively of the total dry matter content in the milk.

The dry matter utilization degree in Mozzarella is 52.17%, in White Brined – 50.04% and in Pecorino - 48.32%, whereas the loss rate in the whey is 47.83%; 49.56% and 51.68% respectively. The rate of transformation in the respective three types of cheese is 0.5217%, 0.5004% and 0.4832%.

In addition, the yield of the soft Mozzarella type of cheese from goat's milk is 18.13±0.43%, the yield of White Brined is 12.50±0.37% and that of Pecorino – 9.18±0.31%, which means that for the production of 1 kilogram of Mozzarella type of cheese from goat's milk one needs 5.5 liters of milk, whereas for 1 kg of White Brined - 8.0 liters and for Pecorino - 10.9 liters of milk.

Our results regarding the yield of the cheeses from goat's milk have somewhat higher values than the results found in the studies from other researches, which is probably due to the higher dry matter content in the milk. The same conclusion was made by Casu et al. (1989) when he studied the yield of goat's milk cheese from different breeds of goats. He found that for production of 1 kg of cheese with mixed milk from Saanen and Italian Alpine breeds of goats (with fat content of 2.57-2.92 % and protein content of 2.60–2.63 %) one needs 15.07 liters for the traditional hard cheese and 9.36 – 10.10 liters for the modern soft type of goat cheese. At the same time, for the production of 1 kg of cheese with milk from the Sardinian breed of goats (with fat content of 4.54-4.60% and proteins – 3.56-3.60%) 9.09 liters are needed for the hard type of cheese and 5.84-5.60 liters for the soft goat cheese.

Similar results were attained by Yener et al. (1989), according to which the yield of the White Brined type of cheese in Turkey, immediately after pressing is in the range of 11.27-14.16%, whereas the loss during the ageing is around 10%.

Conclusions

The salt equilibration in the cheese mass occurs on the 15th day in Mozzarella and on the 60th day in White Brined, whereas the salt content in Pecorino on the 90th is again by 1% lower in the inner layer in relation to the other two layers.

The rate of dry matter utilization is 52.17% in Mozzarella, 50.64% in White Brined and 48.32% in Pecorino. Accordingly, the yield of Mozzarella is 18.13±0.43%, of White Brined - 12.50±0.37% and the yield of Pecorino - 9.18±0.13%.

KINETIKA DIFUZIJE SOLI I RANDMAN NEKIH TIPOVA KOZJIH SIREVA

Sažetak

Istražena je kinetika difuzije soli tijekom zrenja tri vrste kozjeg sira (Mocarela, Bijeli salamureni sir i Pekorino). Analize su učinjene periodično svakih 72 sata, 5-tog, 10-tog, 40-teog, 50-tog, 60-tog i 90-tog dana od zrenja sira.

Istovremeno smo ispitivali koncentraciju soli u tri sloja sira: unutrašnjem (1), srednjem (2), vanjskom (3). Izjednačavanje soli u sirnoj masi kod sira Mocarela počinje 15-tog dana; kod Bijelog salamurenog sira 60-tog dana dok kod Pekorino sira sadržaj soli je 90-tog dana za 1% manji u unutrašnjem sloju nego u druga dva sloja. Stupanj iskorištavanja suhe tvari kod Mocarela sira je 52,17 %, kod Bijelog salamurenog sira je 50,64 % i kod Pekorino 48,32 %. Suglasno tome, randman sira Mocarela je 18,13±0,43 %, kod Bijelog salamurenog sira je 12,70±0,37 % i kod Pekorino sira 9,58±0,37 %.

Ključne riječi: kozji sir, difuzija soli, randman

References

BALTADIJEVA, M..A. et all. (1985.): Un nuovo tipo di fromaggio “Remelia” di latte di capra. *Sci. Tec. Latt-Casseinaria 35*, 451-464.

BALTADIJEVA, M..A.(1993): Tehnologija na mlecnite produkti. Zemizdat, Sofija, 86-90.

CASU, S. (1989.): Caracteristiques du lait des chévre sordes et production fromage en liasom avec la production fromage. Eur. Publication No. 11893, 329-334.

KINDSTEDT, P.S. (1993.): Efeect of manufacturing factors composition and proteolysis on the functional characteristics of Mozzarella cheese. Crit.Rev. *Food Sci. Nutr., 33*, 2,167.

KINDSTEDT, P.S. et all. (1996.): Distribution of salt and moisture in Mozzarella Cheese with soft surface defect. *J.Dairy Sci. 79*, 12, 2278-2292.

LAHAYE, M.P. (1992.): Presentation de la filiere caprine du 30 mars du 10 achril 1992. ACTIM, Paris.

MALLATOU, E. et all. (1994.): Manufacture of Feta cheese from sheep milk, goat milk and diferent mixteres. *Int. Dairy J. 4*, 641-644.

MORRIS, H.A.(1985.): Salt difuzion in Cheddar cheese. *J. of Dairy Sci. 68*, 8, 1851-1858.

SUTHERLAND, B.J (1974.): Same observation on salt and moisture concentration gradiente i cheddar cheese. Austral. *J.Dairy Techn., 29*. No 2.

SCOTT, R. (1986.): Flavour in cheese in Cheesemaking Practice – second edition, ed. Elsevier APPL. Sci. Publ. Ltd. New York.

SCHROEDER, C.L. (1988.): Reduction of sodium hloride in Cheddar cheese. Efect on sensory. Microbiological and Chemical Properties. *J.Dairy Sci, 71*, 8, 2010-2020.

YENER, S.M. (1989.): Milk production from goats. CIHEAM. Le lait dans la région méditerranéenne, No 6, 149-157.

STAMENOVA, V. (1985.): Isledvane na osnovnite tehnologicni svojstva na koze mleko i razrabtvane proizvodstvo na tvrdo sirene. Zamizadat, Sofija, 90-94.

TOMAS, T. (1981.): Vlianieto na solta vrhu fermentaciяata i proteolizata na sirenje Cedar. Sp. Nю Zeland ъa deйri Saйъne vid tehnol., 16.

Autor’s addresess - Adrese autora:
Dr. sc. Sonja Srbinovska, Assis.Prof.,
Dr. sc. Tihomir Čizbanovski, Prof.,
Dr. sc. Vladimir Džabirski, Assis.Prof,
Dr. sc. Sreten Andonov, Assis.Prof,
Faculty of Agriculture, Skopje;
Dr. sc. Bone Palasevski,
Livestock Institute, Skopje

Received - Prispjelo:
November 15, 2000.
Accepted - Prihvaćeno:
December 07, 2000.