High pressure in the technology of milk and soft cheese

Valerii Sukmanov[1], Viktoriia Kiiko[2]

1 – Poltava University of Economics and Trade, Poltava, Ukraine
2 – National University of Food Technologies, Kyiv, Ukraine

Keywords:

High-pressure
Milk
Cheese

Article history:

Received 18.01.2016
Received in revised form 03.03.2016
Accepted 24.03.2016

Corresponding author:

Viktoriia Kiiko
E-mail:
victoriya_kiyko@ukr.net

Abstract

Introduction. This work is devoted to the use of technology of high pressure in the production of milk and soft cheese, the substantiation of rational options of treating by high pressure of domestic raw milk in the production of drinking milk and soft cheese.

Materials and methods. The objects of research are: milk, processed with high pressure, soft cheese, produced with the use of high pressure. The mineral composition of milk and sour-milk cheese were determined by atomic and absorption spectrophotometry on the atomic and absorption spectrophotometer «C-115 PC», the rheological properties of soft cheese were tested on electromechanical universal testing machine SANS CMT2503.

Results and discussion. With the help of research the mechanism of pressure and duration of treatment on the micro flora of milk and soft cheese has been found. Processing options have been selected at which inactivating effect of micro flora of milk and soft cheese is achieved.

In the process of experimental studies the rational processing options have been established and proved: for milk – the pressure of 300-330 MPa, the temperature is 40–45 ^{o}C, the duration of exposure $30 \cdot 60^{1}$s; for cheese – the pressure 450–580 MPa, the temperature is 18 ^{o}C and the duration of exposure – $20–30 \cdot 60^{1}$c.

In assessing physical-chemical characteristics of milk and cheese in comparison with control samples it was established that the total content of protein, fat, lactose and mass fraction of solid substances varies slightly.

The content of essential vitamins in milk and soft cheese is a sign of the maximum preservation. In milk treated by high pressure fat soluble vitamins are stored in 4–6 times more and water soluble in 2–3 times more than in pasteurized milk. In the soft cheese vitamins content is stored in 1,5–2 times more than in those produced by traditional technology.

According to the evaluating marks of sensor characteristics the products produced by the technology of high pressure received the highest scores: milk has got 98,6 points, soft cheese has got 96,4. Decline in consumer properties of control samples during storage was significantly faster than in the samples treated with high pressure, which are the result of enzymatic activity and the development of surviving micro organisms.

Conclusions. Technology of milk and soft cheese by using high pressure allows for microbial sterility of products to increase their shelf life, to preserve enzyme-vitamin complex feedstock.

Introduction

For the last decades high pressure technology has been widely applied in food industry that makes it possible to manufacture preservatives-free products of new quality, thus eliminating loss of vitamins and precious nutrients with improved taste and aromatic properties. High pressure processing of food products has been successfully applied in Europe, North America, Japan and New Zeeland.

Fundamental scientific basis created by our predecessors, constant scientific research and numerous experimental work in research institutes and laboratories, extensive testing and clinical trials expanded significantly the idea of importance of milk and dairy products in human diet. Therefore, the main trends in the development of dairy industry aimed primarily on constant search, development and introduction of new technologies which allow obtaining high quality products with high biological and nutritional value.

The importance and the need in the use of high pressure in food industry are predetermined by numerous available scientific developments and the existing international experience.

Taking into consideration the needs of the industry and market requirements, the scientific laboratory of high pressure has made a complex of scientific research work in high pressure effects on safety, nutritive and biological value of milk and milk products, the increasing of their shelf life, the expansion of assortment by creating new dairy products with improved consumer properties [1].

Recent research in the sphere of the use of high-pressure technology with the aim to create high-quality dairy products are widely reflected in scientific works of many foreign researchers. The greatest interest are the studies, highlighted over the last five years in the works of scientists: Bruno Ricardo de Castro Leite Júnior and others[2], Bibiana Juan', Anna Zamora and others [3], Luciana M. Costabel, Carina Bergamini and others [4], G.G. Amador-Espejo and others [5], Evelyn, Filipa V.M. Silva [6], Francisca I. Bravo, Xavier Felipe, Rosina López-Fandiño, Elena Molina [7, 12], Sergio I. Martínez-Monteagudo, Michael G. Gänzle, Marleny D.A. Saldaña [8], Genaro Gustavo Amador Espejo, M.M. Hernández-Herrero, B. Juan, A.J. Trujillo [9], G.G. Amador-Espejo and others [10], Hasmukh A. Patel, Thom Huppertz [11], Bravo FI, Molina E, López-Fandiño R. [13].

In Ukraine, the problem of the use of high pressure technology does not lose its relevance, the solution of which will help to receive products with high sanitary-bacteriological indexes without losing the natural food properties.

This work is devoted to scientific developments in the use of technology of high-pressure in the production of milk and soft cheese, basing the expediency and prospects of introduction of this technology in the domestic industry.

Materials and methods

The objects of research are: milk, processed by high pressure, soft cheese, produced with the use of high pressure. Control samples are raw cow's milk, heat-treated (pasteurized), mild cheese, produced by traditional technology, described in works [14, 15].

For the processing of raw milk high pressure, the sealed, in a special container, samples were placed in an optical camera installation of high pressure (up to 1000 MPa). The camera device allows to measure temperature changes in the range of 5 to 95 °C.

High pressure processing parameters on the stage of research are the following: the pressure from 300 to 600 MPa, the processing time: from 10x60s to 30x60s, milk cures temperature 40-45^{o}C; cheese process temperature of the product at the moment of

completing its self pressing: 18±2°C. Experimental samples of cheese were made from unpasteurized standardized milk with fat content 2.4%.

The mineral composition of milk and soft cheese were determined by atomic and absorption spectrophotometry on the atomic and absorption spectrophotometer «C-115 PC», the rheological properties of mild cheese was tested for electromechanical universal testing machine SANS CMT2503 production «Shenzhen SANS Testing Co. Ltd.».

The content of Vitamin A was examined by colorimetric method; Vitamin C was determined by indophenols method; vitamins B_1 (thiamine) and B_2 (riboflavin) – by fluorimetric method.

The number of mesophilic aerobic and facultative anaerobic microorganisms in milk and soft cheese were determined by the method of quantitative crop of diluted samples of tested material on nutrient media. To do this, there were prepared Tenfold dilution of prototypes, followed by entering it in the amount of 1 ml sterile Petri cup and poured it melted and cooled to 40-45 °C with nutrient agar. After incubation determined number of colony forming units per unit volume of research material.

Organoleptic evaluation of the test samples of milk and cheese was made by the developed 5-point scale based on weight coefficients for each indicator. The change of flavoring properties was assessed by the profile method [16].

Results and discussion

In order to improve parameters of high pressure processing we have performed complex researches of microbiologic, physical and chemical properties of products.

According to data of the performed tests there has been adopted biophysical model which enables grounding of inactivation mechanism of milk microbial flora depending on technology parameters of treatment process and appropriateness of the chosen modes.

Concentration of microbial population in milk depends on temperature and pressure as shown in the Fig. 1.

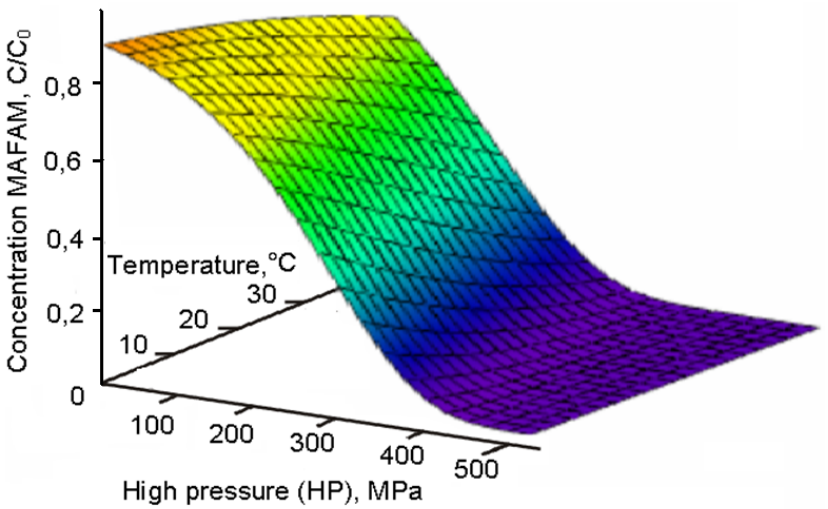

Fig. 1. Response surface and isolines of sections of concentration dependence of aerobic mesophilic count, colony forming unit/sm^3 in milk from influencing factors (pressure, temperature)

In case of high pressure processing at lower temperature (up to 40^0C) high inactivating effect may be achieved by applying pressure of 400-600 MPa. Increase of temperature shifts inactivation threshold to lower pressure, namely at temperature of 40-45^0C it is enough 300-330 MPa to achieve the desirable effect. Influence of processing by pressure of 400, 500, 600 MPa corresponds to sterilization effect, but in that milk there occur denaturation processes. The most inactivating effect in result of milk processing by high pressure has been achieved at temperature 40-45^0C and duration of processing $30*60^1$C.

Thus, in soft cheese processed by high pressure of 300 MPa during 10, 20, and 30 minutes there have been found coliform bacteria. Application of 450 MPa pressure and higher during more than 10 minutes effectively inactivates opportunistic and pathogenic microflora.

According to optimization of high pressure processing there have been established the following parameters of high pressure technology (pressure, temperature, duration of processing): for milk – 300–330 MPa, 40–45^0C, $30 \cdot 60^1$ c; for cheese – 450–580 MPa, 18 °C, $20–30 \cdot 60^1$ c. These parameters make it possible to the best advantage to preserve biochemical properties of milk and are strong inhibiting factors as to microflora of the product.

In assessing physical-chemical characteristics of milk and cheese in comparison with control samples it was established that the total content of protein, fat, lactose and mass fraction of solid substances varies slightly.

Results of determination of basic vitamins content have proved maximal preservation thereof. There have been investigated change of quantity of basic vitamins A, B_1 and B_2, PP, C, which are important components of milk and soft cheese, and partially form biologic value thereof (tab.1).

Table 1

Content of basic vitamins in the tested milk and soft cheese, mg %

Vitamins, мг%	Content in milk		Content in milk, processed by high pressure		Content in soft cheese	
	Raw milk	Pasteurized	300MPa -40°C- $30 \cdot 60^1$c	330MPa - 40°C- $30 \cdot 60^1$c	Control samples (Cheese, produced from the pasteurized milk)	Produced with the use of HIGH PRESSURE
Vitamin A	0,031	0,018	0,027	0,025	0,211	0,254
Vitamin B_1 (thiamin)	0,042	0,037	0,036	0,037	0,032	0,051
Vitamin B_2 (riboflavin)	0,160	0,124	0,160	0,160	0,354	0,405
Vitamin PP (niacin)	0,09	0,09	was not determined	was not determined	0,309	0,407
Vitamin C	1,43	0,92	1,23	1,21	0,62	1,12

The comparative characteristic of the obtained results proves more favorable influence of high pressure on milk and soft cheese if compared to traditional production technology. Thus, in high pressure processed milk there have been preserved 4–6 times as much of fat-soluble vitamins and 2–3 times as much of water-soluble vitamins; in soft cheese produced with applying high pressure processing there are basic vitamins 1,5–2 times as much.

We have tested changes of several basic mineral components of milk and soft cheese playing an important role for stability of milk protein system and its transformation in the process of soft cheese production. Results of determination mineral elements in milk and cheese are given in the tables 2 and 3.

According to the data shown in the table it is obvious that high pressure processes and milk pasteurizing lead to change of salt composition. Thus, upon pasteurizing soluble calcium and phosphor levels decrease by 13% and 29.8% that may occur due to calcinations of casein complex at heating up to higher temperatures. High pressure processing involves increase of calcium content by 7% at 300 MPa, and to 12% at 330 MPa. Phosphor content in the result of high pressure milk processing is increased to 36.2%. Increase of calcium and phosphor levels probably takes place due to casein micelle fragmentation into smaller sub-micelles connected by mineral potassium phosphate (citrate), and as a result salts transfer from colloid state into solution.

Table 2

Content of basic mineral elements in milk processed by various means

Processing options	Content mineral elements (mg/ml)				
	Ca	P	Na	K	Mg
Raw milk	1,0	0,47	0,68	1,14	0,11
Pasteurized milk	0,87	0,33	0,73	1,12	0,12
300MPa -40ºC-30·60[1]c	1,07	0,64	0,71	1,1	0,12
330MPa -40ºC-30·60[1]c	1,12	0,64	0,71	1,12	0,13

High pressure of milk processing results in increase of Na concentration at an average of up to 7% and 4% if compared to check sample.

Content of potassium and magnesium salts upon various processing remained almost the same.

For determination of salts in cheese soft cheese has been taken as a check sample. The cheese has been produced without pasteurizing of milk mixture, as in the result of milk pasteurizing balance between various forms of potassium salts become destabilized, and as a consequence its ability to change into enzyme rennet declines.

Test data prove slight decrease of Ca and Na in soft cheese (by 0.85% and 0.83% consequently), produced with application of high pressure processing technology; content of Mg, K, Fe, Zn, Cu salts remained almost the same, cadmium is not found.

Table 3

Content of basic mineral elements in soft cheese

Mineral elements	Content mineral elements in soft cheese, mg/100 g	
	Control samples (Cheese, produced without pasteurization of milk), mg/100 g	Produced with the use of HIGH PRESSURE , mg/100 g
Ca	549,59	544,96
Mg	27,41	27,39
K	85,68	85,66
Na	1231,13	1221,02
Fe	0,61	0,7
Zn	0,84	0,82
Cu	0,01	0,02
Cadmium	Not found	Not found

We have tested rheological indices of soft cheese "penetration coefficient", "limit cut tension" and "cutting operation" performed by electromechanical universal test machine SANS CMT2503 of Shenzhen SANS Testing Co. Ltd.

Analysis of change dynamics of the above mentioned indices revealed, that penetration coefficient and cutting operation significantly differentiate from these parameters in check sample and significantly depend on processing pressure. Limit cut tension has been to lower degree influenced by processing parameters and if compared to the check sample changes insignificantly.

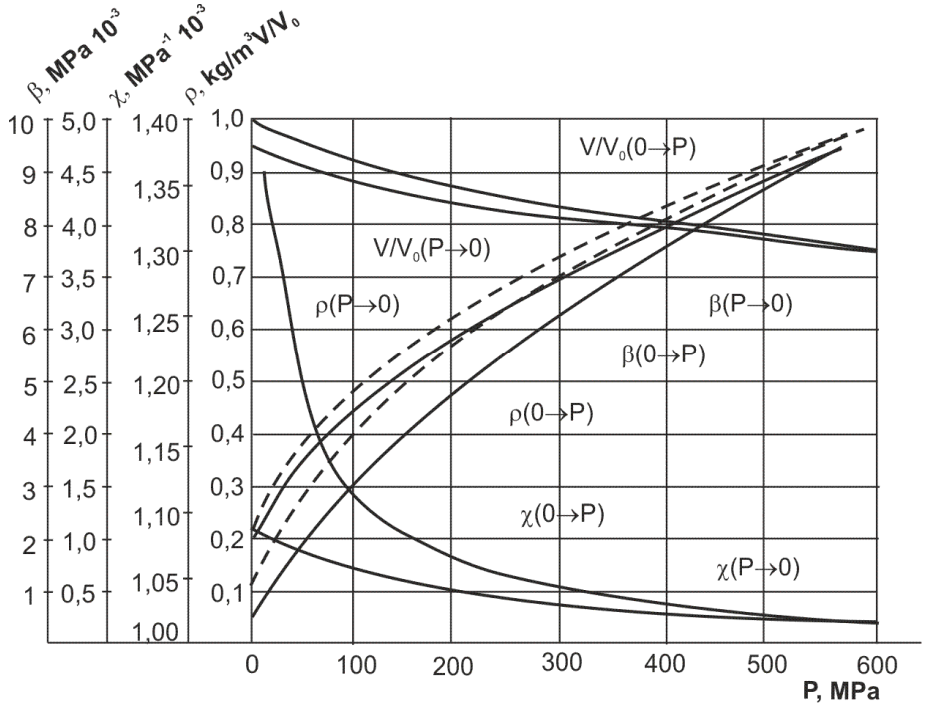

Fig. 2. Change of compression indices high pressure processed of soft cheese

In the result of experimental researches of compression properties of soft cheese (Fig. 2) it has been determined that during processing by 0 – 600 MPa pressure there take place changes in its rheological indices as follows:

- Relative product volume decreases up to 0.76, but upon pressure decrease it increases to 0.95 of the initial value;
- Product density increases by 29% (from 1, 047 kg/m^2 up to 1,351 kgr/m^2); upon pressure decrease density falls to 1,085 kg/m^2, that equals to 3.6% of the initial value;
- Volume compression modulus in case of pressure rise increases almost 17 times as much (from $0{,}55\times10^{-3}$ MPa up to $9{,}4\times10^{-3}$MPa) and then returns to the value of $2{,}0\times10^{3}$ MPa;
- Isothermal compression coefficient in case of pressure rise decreases by 77.3% (from $1{,}1\times10^{-3}$ up to $0{,}25\times10^{-3}$ MPa^{-1}) and then upon pressure decrease its value exceeds $4{,}5\times10^{-3}$ MPa $^{-1}$.

In order to use the obtained experimental values of the parameters for predicting product status with various process parameters, calculations and projecting of technology equipment for production of soft cheese by applying high pressure technology experimental curves have been described by mathematical functions.

Functional $\chi = f(P)$ и $\beta = f(P)$ connections are described by general function (1):

$$y = a + b \cdot e^{-\frac{x}{c}} + d \cdot e^{-\frac{x}{g}}, \quad (1)$$

Functional $\rho = f(P)$ и $V/V_0 = f(P)$ connections are described by general function (2):

$$y = a + b \cdot x + c \cdot e^{-\frac{x}{d}}. \quad (2)$$

Results of processing and statistic analysis of the obtained connections are given in the table 4.

Thus, in the result of experimental researches there have been obtained values of rheological indices for various parameters of production process and there has been performed comparative analysis for samples of soft cheese produced by traditional technology and high pressure technology.

Table 4

Results of mathematical processing of the functional connections

Parameters		R^2	F-statistics	Values of the coefficients				
				a	***b***	***c***	***d***	***g***
$\chi = f(P)$	0 → P	0,997	1835,22	0,393	149,86	326,59	-149,25	329,28
	P → 0	0,998	4980,93	0,061	6,98	15,5	2,42	157,42
$\beta = f(P)$	0 → P	0,999	17668	19,4	-0,84	64,46	-16,45	1152,56
	P → 0	0,999	36032	16,94	-0,41	44,49	-15,92	770,89
$\rho = f(P)$	0 → P	0,999	29087	820,5	0,96	-586,16	221,16	-
	P → 0	0,999	17527,4	2544,52	-0,41	-2140,68	710,94	-
$V/V_0 = f(P)$	0 → P	0,998	4425,07	0,84	-0,0002	0,159	192,07	-
	P → 0	0,997	3180,8	0,63	$3\cdot10^{-5}$	0,312	428,8	-

Complex evaluation of organoleptic indices has made it possible to determine that products produced by high pressure technology show the highest induces: milk – 98.6 points, soft cheese – 96,4 points.

Profile analysis of taste properties of high pressure processed milk has revealed high level thereof. Raw milk and pasteurized milk are included into your rating with 89.5 points and 81.2 points consequently, and rank as good quality products. First and foremost, it is connected with appearance of fatty film on the surface and peculiar pasteurizing taste, as the signs of denaturation of whey protein. Change of taste properties of high pressure processed milk if compared to raw and pasteurized milk are represented by profile charts (fig 3, 4).

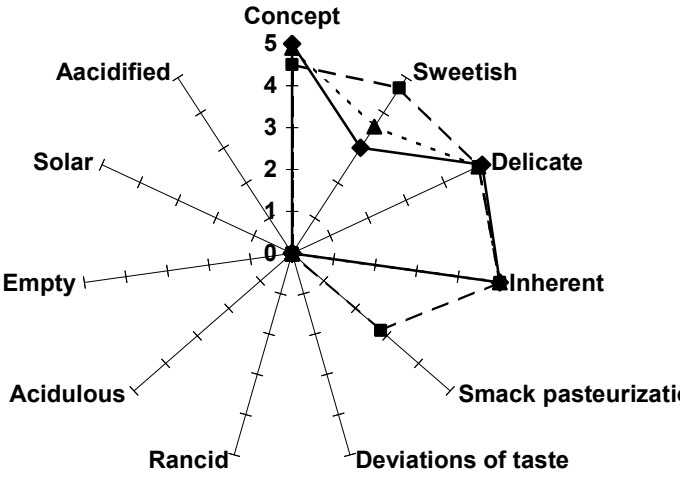

Fig 3. Taste profile chart of the tested samples at the beginning of storage period:
——— raw milk;
- – - – - pasteurized milk;
····· high pressure processed milk.

Taste profiles of high pressure processed milk are similar to raw milk taste, except of more pronounced sweet flavor in case of high pressure processing. These differences are more characteristic of pasteurized milk.

According to results of organoleptic evaluation both samples of cheese are of high quality and possess highest quality indices. Soft cheese produced with application of high pressure technology ranks higher if compared to the check sample, thus, it may be concluded that new high pressure technology positively influenced organoleptic properties of soft cheese (fig 5, 6).

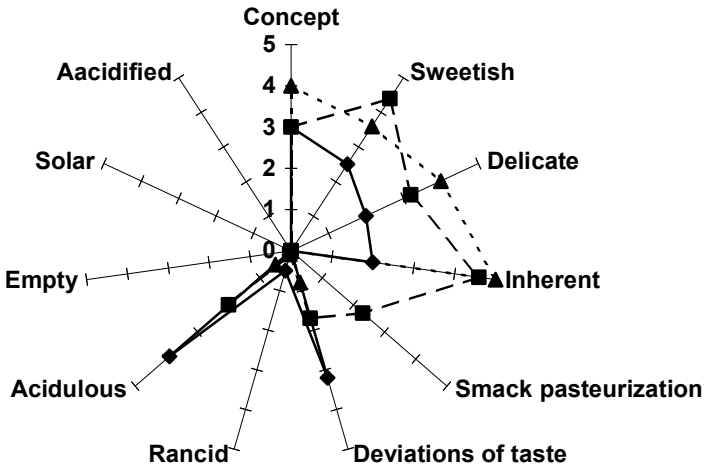

Fig 4. Taste profile chart of the tested samples during the storage period:
——— raw milk;
- – – – - pasteurized milk;
····· high pressure processed milk.

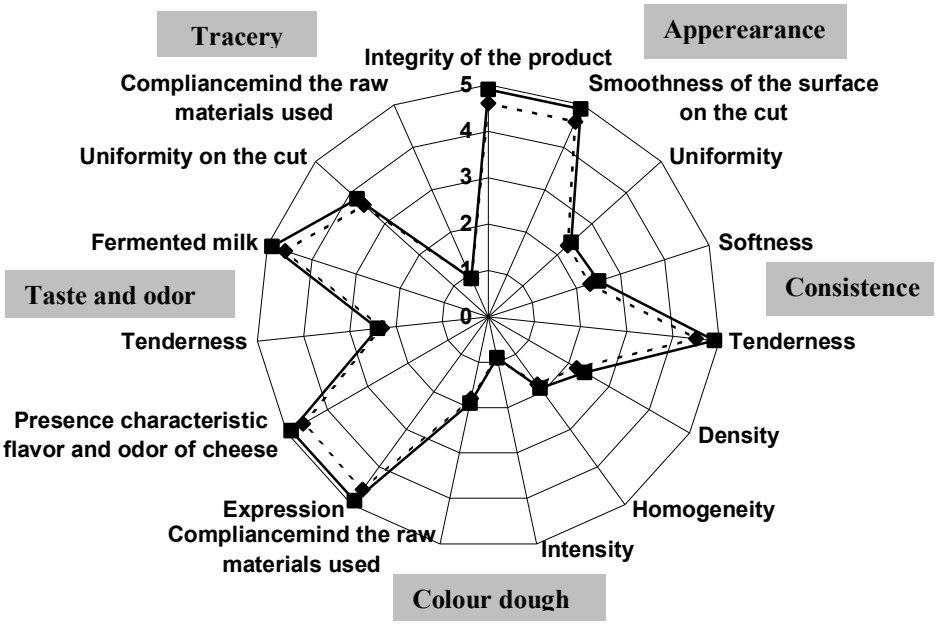

Fig 5. Profile chart of organoleptic indices soft cheese
- – – – - Control sample
——— Soft cheese produced with the use of high pressure

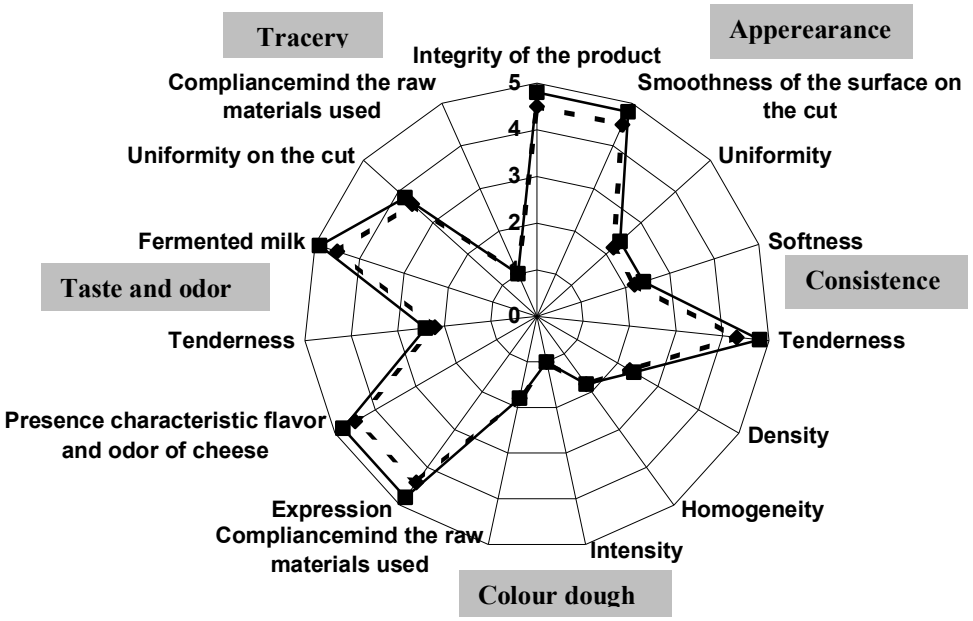

Fig 6. Profile chart of organoleptic indices soft cheese during the storage period

- – – – - Control sample

——— Soft cheese produced with the use of high pressure

If compared to the check sample soft cheese looks more attractive with more pronounced flavor if compared to the check sample. Its body is more homogeneous, soft and elastic, while the check sample is harder and a little crumbly. To our opinion such changes in soft cheese have become possible due to increase of attached moisture volume under high pressure.

Decline in consumer properties of control samples during storage was significantly faster than in the samples treated with high pressure, which is the result of enzymatic activity and the development of surviving micro organisms.

Conclusions

The research and study of the mechanism of high pressure combined with a thermal treatment on inactivation of microflora and change the components of milk and soft cheese gave grounds to determine rational modes of the use of high pressure technology.

During the storage of milk processed by high pressure in the first three days, a decrease of the concentration of microorganisms is happened, at the expense of processing efficiency increases to 98.6%. Further storage of such milk accompanied by increased microbial numbers, but with a lower level of intensity than in raw milk and processed high temperatures.

The changes in physic-chemical and biochemical parameters together determine the pattern of changes milk quality and soft cheese, processed by high pressure, in particular vitamin, mineral composition, rheological and organoleptic properties.

The presented analytical summary of high pressure effects on the quality of milk and soft cheese proves the prospects in implementation of this technology in the dairy industry with the aim of producing products with high biological value of durability.

It should be noted that the research in this area continues, in particular, the most important is the question of technological properties of milk processed by high pressure and prospects for its further use in the manufacture of dairy products.

References

1. Sukmanov V., Sklyarenko E. (2012), Vysokoe davlenie kak metod uvelicheniya srokov khraneniya svezhikh myagkikh syrov i povysheniya ikh potrebitel'skikh svoystv, *Produkty i ingredienty*, 1, pp. 28–31.
2. Bruno Ricardo de Castro Leite Júnior, Alline Artigiani Lima Tribst, Carlos Francisco Sampaio Bonafe, Marcelo Cristianini (2016), Determination of the influence of high pressure processing on calf rennet using response surface methodology: Effects on milkcoagulation, *Food Science and Technology,* 65, pp. 10–17.
3. Bibiana Juan, Anna Zamora, Joan Miquel Quevedo, Antonio-José Trujillo (2016), Proteolysis of cheese made from goat milk treated by ultra high pressure homogenization, *Food Science and Technology,* 69, pp. 17–23.
4. Luciana M. Costabel, Carina Bergamini, Sergio R. Vaudagna, Alejandra L. Cuatrin, Gabriela Audero, Erica Hynes (2016), Effect of high-pressure treatment on hard cheese proteolysis*, Journal of Dairy Science*, Available online 24 March 2016.
5. Amador–Espejo G.G., Gallardo–Chacon J.J., Nykänen H., Juan B., Trujillo A.J. (2015), Effect Of Ultra High–Pressure Homogenization on hydro- and liposoluble milk vitamins, *Food Research International,* 77(1), pp. 49–54.
6. Evelyn Filipa V.M. Silva (2015), High pressure processing of milk: Modeling the inactivation of psychotropic *Bacillus cereus* spores at 38–70 °C, *Journal of Food Engineering,* 165, pp. 141–148.
7. Francisca I. Bravo, Xavier Felipe, Rosina López-Fandiño, Elena Molina (2015), Skim milk protein distribution as a result of very high hydrostatic pressure, *Food Research International,* 72, pp. 74–79.
8. Sergio I. Martínez–Monteagudo, Michael G. Gänzle, Marleny D.A. Saldaña (2014), High–pressure and temperature effects on the inactivation of *Bacillus amyloliquefaciens*, alkaline phosphatase and storage stability of conjugated linoleic acid in milk, *Innovative Food Science & Emerging Technologies,* 26, pp. 59–66.
9. Genaro Gustavo Amador Espejo, M.M. Hernández-Herrero, B. Juan, A.J. Trujillo (2014), Inactivation of *Bacillus* spores inoculated in milk by Ultra High Pressure Homogenization, *Food Microbiology,* 44, pp. 204–210.
10. Amador-Espejo G.G., Suàrez-Berencia A., Juan B., Bárcenas M.E., Trujillo A.J. (2014), Effect of moderate inlet temperatures in ultra–high–pressure homogenization treatments on physicochemical and sensory characteristics of milk, *Journal of Dairy Science* 97(2), pp. 659–671.
11. Hasmukh A. Patel, Thom Huppertz (2014), Effects of High–pressure Processing on Structure and Interactions of Milk Proteins, *Food Science and Technology*, *Chapter 8*, pp. 243–267.

12. Bravo Francisca, Felipe Xavier, López-Fandiño Rosina, Molina Elena (2013), High-pressure treatment of milk in industrial and pilot–scale equipments: effect of the treatment conditions on the protein distribution in different milk fractions, *European Food Research and Technology,* 236 (3), pp. 499–506.
13. F.I. Bravo, E. Molina, R. López-Fandiño (2012), Effect of the high-pressure-release phase on the protein composition of the soluble milk fraction, *J Dairy Sc*i, 95(11), pp. 6293–6299.
14. Kongo J.M., Malcata F.X. (2016). Cheese: Types of Cheeses – Soft, *Encyclopedia of Food and Health*, pp. 768–773.
15. Janet H Galloway (2007) Production of soft cheese, *International Journal of Dairy Technology*, 48 (2), pp. 36–43.
16. ISO 6564 (1985), *Sensory Analysis – Metodology, Flavour profile methods*.
17. Wendin K. Langton, Caous M., L.Hall C. (2000), Dynamic analysis of sensory and microstructural properties of cream cheese, *Food Chemistry*, 71, pp. 363–378.
18. Sukmanov V., Malygina V., Kiyko V. (2011), Analitichniy oglyad vikoristannya tekhnologiï visokogo tisku u virobnitstvi pitnogo moloka, *Produkty i ingredienty Journal*, 11(86), pp. 38–41.