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Qualitative Models and Quality Management of Probiotic Dairy Products Enriched with New Sources of Selenium

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Abstract. Dairy products enriched with functional ingredients and probiotic microorganisms are an important factor in ensuring the quality of life of the population. Since the authors have developed new cereal and collagen supplements for the enrichment of probiotic dairy products with bioavailable selenium, this study aims to justify new probiotic products formulation, to develop the block diagram of its production with selenium-containing additives as a basis for HACCP system introduction as a safety tool of new probiotic products (PP). For the quality characteristics of PP the main groups of indicators: microbiological, organoleptic, physico-chemical indicators and functional properties were selected. The quality index of the developed PP with selenium-containing cereal and collagen additives was 0.83 and 0.87, respectively. Based on the preferred consumer, chemical composition, taste characteristics and influences on the content of solids, proteins, fats and carbohydrates, the dosage of fruit filler in the formulation of PP in the amount of 8-10% is reasonable. Critical control points of PP production were determined; critical limits, corrective actions and monitoring procedures for each critical control points were established; verification procedures were also discussed for HACCP plan implementation.

1. Introduction

Trends in healthy eating have a great influence on consumer demand [1;2]. The basic trend of the modern consumer market is the demand for food ingredients focused on the final consumer, integrated solutions that ensure the rational use of raw ingredients, including those that meet the criteria of "green" standards [3, 4, 5, 6].

Production application of biotechnological processes is relevant in connection with the growing needs of society in biologically active compounds with protective, antioxidant, bio-protective properties [7, 8, 9]. Dairy products enriched with functional ingredients and probiotic microorganisms play an important role in ensuring the quality of life of the population [10,11].

Previously, we have substantiated biotechnological approaches to obtaining collagen and cereal additives enriched with selenium, compatible in functional, technological and organoleptic properties with food systems based on milk. When receiving a selenium-containing collagen Supplement (CDS) was implemented, an approach for the immobilization of selenium using bio-modification collagen proteins [12]. When receiving the selenium-containing cereal additives (CPAS) classical biotechnolo-



gical approach to wheat germination was applied, while the use of dimethyldipirazolilselenid in the composition of the liquid phase during germination was new [13].

The study aims to justify new probiotic products formulation, develop the block diagram of its production with selenium-containing additives as a basis for HACCP system introduction as a safety tool of new probiotic products (PP).

2. Experimental technique

When substantiating the formula-component composition of selenium-rich probiotic products (PP), the methodology of qualimetric modeling of the combined food systems on the milk basis was used [14]. The stages of the research included qualitative modelling (the analysis of normative-technical documentation and legal sources of products, prototypes; identification of evaluation criteria of quality; calculation of high-quality potential of the product prototype), the development and testing of formulations of PP (analysis information data base on the composition and properties of raw materials; formation of functional and technological project of the finished product; substantiation of the content of the prescription components); justification of the modified technological scheme of production; production of prototypes; analysis of organoleptic characteristics, nutritional value and safety of PP [14, 15].

In accordance with the principles of qualimetry assessment of the product quality is considered as a multi-stage process consisting of the assessment of individual indicators that most fully characterize the quality of PP. The quality was considered as a hierarchical set of properties representing the interest for a consumer [16].

To characterize the quality of PP, the main groups of indicators were selected: microbiological, organoleptic, physical chemical parameters and functional properties (groups a, b, d, c) [16, 17, 18].

The absolute value of the i - unit index of the products quality P_i was measured, which can vary in the range of its maximum P_{imax} and minimum P_{imin} values. Conformity assessment of the current value of the base level R_{ibas} was provided .

Let us assume that each property of the set of the kinds is characterized by a parameter K_i and a weighting coefficient M_i , which determines the degree of influence of complex indicators on the quality of the product [16, 19].

For the quantitative determination of the indicator of the quality of PP equation (1), A. M. Brazhnikova was used [16]:

$$K = M_a \sum_{i=1}^i m_a K_a + M_b \sum_{i=p+1}^p m_b K_b + M_c \sum_{i=p+1}^q m_c K_c + M_d \sum_{i=q+1}^m m_d K_d \quad (1)$$

where M_a, M_b, M_c, M_d are the weighting coefficients for each group of properties: microbiological, organoleptic characteristics, functional properties and nutritional value, respectively, and

$$M_a + M_b + M_c + M_d = 1; \quad (2)$$

m_a, m_b, m_c, m_d -the weighting coefficients of each i -th relative quality index in each property group, where

$$\sum_{i=1}^i m_a = 1, \sum_{i=1}^p m_b = 1, \sum_{i=p+1}^q m_c = 1, \sum_{i=q+1}^n m_d = 1 \quad (3)$$

$i=5, p=4, q=4, n=5$

For the food systems

$$K_i = 1 - \left(C_i - C_i \frac{P_i}{P_i^{6a3}} \right), \quad (4)$$

where K is the relative quality index ($0 \leq K \leq 1$); C is the coefficient;

$$C_1 = \frac{P_i^{\text{gas}}}{P_i^{\text{max}} - P_i^{\text{min}}} \quad (5)$$

For analytical studies of the quality of probiotic products conventional standard and modified methods were used (tables 1).

Table 1. Methods of a research.

The defined indicators	Documents on research methods
Mass fraction of moisture and dry matter	GOST 3626
Mass fraction of fat	GOST 5867-90
Protein	GOST 23327-98
Microbiological indicators of dairy products	GOST 32901-2014; TR CU 033/2013 [20]
Titrate acidity	GOST 3624 - 92
Assessment of taste and smell	GOST 28283
The number of mesophilic aerobic and facultative-anaerobic microorganisms	GOST R 53430-2009
Yeast and mold fungi	GOST 10444.12-88
The number of bacteria of the group of E. Coli (coliform bacteria)	GOST R 52816-2007
The amount of lactic acid microorganisms	GOST 10444.11-89
Vitamin C	GOST 30627.2
Vitamin E	GOST R 52147-2003
Selenium	MUK 4.1.033-95 (fluorimetric method) [21]

3. Discussion

PP refers to functional dairy products. For their production ingredients of natural origin were used. According to this group of functional properties and microbiological indicators, a weighting coefficient was assigned, exceeding the importance of the other indicators. This is due to high microbiological risks connected to the sparing heat treatment. Organoleptic and physical chemical parameters obtain the lowest weighting factor, as they can be corrected by varying the main ingredients.

The results of the research allowed to develop a qualimetric model of quality assessment of PP taking into account the peculiarities of their rheological and physical chemical properties (tables 2 - 3).

The obtained models were used for optimization of PP formulations according to microbiological, organoleptic, physical chemical parameters and functional properties. According to the results of calculations, the quality indicator of the developed PP with SZD and SKD was 0.83 and 0.87 respectively. Thus, the developed formulations were recommended for use in industry.

Based on the calculations of the quality index of PP for the developed qualimetrical models, taking into account the functional properties of the product, the requirements for functional products and the degree of SFP satisfaction in selenium, the dosage of SDS of 9% and SKD-3 % is viable.

The analysis of probable dangerous factors has been carried out by production of PP. As sources of dangers all production phases have been analysed: intake of raw materials, storage, pasteurization, zakvashivaniye, souring, pouring, packing, storage and transportation. The technological scheme of receiving pro-biotic drink with identification possible CCPs (Critical Control Points) is submitted in the figure 1.

Further the following technological processes: stages of acceptance of raw milk, pasteurization of milk, souring have been carried to CCPs which should be controlled and traced to minimize or exclude potential dangers (table 4).

As the main criteria for assessment of CCPs changes of temperatures on time have been accepted. Strict monitoring of the technological modes and the correcting actions will provide decrease in degree of risk in production of dangerous fermented milk products.

Table 2. Qualimetric evaluation model of PCB from the FDD

Composite indicators	in-Composite indicators	Individual indicators	Cal. Weighting	P_i^{\min}	P_i^{\max}	P_i	P_i^{gas}
a-microbiological safety indicators	0.27	Product weight (g, cm ³), in which the following factors are not allowed:	0.2	200	0.1	200	100
		-CGB (coliforms)			25		
		- pathogenic, including Salmonella	0.2	200		200	100
		-- S. aureus staphylococci	0.2	200	1.0	200	100
		-Yeast, CFU/cm ³ (g), not more	0.2	0	50	0	0.01
		- Mold, CFU / cm ³ (g), not more	0.2	0	50	0	0.01
b-organoleptic parameters	0.24	Color, points	0.1	0	5	5	5
		Consistency, points	0.35	0	5	4	5
		Taste and smell, points	0.45	0	5	5	5
		Appearance, points	0.1	0	5	5	5
C-functional properties	0.27	Se, µg/100g	0.25	6	30	9	12
		Dietary fiber, µg / 100 g	0.25	3	15	4.5	5
		C, mg	0.25	7	35	2.3	15
		E, mg	0.25	1	5	3	3
d-physical and chemical parameters	0.22	Mass fraction of vegetable protein, %	0.2	1	20	10	10
		Mass fraction of milk protein, %	0.2	2.8	3.2	2.8	2.9
		Acidity, T0	0.2	75	140	88	100
		Mass fraction of skimmed milk solids, %	0.2	8.5	9.5	8.6	8.7
		Temperature at release, 0C	0.2	2	6	4	4

Table 3. Qualimetric model of evaluation of PP with SKD.

Complex indicators	Coef. weight groups	Individual indicators	Cal. weightinesses	P_i^{\min}	P_i^{\max}	P_i	P_i^{bas}
a-microbiological safety indicators	0.27	Product weight (g, cm ³), in which are not allowed:			0.1		
		-CGB (coliforms)	0.2	200		200	100
		- pathogenic, including Salmonella	0.2	200	25	200	100
		-- S. aureus staphylococci	0.2	200	1.0	200	100
		-Yeast, CFU/cm ³ (g), not more			50	200	100
		- Mold, CFU / cm ³ (g), not more	0.2	0	50	0	0.01
			0.2	0		0	0.01
b-organo-leptic characteristics	0.24	Colour, points	0.1	0	5	5	5
		Consistency, points	0.35	0	5	4	5
		Taste and smell, points	0.45	0	5	5	5
		Appearance, points	0.1	0	5	5	5
C-functional properties	0.27	Se, µg/100g	0.25	6	30	9	12
		Dietary fiber, µg / 100 g	0.25	3	15	4.5	5
		C, mg	0.25	7	35	2.3	15
		E, mg	0.25	1	5	3	3
d-physical and chemical parameters	0.22	Mass fraction of vegetable protein, %	0.2	1	20	10	10
		Mass fraction of milk protein, %	0.2	2.8	3.2	2.8	2.9
			0.2	75	140	88	100
		Acidity, T0					
		Mass fraction of skimmed milk solids, %	0.2	8.5	9.5	8.6	8.7
		Temperature at release, °C	0.2	2	6	4	4

Table 4. Influence of the amount of fruit filler on the performance of PP.

Critical Control Points	Risk	The controlling actions	Level of risk
CCPs 1	Acceptance of raw milk	Temperature of storage of milk $T = 4 \pm 2^\circ\text{C}$. Lack of serious metals, antibiotics, aflatoxins	High
CCPs 2	Pasteurization of milk	Observance is strict limited temperature pasteurizations of $T = 85 \div 87^\circ\text{C}$ with endurance of 5-10 min.	High
CCPs 3	Souring	Control of temperature souring of $T = 23 \div 25^\circ\text{C}$ and souring time	High

CCPs are processing step where control measures could be performed to prevent, eliminate and reduce any identified hazards (biological, chemical and physical) to an acceptable level.

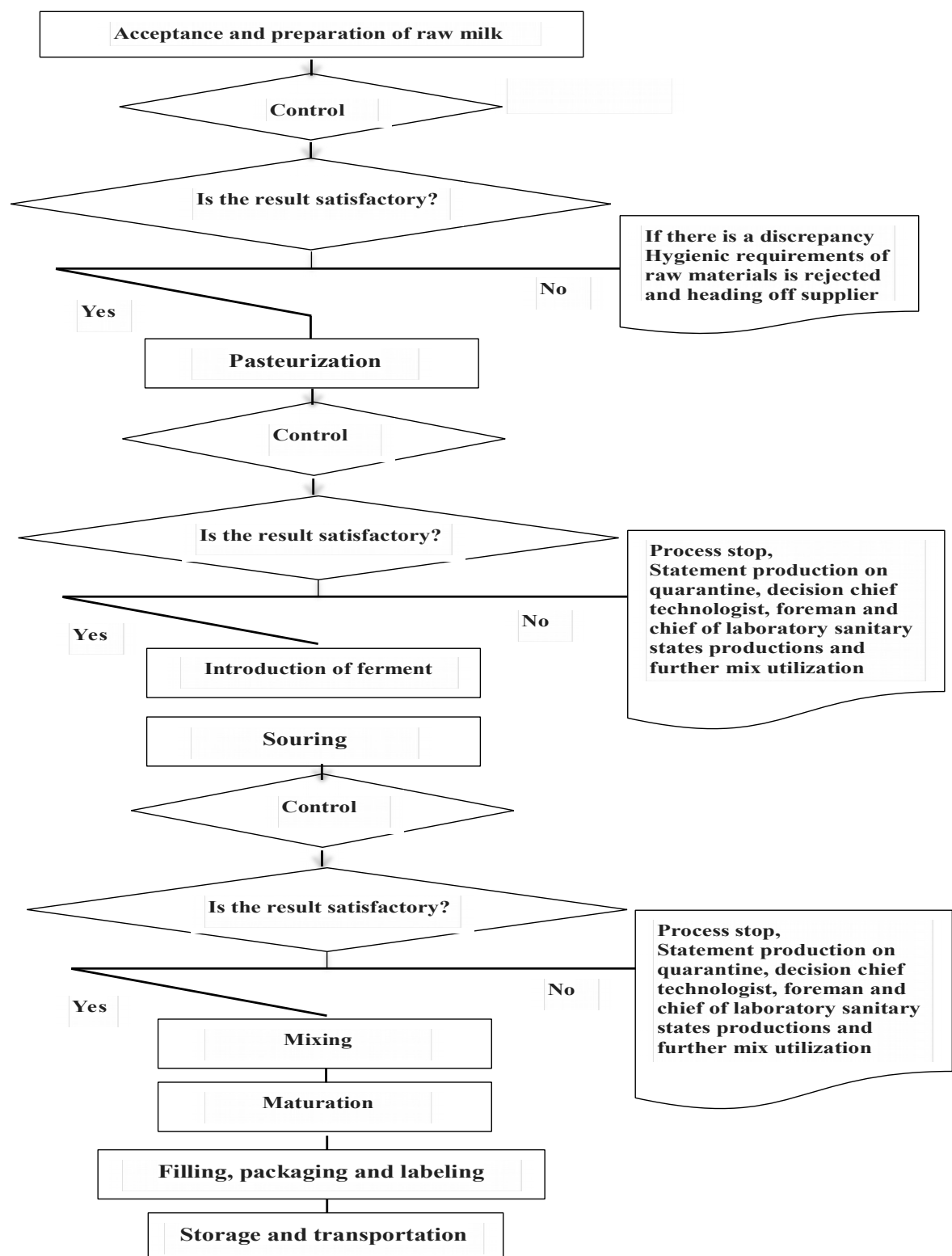


Figure 1. Technological scheme of receiving a (PP) probiotic product.

Critical limits of each identified CCP during preparation PP were determined. The critical limits of receiving raw ingredients should be listed in supplier guarantee specifications of each ingredients and have to be regulated by TP TC 033-2013 [20]. So levels of different hazards in raw ingredients should be under the maximum values listed in guides of microbiological specifications and criteria for milk products [20]. At the same time, microbiological, chemical and visual inspections of all raw materials should be taken into consideration according to established HACCP plan. Sieved grains should not contain physical hazards was the critical limit of cleaning grains step.

Visual inspection of supplier guarantee for each ingredient and cleaned grains could be established as monitoring procedures for CCPs of receiving raw ingredients and cleaning grains, respectively. Different corrective actions for each identified CCP were established. A corrective action for the receiving raw ingredients used in preparation Kishk was reject any doubtful ingredients as it not accompanied by supplier guarantee. Re-sieved cleaned grains are the corrective action should be taken for cleaning grain step if any physical hazards are seen visually. Check and repair incubation and drying conditions (temperature and time) and reprocess if necessary were the corrective actions could be established when monitoring procedures of incubation and drying steps had been indicated that, the critical limits of those steps were exceeded.

In the process of developing PP with FDD and SKD maximum playback of consumer properties of traditional analogue was set as the goal. The use of berry-fruit fillers in PP technology allows providing the following consumer properties: enrichment with carbohydrates, vitamins, providing sweet taste, expansion of the range and improvement of organoleptic characteristics [22, 23].

In the development of pilot batches of PP the dosages of fruit filler 5, 10, 15 and 20%, introduced after fermentation of the milk base were tested. Denfruit Strawberry N 636 was used.(table 5).

Table 5. Influence of the amount of fruit filler on the performance of PP.

Recipe Formulation	Fruit filling, %	Mass fraction, %			
		proteins	fats	carbohydrates	dry fat-free substances
Control	0	3.60	2.80	7.20	15.00
1	5	3.35	2.65	9.15	17.25
2	10	3.10	2.45	11.85	19.85
3	15	2.90	2.28	13.95	21.35
4	20	2.70	2.05	16.50	23.42

At the same time, the introduction of a different mass fraction of the fruit filler had an impact on the formation of the PP taste, as the most important characteristics of the group of organoleptic indicators. Varying the dosage of the filler from 5 to 20 % led to the appearance of the corresponding flavour, increasing with the rise in the dosage in %: 5-fermented milk, with a weak flavour; 10 sour-milk taste with a flavour of the filler; 15-fermented milk with a pronounced sweet taste; 20 - fermented milk with a sugary - sweet taste.

The results of studies on the justification of the amount of fruit filler in the formulation of PP show that it is advisable to use it in a dosage of 8-10 %. This will ensure that the mass fraction of proteins, fats and dry substances in PP meets the requirements of regulatory documents [17, 18].

There are data on the positive effect of the trace elements on the activity of the development of the starter microflora, probiotic including. When choosing a probiotic starter the compliance of probiotic starter cultures to microbiological, genetic, immunological, toxicological and pharmacological criteria described by a number of scientists [1, 23, 24]. To sufficiently tested on a set of indicator strains include *Lactobacillus acidophilus* LA-5 and *Bifidobacterium* BB-12 of the firm Christian Hansen (Holland).

In the formulations of PP we used Nu-trish ABY - 1-starter culture with a certain combination of strains: Bifidobacterium BB-12, Lactobacillus acidophilus LA-5, Streptococcus thermophilus ST, Lactobacillus bulgaricus LB, of the above mentioned firm.

Thus, the modified recipe includes: normalized milk with a mass fraction of fat being 3,0 %; selenium-containing Supplement poly-component probiotic starter culture; fruit filling (table 6).

Table 6. Formulations of PP.

Name of raw material, consumption kg / 1000 kg	Formulations 1	Formulations 2
Milk normalized with a mass fraction of fat 3,0 %	819	859
FDD	90	-
SKD	-	30
Leaven (Nu-trish ABY-1 100 DCU)	0.2	0.2
Fruit filler	80	100
Subtotal:	1000.2	1000.2

Summarizing the results, the technological scheme of PP with selenium-containing additives production was developed, shown in figure 1.

The results of the studies of sanitary and hygienic indicators of P with selenium-containing additives (CDD and SD) are presented in table 7.

Table 7. Microbiological parameters of PP with selenium-containing additives during storage at 4 (±2) °C.

The investigated samples of PP	Number of lactic acid microorganisms in PP, CFU / g, with the duration of storage, day.				
	1	3	5	7	Norma, no less
<i>Streptococcus thermophilus</i> u <i>Lactobacillus bulgaricus</i>					
PP with ACS	$2.7 \cdot 10^7$	$2.1 \cdot 10^7$	$1.7 \cdot 10^7$	$1.15 \cdot 10^7$	$1.0 \cdot 10^7$
PP FDD	$2.9 \cdot 10^7$	$2.2 \cdot 10^7$	$1.8 \cdot 10^7$	$1.3 \cdot 10^7$	$1.0 \cdot 10^7$
The basic recipe	$2.6 \cdot 10^7$	$2.0 \cdot 10^7$	$1.5 \cdot 10^7$	$1.1 \cdot 10^7$	$1.0 \cdot 10^7$
<i>Bifidobacterium</i> u <i>Lactobacillus acidophilus</i>					
PP with ACS	$2.8 \cdot 10^6$	$2.1 \cdot 10^6$	$1.7 \cdot 10^6$	$1.15 \cdot 10^6$	$1.0 \cdot 10^6$
PP FDD	$2.9 \cdot 10^6$	$2.2 \cdot 10^6$	$1.8 \cdot 10^6$	$1.3 \cdot 10^6$	$1.0 \cdot 10^6$
PP on the base formulation	$2.7 \cdot 10^6$	$2.0 \cdot 10^6$	$1.4 \cdot 10^6$	$1.1 \cdot 10^6$	$1.0 \cdot 10^6$

The number of microorganisms tends to decrease in all the investigated samples of PP, but by the end of the storage period this indicator was 4.5% higher for PP with ACS and 18.2% higher for PP with FDD compared to the control sample. This indicates that the formulations of the experimental PP contain more components providing a beneficial effect on the processes of the microorganisms activity in the combined probiotic [25].

4. Conclusion

In modern conditions, the priority of ensuring the safety of the consumer market, both from the standpoint of the formation of the consumer basket, and from the point of view of its filling with safe and balanced food products, the role of the research in the field of new raw materials ingredients and technologies, the methodology of the quality control and safety of farm products is becoming more and more important. Taking into account the role of the enriched dairy products as a factor in ensuring the

quality of the population life, recommendations for the production of PP based on cow milk enriched with bioavailable selenium in the composition of cereal and collagen supplements are scientifically substantiated. Qualimetric models of selenium-enriched probiotic products were developed.

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