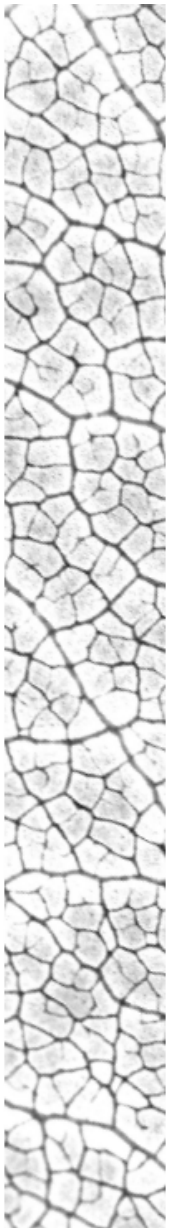

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Food safety control of halloumi type cheese production

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Abstract
In food production, the main criteria are quality and safety. The article presents the results of the adaptation of the elements of HACCP, FTA and FMEA analyzes to the production of semi-hard cheese of Halloumi type made from goat milk. A description of the object of research is also conducted - semi-solid cheese of the Halloumi type of cheese according to the following indicators: ingredient composition, physical and chemical properties, safety standards. The purpose of this work is to identify the critical control points and to analyze the existing risk factors characteristic of the process of producing cheese like Halloumi. The control system of halloumi cheese safety based on the concepts of HACCP. The main risk factors and critical control points have been identified during the production of halloumi cheese. The combination of widely used FTA and FMEA methods highlighted the potential hazards and the ways to prevent them. The elements of HACCP, FTA and FMEA analysis adapted to the production of halloumi cheese from goat milk. For prevention of production of low quality cheese a technological flowchart of cheese production has been developed. The algorithm for determining critical control points is determined by the Decision Tree method. According to conducted research four critical control points during the production of halloumi type cheese determined. The results revealed that there were 11 risks from 8 steps of the production process. The total value of the priority number of the risk of production of Halloumi type cheese is equal to 66. The FTA analysis showed six reasons of defect risks and ways of solution. Application of food safety control systems guarantee the production of safe, high quality cheese by all-round control of processing line.

Keywords: halloumi, risk, hazard, safety, quality, HACCP, FTA and FMEA analyzes

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INTRODUCTION

Modern man cannot imagine his diet without milk and dairy products, and, in the first place, cheeses. Today, cheeses from near and far abroad are gaining increasing popularity among the population. From a practical point of view, Cypriot Halloumi cheese is of particular interest.

Halloumi Cheese is the national pride of Cyprus: in 1999, Cypriots officially established the trade name “Halloumi” for the island. In addition, industrial and private production of this cheese is flourishing in Cyprus (Parademas and Robinson 1998).

Now this cheese is produced all over the world. This cheese has a high melting point, so that it can be fried. Halloumi is unusual in that neither acid nor acid-forming bacteria are used in this cheese. Traditionally, this cheese is made from goat or sheep milk, as well as from their mixture. This cheese has white flesh, which has a characteristic layered texture, somewhat reminiscent of Mozzarella. Halloumi has a salty taste. Cheese may not deteriorate up to a year if it is kept frozen (below -18 ° C), and thawed to + 4 ° C before being put on the supermarket shelf.

Today, Kazakhstan has all raw material possibilities for the production of this kind of goat cheese, which in turn will solve the problem of import substitution and expand the range of cheese on the country’s market. However, the solution of the strategic task of import substitution can be achieved by introducing modern management methods and a system of integral control of the quality and safety indicators of raw materials and products at the stages of the production process (Zelenkin 2013).

The department “Technology of food products and light industry products” of the Shakarim State University of Semey conducts research on the development of technology for the production of Halloumitype of cheese from goat milk.

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In the analysis of international experience in managing the quality of products of foreign countries, the characteristic features of foreign systems that differ from domestic quality management systems were identified.

To ensure the production of safe, high quality products, the ubiquitous control of individual factors of production is necessary (Fox et al. 2000).

An enterprise can ensure the fulfillment of these conditions by improving its production system based on the HACCP (Hazard analysis and critical control points), FMEA (Failure Mode and Effects Analysis) and FTA (Fault Tree Analysis) systems (Putra et al. 2015). These systems will provide an enterprise that produces food products entering the world market and retaining positions in local, domestic markets.

To obtain safe products, the manufacturer needs to develop, implement and maintain procedures based on the principles of HACCP, which are based on hazard analysis, risk assessment and the determination of critical control points during the production process (Denisova et al. 2013, Drankova and Sopin 2013, Kapshakbayeva et al. 2018).

FMEA (Failure Mode and Effects Analysis) - analysis of types and consequences of failures, is a structured approach to identifying potential failures (defects) that may exist when creating a product or developing a process. The results of this analysis, as a rule, are presented in the form of a table. This methodology is a technology for collecting and analyzing the possibility of defects and assessing their impact on the consumer. An integrated approach to the FMEA analysis is proposed in this article for conducting qualitative risk analysis in the production of Halloumi type of cheese (Miroshnikov 2014).

The FTA method is visually represented as a logical diagram. Fault combination analysis is a significant FTA advantage over FMEA. Combining methods allows maximizing their advantages and minimizing their disadvantages (Sharov and Makarov 2011).

The purpose of this work is to identify the critical control points and to analyze the existing risk factors characteristic of the process of producing cheese like Halloumi.

To achieve this goal the following tasks are set:

1) to conduct a description of semi-hard cheese according to key quality and safety criteria;
2) to systematize the types of hazards characteristic of each stage of the life cycle;
3) to identify critical control points in the production process;
4) to analyze the causes and consequences of the production of cheese;
5) to identify risk situations of the production process of cheese.

MATERIALS AND METHODS

The work was done at the department of “Technology of food products and products of light industry” of the Shakarim State University of Semey, and at Federal Altai Scientific Center for Agrobiotechnology, Siberian Research Institute for Cheese Making, Barnaul, Russian Federation.

When performing the work, the methodology described in the national standards ST RK 1179-2003 was used. Quality systems. Food quality management based on HACCP principles. General requirements ST RK ISO 9001-2016.Quality management systems. Requirements, as well as the provisions of Articles 10 and 11 of the Technical Regulations of the Customs Union “On the safety of food products” (TR CU 021/2011) (Technical regulations of the Custom Union “On food safety” (TR CU 021/2011), National Standard of Republic of Kazakhstan 1179-2003, National Standard of Republic of Kazakhstan ISO 9001:2016).

After determining all possible hazards and all possible types of failures, it is necessary to proceed to the determination of the severity **(**S), occurence (O) and detection (D) to identify the priority number of risks (PNR). The detection score for each rating varies from 10 for practically undetectable defects (causes) to 1 - for almost reliably detectable defects (causes) (Tambunan 2013). The priority number of risk is calculated by the formula:

PNR = SxOx D:

For defects that have several causes, several PNR are respectively determined. Each PNR can have values from 1 to 1000, i.e. maximum PNR = 10 * 10 * 10 = 1000 - the worst state; minimal PNR = 1 * 1 * 1 = 1 - the best attainable state.

For the priority risk number, a critical limit (PNR CL) must be set in advance from 100 to 125. The reduction corresponds to the creation of higher-quality and reliable objects and processes. Enterprises that have been using this methodology for a long time, in especially responsible cases, work with the PNR limit 30 <R <50.

When PNR <R, it is assumed that PNR lies in the area of acceptable risk, therefore, the estimated factor is non-hazardous; if the value of PNR> R is in the area of unacceptable risk, which corresponds to the hazard factor; with PNR = R, the risk factor relates to the area of unacceptable risk.

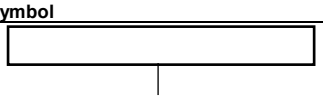
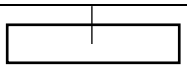
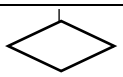
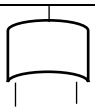
Qualimetric scales of significance of potential failure (S), probabilities of the occurrence of the defect (O), the probability of detection of the defect (D) are presented in **Table 1** (Carrascosa et al. 2016, Shigabayev and Mukhamadullina 2013, Tsany et al. 2017).

When building the Fault Tree, certain symbols are used that carry meaning in them (Bluvband et al. 2005, Potential Failure Mode and Effects Analysis (FMEA) 1995). **Table 2** shows the symbols used in building the FTA for the production of Halloumi cheese.

Table 1. The qualimetric scale of potential failure

Factor S		Factor O		Factor D	
1 – very low (almost no problem)	Failure may adversely affect the process.	1 – very low	Less than 1 time in 5 years	1 – almost certainly the defect will be detected	Failure prevention
2 – low (problems are solved by the employee)		2 – low	Once every 3-5 years	2 – very good detection	
3 – not very serious		3 – not very low	Once every2-3years	3 – good	Control is carried out with the help of measuring tools.
4 – below average		4 – below average	Once a year	4 – moderately good	
5 – average		5 – average	Once in half a year	5 – moderate	
6 – above average	Failure may affect the customer process	6 – above average	Once in 3-4 months	6 – weak	No control manual or visual control
7 – quite high		7 – close to high	Once in a month	7 – very weak	
8 – high		8 – very high	Once in a week	8 – bad	
9 – very high	Threat to life or violation of legislation	9 – very high	Once in 3-4 days	9- verybad	
10 – catastrophic (danger to people)		10 – 100%	More often than once a day	10- almost impossible to detect	

Table 2. Symbols used in the construction of FTA

Symbol	Name	Description
	Top of the event	Event top corresponding to system malfunction
	Intermediate event	Intermediate event corresponding to a fault of higher level than the main event
	Basic event	The main event, has reliability information.
	Undeveloped event	The part of the system that is not developed
	Or gate	Event of exit, and / or at least one of the event.

RESEARCH RESULTS

For the solution of the first task of research, product information was compiled. The product belongs to the group of semi-hard cheeses without ripening, is produced from goat pasteurized milk by rennet coagulation with the subsequent processing of the cheese curd, the second heating of the cheese grain, and also by boiling the cheese heads in hot cheese whey. Cheese is intended both for direct consumption, and can be subjected to frying, has the shape of a bar with a height of 3-5 cm, a diameter of 8-10 cm and a mass of 200-250 g. A detailed description of the product, including the composition, characteristics and safety indicators, is presented in the product card (**Table 3**).

In the technological process of production of Halloumi type of cheese there are a number of drawbacks, dependent and independent of the equipment. One of these is the quality of milk, which in turn can affect the coagulation of milk proteins. Production of this cheese is not associated with a high risk during production, which is due to the fact that one of the final stages of the production process is cooking of cheese heads in hot deproteinized whey, respectively, the risk of contamination of foreign microflora is reduced.

To solve the second task of work in full compliance with the first principle of the HACCP system, an analysis of risk factors characteristic of the process of soft cheese production was carried out. Hazard analysis and identification of appropriate control measures have three objectives. First, the hazards that must be eliminated when implementing the HACCP plan are identified, and measures to eliminate them are identified. Secondly, the analysis can show that it is necessary to make some modifications in the process or in the product itself in order to improve it or make it even safer. As a result of this analysis, a basis appears for determining the critical control points (CCPs), which are referred to in the second principle of HACCP (Abid et al. 2009, Norton 2003), which in turn solves the third problem. Risk analysis is preceded by comprehensive work on the systematization and characterization of common hazards in the production of halloumi type of cheese. There are various approaches to the analysis of risk factors, we will use the recommendation on the construction of the chart, which is presented in ST RK 1179-2003. The analysis of hazardous factors characteristic of the technological process of soft cheese production showed that all four types of hazards are inherent in the product at different stages of its life cycle as part of production. At the same time, the risk unacceptable for the consumer of cheese is of a biological nature (microorganisms), and also caused by the presence of pathogenic microorganisms in the composition of the product.

Table 3. Product Card

List of questions on the source information / Source of information	Components / Indicators	Norm
1. Product Name / Project of Technical conditions	Semi-hard goat cheese	
2. Product contents/ Project of Technical conditions	Pasteurized goat milk, E509 calcium chloride, enzyme preparation of animal origin, salt.	
3. Key Product Features / Project of Technical conditions	Physical and chemical	
	Mass fraction of fat in the dry matter of cheese,%	47.1
	Mass fraction of moisture,% not more than	41-43
	Mass fraction of moisture in the fat-free substance,%, not more	55-57
	Mass fraction of salt,%	1.5-2
4. Safety indicators / Technical regulations of the Customs Union. 033/2013	4.1 Microorganisms	
	Coliform bacteria	Not permitted in 0,001 cm^3 (g) of product
	Pathogenic (including salmonella)	Not permitted in 25 cm^3 (g) of product
	Staphylococcus S. aureus	Not permitted in 0,001 cm^3 (g) of product
	Listerias L. Monocytogenes	Not permitted in 125 cm^3 (g) of product (5 samples of 25 g each)
	4.2 Antibiotics	
	Levomycetin (Chloramphenicol)	Not permitted (less than 0.0003 mg / kg (l))
	Tetracyclinegroup	Not permitted (less than 0.01 mg / kg (l))
	Streptomycin	Not permitted (less than 0.2 mg / kg (l))
	Penicillin	Not permitted (less than 0.004 mg / kg (l))
	4.3 Toxic elements	
	Lead	Not more than 0.5 mg / kg
	Arsenic	Not more than 0.3 mg / kg
	Cadmium	Not more than 0.2 mg / kg
	Mercury	Not more than 0.03 mg / kg

Table 4. Potential hazards in cheese production

Process stages, potential hazard	Controlled parameter	Acceptable values
Acceptance of raw materials - chemical - physical - microbiological	- the content of somatic cells in 1 cm^3, acidity ^0T - residues of disinfectants, impurities, suspended particles - amount of mesophilic aerobic and optional anaerobic microorganisms, colony forming units; purity group	-1.0 * 10^8 cells in 1 cm^3; not less than 14.0-21.0 ^0T - not permitted - 5,0*10^3; not below II
Pasteurization and cooling - microbiological	- survival of pathogenic and conditionally pathogenic microorganisms	not permitted
Enzyme introduction and fermentation - microbiological - physical	- penetration of extraneous microflora - foreign inclusions due to poor-quality washing of equipment, non-compliance with hygiene rules by staff	not permitted
Curd processing, molding, self-pressing: - microbiological - chemical - physical	- penetration and development of extraneous microflora - detergent and disinfectant residues - extraneous inclusions	not permitted
Moulding: - microbiological	- penetration and development of extraneous microflora	not permitted
Storage: - microbiological - physical	- penetration and development of extraneous microflora - extraneous inclusions	E. coli bacteria, S. aureus – not allowed in 0,001 gr. product Pathogens, including salmonella and L.monocytogenes are not allowed in 25 gr. of product Yeast, mold - notallowed

Dangerous factors that must be considered in the production of cheese on the basis of goat milk, as well as the permissible values set out in the Technical regulations of the Customs Union 033/2013, are given in **Table 4**.

Critical control points were determined by conducting an analysis separately for each factor taken into account (Vayskrobova 2011) and examining successively all the operations included in the flowchart of the production process. In order to control the critical points, in accordance with HACCP, it is necessary to refer to the flowchart of the process for the production of semi-hard goat cheese (**Fig. 1**).

As a result of the analysis of the initial information, a technological flowchart of cheese production has been developed to prevent the production of poor quality products, quality control and safety (**Table 5**). The algorithm for determining critical control points is determined by the Decision Tree method (Scipioni et al. 2002). An example of determining the CCP in production is given in **Table 5**.

According to **Table 6**, it can be concluded that the control critical point in the production of Halloumi type of cheese will be the stage of pasteurization, moulding, salting and storage.

The FTA-FMEA failure analysis methodology is proposed as a method of analyzing the safety of technical systems. This is an innovative combination of two traditional and widely used methods of reliability analysis: “Failure Mode and Effects Analysis” (FMEA) and “Fault tree analysis” (FTA) (Segismundo and Miguel 2008, Wahyunegara et al. 2013).

Table 6 presents an analysis of the causes and consequences in the production of Halloumitype of cheese.

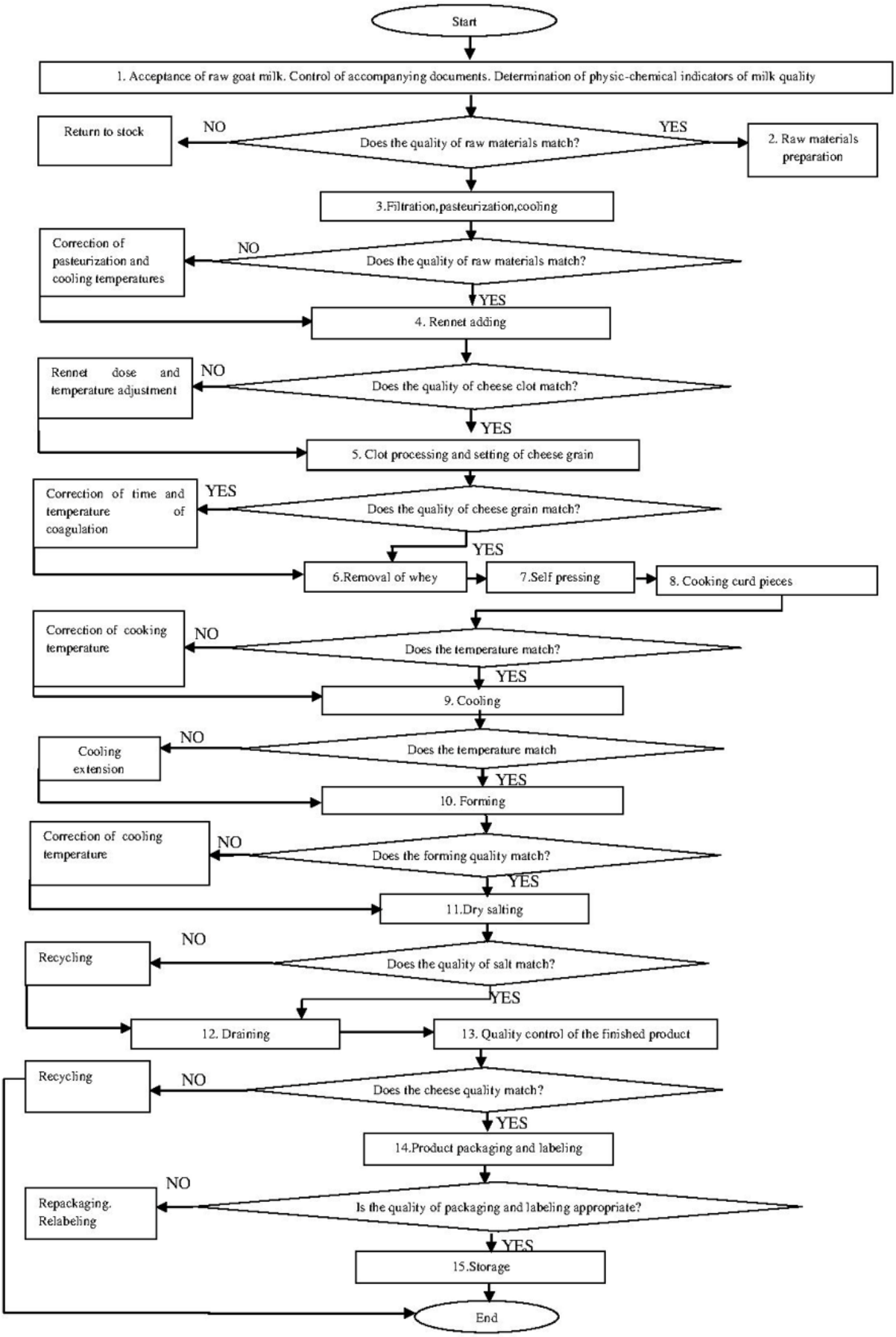


Fig. 1. Block diagram of the technological process of production of Halloumi type of cheese

Table 5. Determination of the CCP in the production of Halloumi type of cheese

Stage of process	Hazard factors	Questions				Will it be the stage of the CCP
		Q1	Q2	Q3	Q4	
Acceptance of raw milk	Microbiological factors: - contamination of raw materials by pathogenic microorganisms	No	No	Yes	Yes	No
	Physico-chemical: - penetration of disinfectants and extraneous materials	Yes	No	Yes	Yes	No
Pasteurization and cooling	Microbiological: - survival and penetration of pathogenic microorganisms	No	Yes	No	No	YesCCP1
	Physical: - violation of technological parameters of pasteurization	No	Yes	No	No	
Milk coagulation and curd treatment	Microbiological: - penetration of pathogenic microorganisms	No	No	Yes	Yes	No
Self pressing	Microbiological: - penetration of pathogenic microorganisms	No	No	Yes	Yes	No
Moulding	Microbiological: -penetration of pathogenic microorganisms	No	No	No	No	No CCP2
Salting	Microbiological: -penetration of pathogenic microorganisms	Yes	Yes	Yes	No	Yes CCP3
Storage	Physico-chemical: - violation of storage temperature, humidity, pH, acidity.	No	No	Yes	No	Yes CCP4
	Microbiological: - E. coli contamination, yeast	No	No	Yes	No	

Table 6. FMEA Analysis of Causes and Effects

Element	Probable defect	Possible consequences of the defect	Probable cause	Actions	Detection method
Equipment and machinery	Contamination by pathogenic microflora	Reduced cheese quality	Inadequate disinfection and processing equipment and violation of sanitary rules and regulations	Careful treatment with detergents and disinfectants before and after each production cycle	Microbiological
Raw milk	Low quality milk	Reduced cheese quality	Unscrupulous suppliers and quality control of raw materials	Improving the communication skills of quality control of raw materials	Physico-chemical and microbiological methods
	Contamination of milk when entering the milk receiving container	Reducing the quality of raw materials	Inadequate disinfection of equipment	Sanitary treatment of premises and equipment	Microbiological
Milk pasteurization	Inadequate pasteurization temperature	Preservation of pathogens	Non-compliance with pasteurization regimes by workers	Constant temperature control	Physical method
Enzyme introduction	Weak coagulation	Flaccid clot	Non-compliance with the dose of enzyme	Control of the dose of the enzyme preparation	Visual
	Contamination during curd formation	Reduced cheese quality	Frequent opening and closing of the starter machine	Regular inspection of the premises and employee hygiene	Microbiological
Curd treatment	Contamination during curd processing	Reduced cheese quality	Non-compliance with the rules of personal hygiene and sanitary rules in the production workshop	Monitoring the cleanliness of the production workshop and personal hygiene of staff	Microbiological
Moulding	Contamination by extraneous microflora	Reduced cheese quality	Non-compliance with the rules of personal hygiene and sanitary rules in the production workshop	Monitoring the cleanliness of the production workshop and personal hygiene of staff	Microbiological
Salting	Contamination by extraneous microflora	Reduced cheese quality	Non-compliance with the microbiological quality control of brine	Regular quality control of cheese	Microbiological
Packaging	Inefficiency of the packaging material	Increase of the cost of packaging.	Poor packaging material	Change of packaging material	Visual

As a result of the analysis, 10 potential hazards were identified that may affect the technological process of cheese production.

Typical values of detection points in the production of cheese are shown in **Table 3**. The critical limit of PNR CLis assumed to be 100.

According to the data obtained, the total value of the priority number of the risk of production of Halloumi type cheese is equal to 66 and lies within the permissible risk area (PNR CL = 100) and can be assessed as non-hazardous.

The next step in risk analysis was to create a fault tree (FTA). The fault tree can reveal the cause of the risk in a more detailed way. The principle of the method is applied in systems that include several interdependent subsystems, as well as to identify hazards and assess risk, the frequency of occurrence of defects or risk situations. The principle of constructing FTA, as a graphical system for constructing a “fault tree”, is a deductive (downward) analysis method aimed at identifying the cause or its combinations that contribute to the accumulation of the risk of defects (Huang et al. 2004).

As a result of the research (**Fig. 2**), 10 risks from 8 production elements were identified: equipment, raw milk, pasteurization, enzyme application, curd processing, moulding, salting and packaging.

Table 7. SOD risk value in the production process of Halloumi type of cheese

Element	Risk	S	O	D	PNR
Equipment	Contamination by pathogenic microflora	1	1	1	1
Raw milk	Low quality milk	3	2	2	12
	Contamination of milk when entering the milk receiving container	2	2	2	8
Milk pasteurization	Inadequate pasteurization temperature	1	1	1	1
Enzyme introduction	Weak coagulation	2	1	1	2
	Contamination during curd formation	2	2	3	12
Curd treatment	Contamination by extraneous microflora	1	1	1	1
Moulding	Contamination by extraneous microflora	4	2	2	16
Salting	Contamination by extraneous microflora	3	1	3	9
Packaging	of the packaging material	1	4	1	4
Total					66
Critical rate					6,6

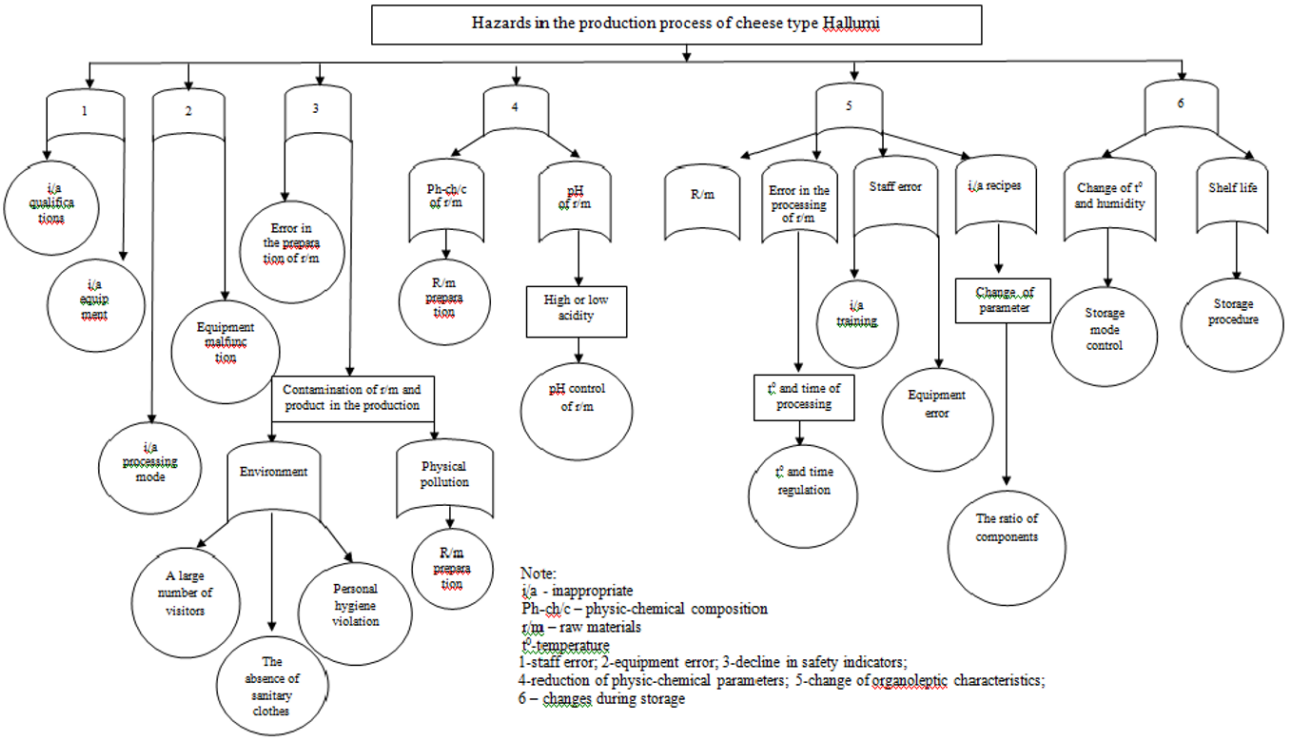


Fig. 2. Sheet of hazards during the production of halloumi type chees

CONCLUSION

The development of the HACCP system, taking into account the technological features of the production of Halloumi type of cheese, allows determining the stages at which risks may arise and also prevent their occurrence. The construction of a production flowchart of the technological process serves as the basis for carrying out a risk analysis and allows the identification of possible hazards. Using an algorithmic assessment of the list of possible hazards, critical control points (CCPs) were established along the process. A necessary condition for the CCP is the presence of a hazard in the considered operation, its identification and taking preventive measures that eliminate the risk or reduce it to an acceptable level (Chelyshkova et al. 2018, Mirzamasoumzadeh and Mollasadeghi 2013, Tel et al. 2018). Thus, to ensure safety in the production of cheese, a systematic approach is needed, taking into account potentially dangerous factors, including microbiological, at all stages of the production process from raw materials to finished products.

An analysis of the FMEA method revealed priority number of risks (PNR) compared to the critical limit of PNR. Critical risks such as contamination by extraneous microflora of equipment, poor quality milk, contamination of milk when entering the milk receiving container, inadequate pasteurization temperature, weak coagulation, contamination by extraneous microflora during curd processing , contamination by extraneous microflora during curd formation, contamination by extraneous microflora during moulding process, contamination by extraneous microflora in the process of making filler and salting, as well as poor packaging material.

The analysis made it possible to identify and describe the risks in the production of Halloumi type of cheese. Application and implementation of the principles of HACCP, FMEA and FTA will significantly improve

production efficiency, product quality, labor productivity, reduce material and time costs, as well as improve production efficiency, product quality, labor productivity, reduce material and time costs, as well as improve the competitiveness of the enterprise.

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