

## FORMATION AND CONTROL OF THE QUALITY OF FOOD AND FEEDS: FROM THE BASIC TECHNOLOGIES TO THE HUMAN FACTOR

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**Abstract.** Today, the European vector of our country's development and the strategy of economic partnership with the EU pose certain challenges for our state. Signing the EU Association Agreement made an important impact on the changes in Ukrainian legislation concerning harmonization of laws and rules in economics. Providing the proper quality of agricultural products remains an important task. It requires improving the organizational and legal support in changing accents in legal regulation: giving manufacturers more freedom in economic issues instead of administering directly. The above-mentioned Agreement gave a good boost to create the State Service of Ukraine for Food Safety and Consumer Protection, which, in turn allowed merging three state organizations to start monitoring food safety and quality "from field to fork." Especially important are the Requirements to the Development, Introduction, and Usage of Standing Procedures based on the HACCP system principles. Today, HACCP-based certification of standing procedures is not obligatory, unlike the presence of Prerequisite Programmes of HACCP, which is obligatory. A Prerequisite Programme must cover 13 processes: from planning the manufacturing, auxiliary, and staff facilities in order to avoid cross-contamination to marking finished products. A number of requirements must be met by each of these processes in particular. The authors of this article have analysed the legislation changes and the latest publications about a number of Ukrainian food enterprises that have introduced the HACCP principles. This analysis has allowed concluding that in these enterprises, this process has caused some changes in their manufacturing technologies and management systems. Groups of factors influencing the products' quality have been outlined. The importance of the human element at various stages of quality formation and control has been emphasized. The existing systems of quality and safety management in food industries have been analysed in detail.

**Key words:** quality control, HACCP, human element in the quality system, microbiological control, quality management systems.

### Introduction. Formulation of the problem

The approaches to the quality control of food and feeds in Ukraine have changed in the last 10 years. Ratification of Ukraine – European Union Association Agreement became a boost to some changes in Ukrainian legislation. The Act of Ukraine "State Control and Compliance with the Legislation for Foods, Feeds, Animal By-products, Health and Well-being of Livestock" [1] has come into operation. It was developed to bring the Ukrainian state control

legislation into compliance with European standards for the safety and quality of food, feeds, health and well-being of livestock (EU Regulations # 854/2004, 882/2004, and 669/2009, and European Council Directive # 97/78/EC).

Some changes have been made to the Act of Ukraine "The Main Principles and Requirements to Safety and Quality of Foods," and the requirements have been approved concerning the development, introduction, and usage of standing procedures based on the principles of food safety regulation system

(Hazard Analysis and Critical Control Points – HACCP) [2]. The progress of individual enterprises and branches of economy on foreign and domestic markets depends completely on how fully their products or services meet the quality standards. Increasing the quality of products is a long-term task. The products' quality must be optimum in any period of their existence, in order to satisfy the consumers' demands as fully as possible at minimum cost. This is

why the problem of ensuring and improving the quality of products is important for all countries and enterprises, since the progress and effectiveness of national economy largely depends on its solution [3].

**The purpose of the research** is to investigate the changes in legislation and the recent publications on introducing the HACCP system by food companies in Ukraine, and to analyse the sequence of changes in the quality management system (Fig. 1).

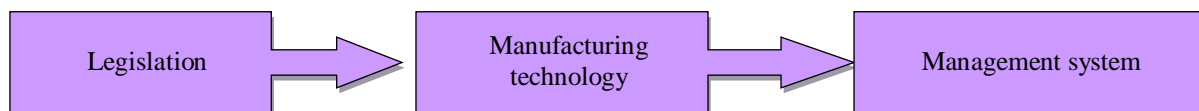


Fig. 1. Logical sequence of changes in the quality management system

Thus, the article was supposed to design a system of food and feed quality evaluation, which has been achieved by solving the following **objectives**:

- systematize and analyse the legal and regulatory basis;
- find and define changes in food quality evaluation;
- monitor and prove the relation between effective management at a manufacture and the human factor at all technological stages.

#### Analysis of recent research and publications

In 2000, the EU activated a so-called “new concept” of food products hygiene reflected in the *White paper on food safety* [4]. According to its principles, the safety policy for food products must be based on a commonly shared comprehensive concept. This concept should comprise the entire food chain, from the manufacturer to the consumer, and all food industry sectors in all member states and all geographic regions of the EU and on its outer borders [4]. The Ukraine – European Union Association Agreement became operative on 1 September 2017, after a long process of ratification [5]. By the results of the session on 17 December 2018, the EU Council acknowledged the progress achieved so far, but Ukraine must fulfil all the preconditions listed in the Association Agreement. These preconditions include the implementation of the corresponding EU legislation in the national legislation, introduction of administrative and institutional reforms, and establishing an effective and transparent administration system. All this is necessary to start negotiations about the Agreement of Conformity Assessment and Acceptance of food products (ACAA) [5].

Providing a proper quality level of agricultural products during the transition to indicative planning, and changing the emphasis in using the legal regulation methods (switching from administrating to giving food manufacturers more economic freedom) requires improving the organizational and legal maintenance of this process [6].

Given the situation in Ukraine, the process of evaluation must be started with regulating and improving its organizational structure, as Professor Ye. Kyrylyuk states [7]. He specifies that, according to modern (particularly, European and American) requirements, a provision for the effectiveness of the entire system is the existence of a single organ to monitor the safety and quality of food products “from field to fork” (equivalent to the FDA in the USA or the EFSA in the EU) [7].

In 2015, the functions of food quality and safety control and consumer rights protection were distributed among three subjects in Ukraine:

- 1) State Veterinary and Phytosanitary Service of Ukraine;
- 2) State Sanitary and Epidemiological Service of Ukraine;
- 3) State Inspection of Consumer Rights Protection of Ukraine [8].

Besides, before 9 December 2010, such controlling structures used to be even bigger since the State Veterinary and Phytosanitary Service of Ukraine was created as a successor to the State Veterinary Medicine Committee, State Plant Quarantine Inspection, and State Inspection of Plant Protection. Order # 442 of the Cabinet of Ministers of Ukraine of 10.09.2014 “Optimization of systems of the central organs of executive government” decreed formation of the following: State Service of Ukraine for Food Safety and Consumer Protection, by reorganizing and merging the State Veterinary and Phytosanitary Service, State Inspection of Consumer Rights Protection, and State Sanitary and Epidemiological Service [9].

Professor D. Krysanov states that development of state standards (later renamed into national standards) and their harmonization with international and European regulatory documents has become the central element in establishing a national technical regulation system [10]. In this process, the socially demanded quality level of agricultural products (where the requirements of manufacturers and consumers would coincide) is achieved by a system of regulating the consumer properties and characteristics of products,

with evaluating them at each stage of planning, manufacture, storing, transportation, and processing, as stated by I. Bugeza, a senior scientist of NAAS [6].

As mentioned above, on 4 April 2018, the Act of Ukraine “State Control and Compliance with the Legislation for Foods, Feeds, Animal By-products, Health and Well-being of Livestock” came into force [1]. With this law, a new system of food quality and safety control started. Particular attention should be given to Sections 3 and 4 of Article 18 of this Act. Section 3: “State control activities are made without warning (notifying) the market operator, except for audit and other cases when such notification is a necessary prerequisite for state control effectiveness. Auditing of standing procedures based on HACCP is made only with notifying the market operator no later than three working days prior to the activity [1]. The notification is made by recorded delivery to the location (residence) of the market operator listed in the Unified State Register of Legal Entities, Individual Entrepreneurs, and Social Organizations, and/or by e-mail to the market operator’s address listed in that Register, or by delivering on receipt personally to the head or a contact person of the market operator.” Section 4: “Activities of the state control can be unannounced in case of detection of incompliance, or reasonable suspicion of incompliance, and also in other cases listed in the law” [1].

From now on, the control is made by only one official body, the State Service of Ukraine for Food Safety and Consumer Protection (SSUFSCP). Besides, a risk-oriented approach to this control is introduced: the lower the risk level of a market operator’s activity, the lower the inspection frequency for this operator. At the same time, state inspectors are granted wide-ranging powers, and high penalties are introduced for violators.

On 1 October 2012, the Ministry of Agrarian Policy and Food of Ukraine approved (Decree # 590) the “Requirements to development, introduction, and use of standing procedures based on the principles of the food safety regulation system (HACCP).” On 20 September 2016, part 7 of the Act of Ukraine “The Main Principles and Requirements to Food Safety and Quality” became operational. It states clearly that all food market operators must have programmes (at least prerequisite) of introducing HACCP. The time limits are set: 3 years from the date when this statute became operational, i. e. before 20 September 2019 [11].

The HACCP system focuses on the highest risks directly related to food production, its technology, and raw materials used. It supposes the presence of additional specific control activities. HACCP is a system method of food safety based on the seven main principles shown in Fig. 2.

Within HACCP, usually three types of hazardous factors are considered: microbiological, chemical, and physical. The microbiological hazard is associated

with microorganisms: bacteria, viruses, zoonoses, mycotoxins.

The system of hazard analysis and critical control points (HACCP):

- active and systemic approach to food safety control as a general continuous system, from growing a product to its consumption, to guarantee the safety of the final food product;

- technical and mental processes that include procurement, reception, storage, cooking, treatment and make up a continuous system;

- evaluation system to identify, monitor, and control contamination hazards for foods in a continuous manufacturing process.

Introduction of HACCP is quite a long process that concerns all services and personnel. It is not limited to just developing documentation and the general arrangement of a manufacture. It is important that all members of the food chain up to the final consumer be scrupulous in their responsibility [17].

This year, the SSUFSCP will make planned audits of the HACCP system for the first time. In general, 4540 economic entities will have HACCP audits, according to the SSUFSCP inspection plan for the year 2019.

The general principles of manufacturing control include: incoming control of raw material and food quality and safety; control of the technological process; control of stored foods; control of the sanitary and technical condition of rooms and equipment; control of the manufacturing conditions and environment; control of the staff’s personal hygiene [12]. Fig. 3 shows a control organization diagram for raw material quality, technological processes, and finished products, with a compound feed manufacture taken as an example.

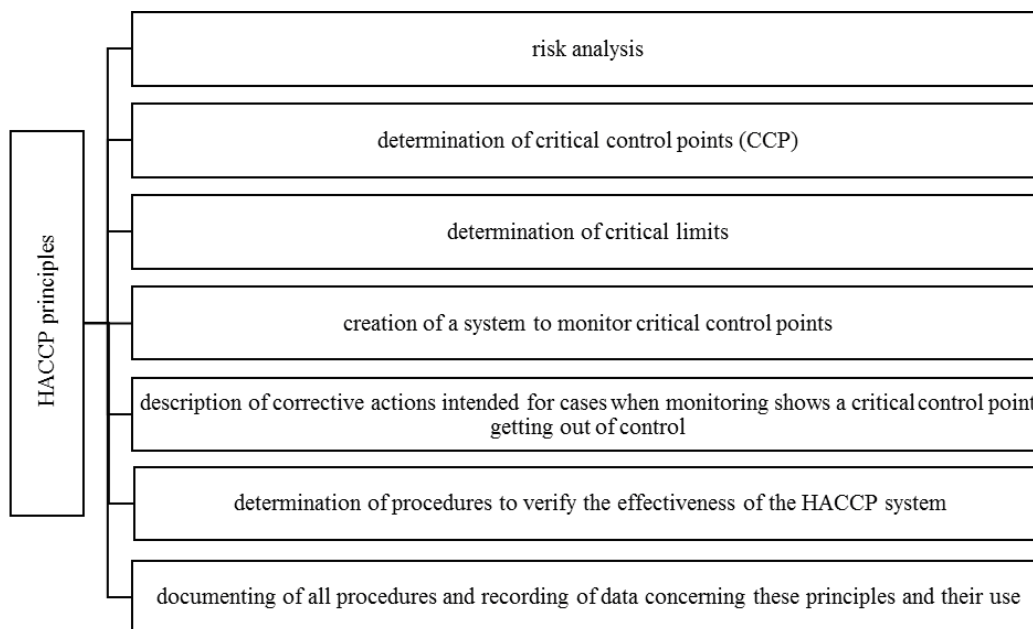
The experience of Alebor Group deserves attention. Introduction of HACCP at the Alebor Group grain elevators has caused changes in the work of the laboratories. The following critical points were specified by the auditor (Fig. 4).

Numerous aspects influence the validity of the results: the personnel’s qualification, orientation training upon starting the job, and further regular training in the course of validation, the correct choice of laboratory equipment and laboratory glassware, knowledge of legislation, the staff’s compliance with hygienic requirements, and even the presence of special work clothes [13].

Analysis of aspects of influence on the quality of products allows making emphasis on the human factor. In order to lower the impact of the human factor, it is necessary to automate the processes of sampling, dosing, and mixing as much as possible. For example, in order to improve the quality of grain sampling, it is possible to combine usage of a “smart” sampler (that will provide proper sampling according to the corresponding requirements, and deliver the samples to the laboratory) and their analysis by

automatic testing sieves and IR analysers. Using automated analysers remarkably influences the time needed for grain fractioning and forming a pure sample, and allows making a simultaneous test of all the required quality factors of grain (protein, fibres, moisture content, fat, starch, ash content, and weight by volume).

The next human factor affecting the product quality is the staff's qualification. Investigations made at the bread-baking manufactures *DP PAT Kyivhlib Hlibokombinat #10* and *DP PAT Kyivhlib Hlibokombinat #12* have shown that the degree of the human factor impact at these manufactures is quite high, accounting for 26 to 36 % of total defects, with an increase in recent years [15].



**Fig. 2. The main principles of HACCP [26].**

Equipment calibration, sampling methods, and general authenticity of results are susceptible to the human factor. Clear working rules must be developed at the manufacture, where the codes of conduct in the premises and laboratories would be specified in order to decrease the probability of violating the technology and methods due to human inadvertence.

It is also important to note that, in a discrete quality control, the control frequency must be increased depending on the production capacities, or continuous monitoring devices must be used in the production process. An example is the systems of automated control of grain temperature in silos during storage by thermal sensors. Their signals are conducted by cables to a computer system. The temperature of grain can be taken within a schedule according to the optimum temperature and the storage conditions. An efficient control system monitors the temperature inside the grain mass and its deviation from normal, and a conclusion about aeration necessity is made by these results [16].

According to the "Standardization" Act of Ukraine of 05.06.2014 [17], all standards are voluntary, but according to Act of Ukraine # 1602

"The Main Principles and Requirements to Food Safety and Quality" of 22.07.2014, it is even possible to work according to contract specifications [18]. In fact, any manufacture must have a list of methods by which its laboratory makes investigations, and can make changes to that list at the client's request, but only if the method has been validated, and it is confirmed by a corresponding record. But the contracts usually specify the use of international standard ISO, and these specifications obligate most laboratories to validate them.

The review of literature and the analysis of changes in control and management of food and feed quality allow making conclusions that effective management at a manufacture depends on people, and that the significance of management (the human factor) is increasing at all technological stages (Fig. 5).

The presence of an effectively functioning food safety control system at a manufacture is confirmed by its external certification in one of the schemes recognized by the world community. There are several such schemes of certification.

Let us consider the existent systems of quality and safety management at food manufactures. The existent models of quality management are shown in Fig. 6.

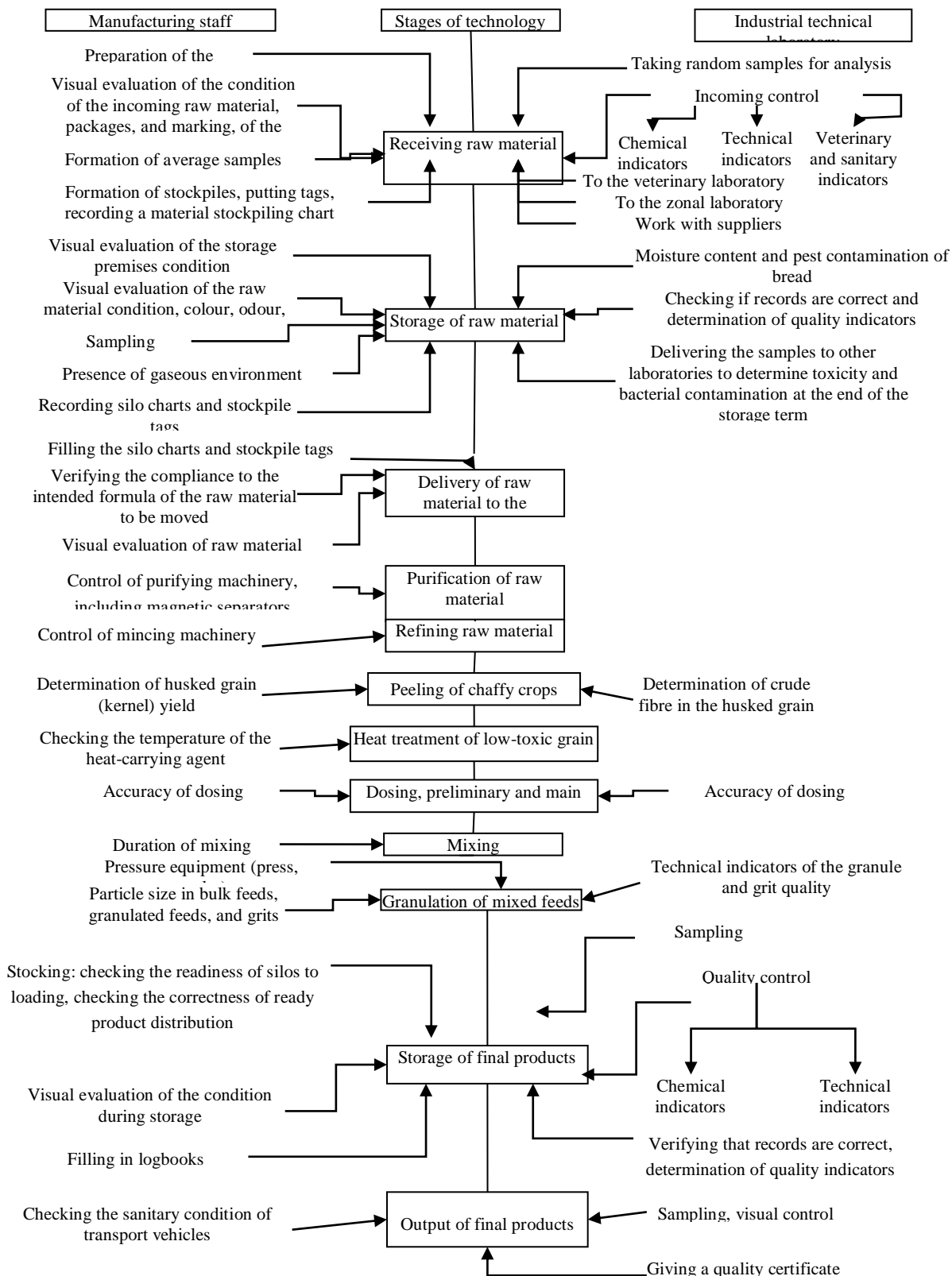


Fig. 3. Organization of control over the quality of the raw material, the technological process, and the final product at a compound feed manufacture [12]

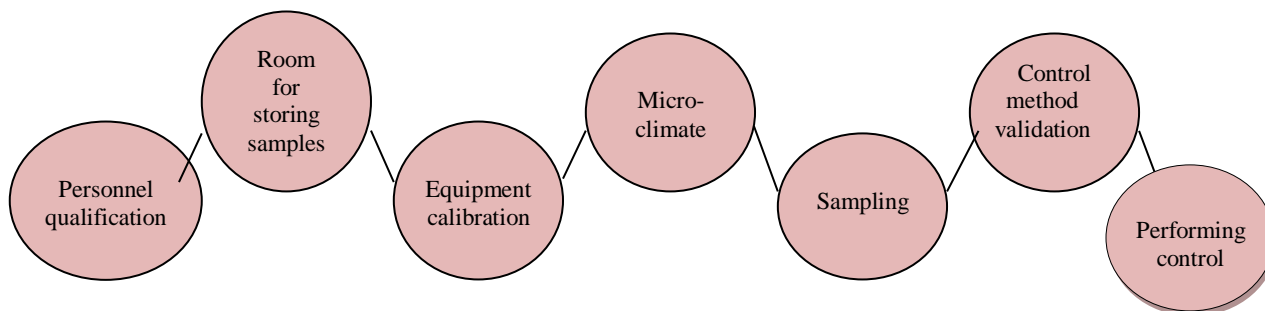


Fig. 4. Possible critical points in the work of the elevator laboratory [13].

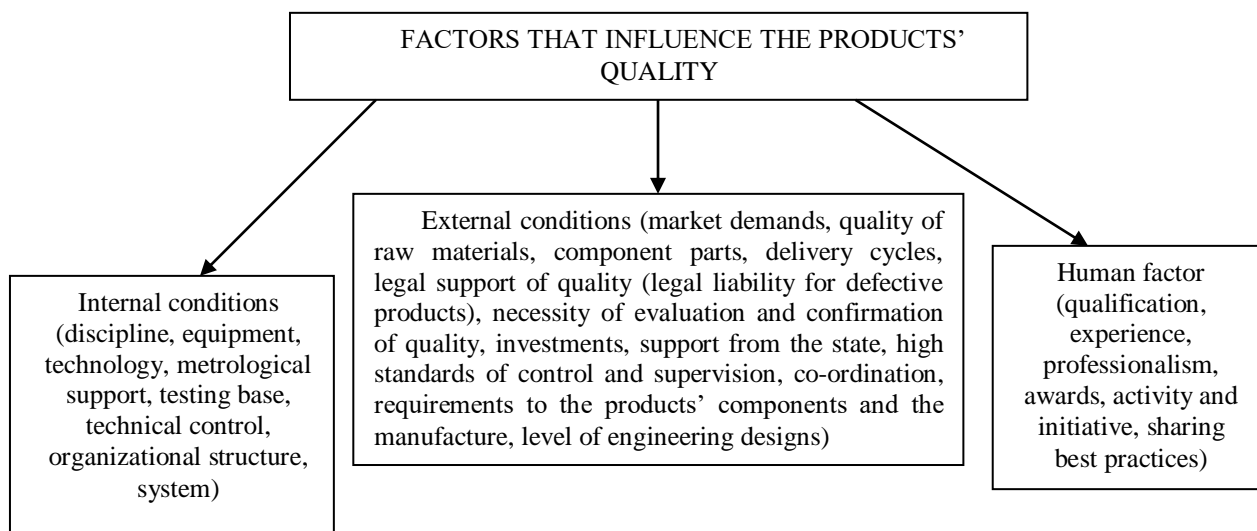


Fig. 5. Factors that influence the products' quality (developed by the authors).

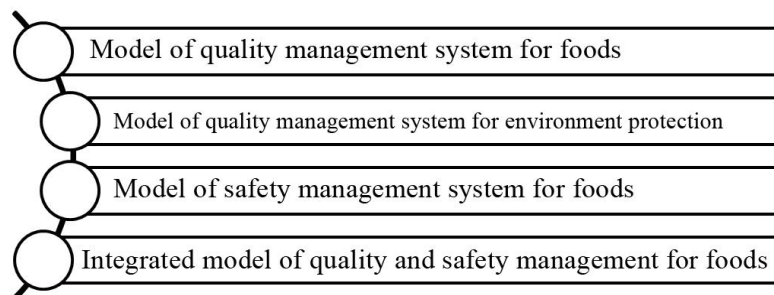


Fig. 6. Models of quality management [18].

Development and implementation of a system is characterized by the specific features of the manufacture's activity, the work scope, and the size of the manufacture, by whether the manufacture is industrial or retail, how many articles it manufactures or sells, and by many other factors.

The main components of quality and safety control in the modern food industry are: the system of quality management (GMP) at a manufacture, complying with international ISO 9000 standards; the system of product safety according to the HACCP principles; the

systems of industrial hygiene and sanitation (GHP); the system of ecological management according to ISO 14000. On 1 September 2005, the standard ISO 22000 was introduced. It specifies requirements to a food safety management system at each stage of the supply chain [4]. A quality management system is necessary at any modern manufacture to achieve the goals of commercial trade (Fig. 7). But the existing system of food safety management requires from manufactures accomplishing some tasks (Fig. 8).

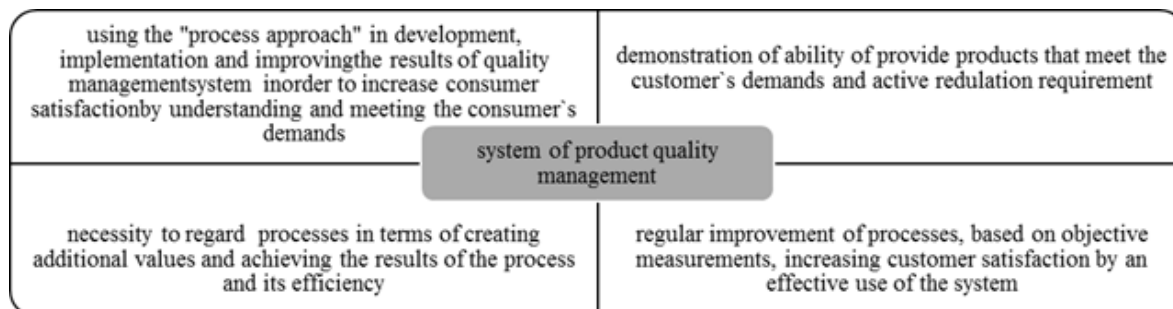


Fig. 7. The structure of a manufacturer's goals implemented via a product quality management system [20].

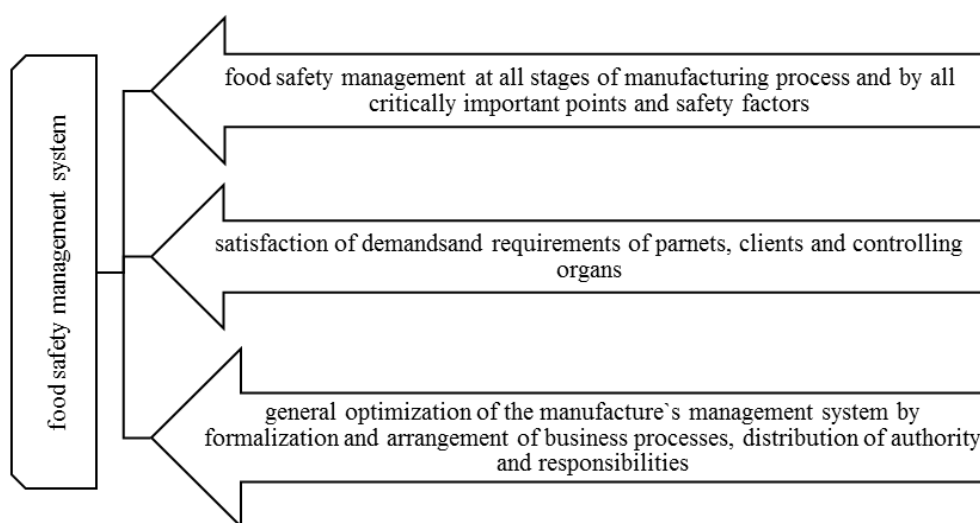


Fig. 8. The structure of a manufacturer's goals implemented via a food safety management system [20]

Currently, the following systems of providing food quality and safety are mainly used in industry [22]:

- Good Manufacturing Practice (GMP);
- Good Hygienic Practice (GHP);
- Hazard Analysis and Critical Control Points (HACCP);
- systems of quality management according to ISO standards: series 9000 includes ISO 9000, ISO 9001, and ISO 9004 (quality management systems), ISO 14000 (ecological management system), and ISO 17025 (requirements to accreditation of a laboratory);
- a system of safety management according to the requirements of ISO 22000 “Food safety management systems – Requirements for any organization in the food chain”.

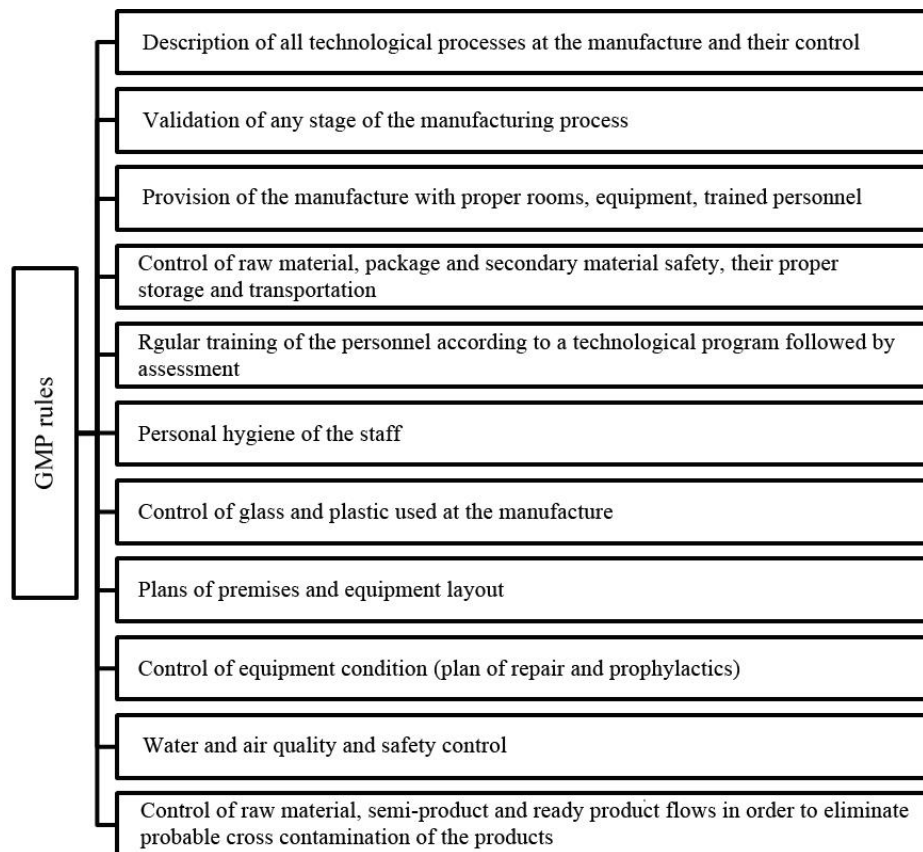
Each of these systems is an effective instrument to provide safety of the food produced, but using these systems in combination is the most effective and successful.

The main GMP schemes contain clear standards and requirements to guarantee a safe delivery (FSA) and responsible working methods (FRA) along the whole chain. This concerns not only the manufacturing capacities, but also storage, transportation, personnel,

and the production process itself. This system is basic for any food and compound feed manufacture. The main rules of the GMP standard are shown in Fig. 9.

Other programmes of preliminary measures, no less important for food safety, are associated with GMP programmes: practice of traceability of products from the field to the final consumer, the procedure of product withdrawal, sanitary and hygienic practice (GHP), the programme of pest control (deratization and insect control), control of chemicals used at the manufacture, the programme of responding consumers' complaints, the programme of control and evaluation of suppliers, the programme of livestock farms mechanization, the programme of internal and external audits.

For this reason, it is necessary to make emphasis on the programme of sanitary-hygienic activities, or hygienic practice. GHP is defined as the “main hygienic activities that must meet the requirements of food production at an acceptable safety level” [24]. This programme specifies regular procedures of the staff health control, hygienic training of the staff, microbiological control of water and surfaces food contacts with, washing and disinfection activities.



**Fig. 9. The basic GMP rules [29]**

The following must be developed at a food manufacture: a procedure of washing and disinfection of the manufacturing premises and equipment (which must include a list of detergents and disinfectants), rules of using them, recommended concentrations, and frequency of treatment. Disinfection means killing microorganisms, including pathogens, but, unlike sterilization, it does not make the object totally free of microbes. Effective disinfection lowers the microbial numbers to a level that is safe for a consumer's health.

If this programme is necessary, its methods must be developed after consultations with experts in that branch. An adequate control method must be specified to evaluate the effectiveness of sanitary activities. For example, there are traditional classical methods of inoculating nutrient media and cultivating for 24–48 hours [25]. However, these methods are usually laborious, time-taking, and not universal. They can be realized only when there is a high-quality laboratory base and professional staff at the manufacture. So, express methods of controlling the manufacture's sanitary condition are more popular. The most promising one is the bioluminescence method based on detecting intracellular ATP (adenosine triphosphate) [26]. ATP is the main source of energy necessary for all living cells to maintain their biochemical reactions. The method's principle is measuring the luminescence (light emission) that occurs because of a biochemical

reaction of oxidation of luciferin by atmospheric oxygen under action of firefly luciferase only in the presence of ATP [27]. In the process, the adenyloxyluciferin complex breaks down, and energy is released as light. The number of light quanta is proportional to the ATP concentration. Thus, ATP is used as an indicator of both organic and microbial contamination of the tested objects. The intensity of light emission is measured directly by luminometers that are reliable, portable, and easy in operation. Using this express method allows taking immediate measures (if required) before starting the technological line, and preventing spoilage.

An important factor in making safe products is preventing cross and secondary contaminations of ready products by various microorganisms. To this end, the manufacture must have clearly specified routes of the staff's movement and ways of transporting any raw materials, semi-products, and ready product. Also, conditions must be created that will totally eliminate the cross contamination.

It is very important to create such conditions for the food safety in which the food, packaging materials, and surfaces in contact with foods will be reliably protected from various kinds of microbiological, chemical, and physical contamination. A complex of food safety activities is developed for each



manufacture individually based on its specific character.

The systems of quality management in the ISO 9000 series are intended, first of all, to create a system of quality management. The main emphasis there is on satisfying the consumer by producing a high-quality product or service [30].

The main principles of the ISO 9000 quality management system:

- consumer orientation: the organizations depend on their consumers and therefore must understand the consumer's current and future demands, satisfy them, and look to surpassing the consumer expectations;

- leadership: leaders determine the uniformity of goals and regulation in the organization, create and maintain conditions where the staff can be entirely engaged in achieving the organization's goals;

- engagement of the staff: the staff is the organization's backbone at all levels, and its total engagement allows using the staff's full capacity to the organization's benefit;

- process approach: the desired result is achieved more effectively when the corresponding resources and activities are regulated as processes;

- systemic approach to the management: specification, understanding, and regulation of a system of interdependent processes in order to improve the results and effectiveness of the organization;

- continuous improvement: it must be a constant goal of the organization;

- decision-making based on facts: effective decisions are based on data and information analysis;

- mutually beneficial relationships with the suppliers: the organization and its suppliers are mutually dependent, and their beneficial relationships increase the ability to produce valuables.

The standards of this series do not cover the food safety, that is why, food industries that aimed at creating both a safety system and a quality management system had to work with several standards and make an integral system of quality and safety on their own. In 2005, a new international standard was approved: ISO 22000 "Food safety management systems – Requirements for any organization in the food chain" [28]. This standard became a kind of compilation of requirements to a safety system and a quality management system. Its developers tried to merge the requirements of ISO 9001 and HACCP. These days, more and more food industries work according to this standard. It is convenient as it covers all requirements to both a quality management system and a safety system in one document.

The ISO 20000 specifies requirements to a food safety management system that includes the following main elements (providing food safety along all the manufacturing chain up to the final consumer):

interactive exchange of information; management system; programmes of creating prerequisites (GMP, GHP etc.); principles of HACCP.

A safety management system must cover the following main fields of the organization's activity: documents administration, managers' responsibility, resource administration, planning and selling safe products (programmes of prerequisites, food safety providing team, description of the product (raw material, ingredients and materials in contact with the food and ready product), area of using the ready product, technological schemes, manufacturing stages, control, analysing hazards, creating a HACCP plan, traceability system, management of emergency situations, handling potentially dangerous products, utilization of low-quality products, withdrawal procedure), validation, verification, and implementation of the food safety management system.

The management system must be aimed at a systemic search for possibilities to improve the quality. This is known to start always with a person, with improving his or her personal skills and knowledge, and further deals with the living and working conditions. A person's continuous improvement and that of the environment create conditions for improving the business processes, because it allows controlling the three main enemies of a technological process: losses, low quality, and unreasonable actions [12].

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### **Conclusion**

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To sum up, it can be said that the human factor is important at any stage of the technological process of food and feeds production. For this reason, the system of food and feeds quality control suggested by the state requires further investigation, because, in our opinion, it is impossible to solve all problems of food control and manufacturing by only these proposed measures and the Act of Ukraine "State Control and Compliance with the Legislation for Foods, Feeds, Animal By-products, Health and Well-being of Livestock" [1]. Besides the standard procedures, it is reasonable to consider programmes of professional development of the staff engaged in formation and control of food and feeds quality. The legislation for procurements needs to be improved since the bidding procedure (for state organizations) does not allow taking quick actions aimed at food and feeds quality control. It is important that all members of the food chain, starting with legislative and controlling bodies, manufacturing facilities and sellers, and up to the final consumer, be conscious in their responsibility.

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## ФОРМУВАННЯ ТА КОНТРОЛЬ ЯКОСТІ ХАРЧОВИХ І КОРМОВИХ ПРОДУКТІВ: ВІД ТЕХНОЛОГІЧНИХ ОСНОВ ДО ЛЮДСЬКОГО ФАКТОРУ

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**Анотація.** На сьогодні європейський вектор спрямування нашої країни та стратегія економічного партнерства з ЄС ставить перед державою певні виклики. Вагомий вплив на зміни в українському законодавстві щодо гармонізації

нормативів та правил у сфері господарської діяльності здійснило підписання угоди про асоціацію. Важливим залишається питання щодо забезпечення необхідного рівня якості продукції сільського господарства, що вимагає вдосконалення організаційно-правового забезпечення процесу зміни акцентів у використанні методів правового регулювання у напрямі від адміністрування до надання більшої економічної свободи виробникам. Зазначена Угода здійснила необхідний поштовх щодо створення Державної служби України з питань безпеки харчових продуктів та захисту споживачів, для організації моніторингу безпеки та якості продуктів харчування «від поля до столу». На окрему увагу заслуговують Вимоги щодо розробки, впровадження та застосування постійно діючих процедур, заснованих на принципах системи управління безпекою харчових продуктів (НАССР). Сьогодні сертифікація постійно діючих процедур, заснованих на принципах НАССР не є обов'язковою, обов'язковою є наявність Програм-передумов системи НАССР. Програма-передумова повинна охоплювати 13 процесів від планування виробничих, допоміжних та побутових приміщень для уникнення перехресного забруднення до маркування готової продукції, в свою чергу для кожного з цих процесів впроваджено, ще ряд вимог. Проведений аналіз змін законодавства та останніх публікацій щодо впровадження системи НАССР низкою харчових підприємств України, привів до логічного висновку, що це викликало ряд змін у технологіях виробництва та системах менеджменту їх організації. Сформовано групи факторів, що впливають на якість продукції. Підкреслено, що на особливу увагу заслуговує вплив людського фактору на різних етапах формування та контролю якості продукції. Проведено детальний аналіз існуючих системи менеджменту якості і безпеки в розрізі харчових виробництв.

**Ключові слова:** контроль якості, НАССР, людський фактор у системі якості, мікробіологічний контроль, системи управління якістю.

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