Development of an automated system histology security of food production

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Abstract. The histological method of research based on nanotechnology, allows to study cells and tissues, the effect of herbal supplements on the quality of meat products. Histology is performed to study the tissues of various organs and systems. Histological examination helps with high accuracy to determine the presence of pathologically altered cells and damage to the structure of tissues in products. The difference of this research method from others, for example, examinations, laboratory tests, is an increased accuracy of obtaining results. Currently, studies are conducted manually, and therefore, there is a need to automate the process of histological analysis. Based on the method of histological analysis, a technological map of the stages of histological research has been developed. Developed a functional diagram and logical equations of the equipment. The software and hardware of the automated histological analysis system is implemented on the Omron controller.

1. Introduction

Safety of food production is currently of great relevance. The introduction of food additives, the manufacture of genetically modified products, the use of low-quality raw materials can significantly degrade the quality of the goods. Modern studies of food products are carried out in different ways, but not always these methods allow a detailed study of the cellular structure and composition of products $^{[1,2]}$. For this there is a more accurate method called histology, used in medicine and veterinary medicine. Algorithm for taking tissues and organs for analysis must be accurate with the obligatory observance of all research rules. After the laboratory technician receives the biological material of the product, it must be placed in formalin or ethanol, cut thin and painted with the help of special means. Methods for dyeing the excised tissue also vary. The most commonly used dyes are hematoxylin and eosin $^{[3,4]}$. As a result of exposure to dyes, the color of the tissue composition changes. The histological method of research is considered the most accurate and in some studies it allows not only to determine the presence of damaged cells, but also the reason for their appearance.

2. Equipment and devices used in studies

For histological studies used material from the products. Pieces of parenchymal organs and tissues were fixed in a 10% solution of neutral formalin. Filling produced in paraffin. From each paraffin
block, sections of 3-4 micrometers were made on a semiautomatic microtome. Sections were stained with hematoxylin and eosin. The OMRON controller was used to build the histological analyzer.

3. The results of the study and their discussion

3.1. The study of changes in the cellular structure of food products under the influence of the processing process

When designing food production, it is necessary to have a methodology for studying the characteristics and assessing the state of the cellular structure (CS) of food products. When processing food raw materials used material and energy flows, characterized by the morphological composition of raw materials, physical, chemical and biological processing. We introduce a system: cell structure - processing (CSR).

To formalize the elements of the CSR system, we introduce a set of elements:

- \( W = \{w_1, w_2, ..., w_n\} \) – many elements of raw materials;
- \( G = \{g_1, g_2, ..., g_k\} \) – many elements of the physical effects;
- \( E = \{e_1, e_2, ..., e_m\} \) – many elements of chemical exposure;
- \( H = \{h_1, h_2, ..., h_l\} \) – many elements of biological effects.

The relationship between elements of the system define binary relations \( R \), which can be understood by the functional relationship, preferences, and other sequence, reflecting the relationship being: \( ER_W, HR_W, GR_W \). Figure 1 shows the relationship of elements investigated CSR system.

![Figure 1. Relationship between sets of elements of the CSR system: R – relations, reflecting the connections of the sets of the system: \( R_{EW} \) – influence of chemical exposure; \( R_{GW} \) – the impact of physical effects; \( R_{HW} \) – the effect of biological effects on the cellular structure.]

Binary relations can be decomposed into more complex ones with the introduction of an additional variable, called a state, if only sets related by a relation can be divided according to a certain attribute to at least two subsets. In this case, such a division is quite possible, for example, based on the effect on the CS on the system: a physiological condition or a pathological condition. We decompose the binary relations \( R \) into two subsets: the physiological state of CSR\(^1\) and the pathological state of CSR\(^2\). In this case, the system is transformed as follows:

\[
ER_{EW}^1[C_E^W, W], C_E^W R_{EW}^1 W^2; \quad
GR_{GW}^1[C_G^W, W], C_G^W R_{GW}^1 W^2; \quad
HR_{HW}^1[C_H^W, W], C_H^W R_{HW}^1 W^2.
\]

The physiological state of CSR is influenced by: the morphological composition of the raw material \( \{S_W\} \), the destruction of the cell structure from the parameters of the management procedures implemented in production.

The physiological state of the CS will determine the dependence:

\[
C_W = \Theta_W + \Delta \Theta_W(E) + \Delta \Theta_W(G) + \Delta \Theta_W(H),
\]
where in $\Theta_W$ - indicator of physiological state of the raw material, $\Delta \Theta_W(E)$ - change in the physiological state of the impact that chemical exposure, $\Delta \Theta_W(G)$ - change in the physiological state of physical impact, $\Delta \Theta_W(H)$ - change in the physiological state of biological effects.

As a model of processes, it is advisable to use semi-Markov processes, characterized by arbitrary probability distribution functions $p_i$ of the residence time of food products in the $i$ state. The transition of the system from the state $C_i$ to the state $C_j$ is carried out under the influence of the flow of events with the probability of transition $\lambda_{ij}$. The determination of the probability $p_i(t)$ of the state of the system $C_1, C_2, ..., C_n$ is determined by solving the system of Kolmogorov equations. Pathological effects on the cellular structure can be described by a state and transition graph (Figure 2).

To determine the state of cell pathology, it is necessary to conduct a histological study.

### 3.2. Development of a flow chart for determining the state of the cell structure

After analyzing the method of histological research, a technological map was drawn up, containing the following steps: 1 – excision of the material; 2 – fixation of the material in the fixing fluid for stopping biochemical processes (various fixators are used in histological practice: simple, containing one component (formalin, alcohol, acetone) and complex, containing two or more components (Carnoy fluid: absolute alcohol, chloroform, glacial acetic acid) acid; Zenker's fluid: potassium dichromate, sodium sulfate, mercuric chloride, formalin, distilled water); 3 – washing (removal of fixer); 4 – dehydration in alcohols of rising concentration; 5 – compaction (filling in Athens); 6 – preparation of histological sections; 7 – dyeing and conclusion sections Flow chart of the preparation of histological preparation is shown in Figure 3.

![Figure 3](image3.png)

**Figure 3.** Technological map of the preparation of the histological preparation:
1 – excision of the material; 2 – fixation of the material; 3 – flushing; 4 – dehydration; 5 – seal; 6 – histological sections; 7 – coloring and the conclusion of cuts.

### 3.3. Construction of ladder-contact scheme of the histological analyzer

Omron controller having good technical and economic characteristics was chosen as software and hardware [5,6]. In the proposed scheme, manual and automatic control of the histological analyzer and a separate nozzle was provided. In tanks for liquids level sensors are provided. Special attention is paid to the work of the injectors. The nozzle control graph is shown in Figure 4.

The logic functions corresponding to the graph of conditions and transitions of nozzle control are submitted in dependence: $Y = (LD \lor Y) \land TIM \land ER$.

The developed ladder diagram is shown in Figure 5.
Figure 4. Graph of conditions and transitions of dispenser control: LD – Load, TIM – Timer, ER – Error, Y – Nozzle operation.

Figure 5. Ladder diagram of dispenser control.

The operator panel developed using the CX-Designer program [7] is shown in Figure 6.

Figure 6. Operator console laboratory analyzer histological analyzer.

Research results:
D – dystrophy
A – atrophy
ND – necrobiosis
NZ – necrosis.

The description of work of the circuit of nozzle control is resulted in Table 1.

Based on the histological examination and the recognition of tissue images, the following results can be obtained that characterize the pathological changes shown in Figure 7.
Table 1. Description of operation of the nozzle control circuit.

| Description of work                                                                 | LD               |
|-------------------------------------------------------------------------------------|------------------|
| Starting the supply of the fixer fluid nozzle.                                      |                  |
| Locking fluid is being fed through a timer-controlled blocking line.                |                  |
| Emergency stop of the nozzle due to the lack of fixing fluid.                       |                  |

![Diagram](image)

**Figure 7.** Examples of morpho-pathological cell damage: a) Hypertrophy; b) Focal desquamation; c) Granular and hydropic degeneration of hepatocytes.

4. Conclusions
The problem of food safety research is considered. A histological method of research is proposed, which allows studying cells and tissues and identifying the pathology of products. The method of histological analysis has been studied, a flow chart of the experiment has been developed. Developed recommendations and automatized system for monitoring the study of the pathologies of food products. With the use of OMRON software and hardware, approaches to the design of the device, a Histological Analyzer, have been developed, which will ensure improved quality control of products.
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