Investigation of Changes in Quality Indicators of Agro-Industry Products During

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Abstract. Quality control is an integral part of production process and sales and one of the main means conformity of the products in line with established requirements. Meat products belong to the category of the most valuable food products. Freezing is a low-temperature preservation method. It provides the development of microbiological processes and a sharp reduction in the rate of enzymatic and physical-chemical reactions sacrificing the quality of the product. There are some methods for evaluating the quality of meat products. One of the promising methods of complex research in this area is the impedance method. An important property of biological tissues is the dependence of their conductivity and relative permittivity on the current frequency. There is a dependence of frequency on electrical resistance dependency in the same way. Its electrical characteristics also undergo changes, given that the cellular structure of meat changes during freezing. These changes are caused by the cell membranes destruction. As a result, the conditions for the passage of electrons and ions inside the meat change. Impedancometry offers a wide range of possibilities for determining the meat freshness, the storage conditions correctness, compliance with technological modes of processing meat raw materials, in particular, the number of freezes that meat raw materials have undergone. The bioimpedance meter will allow you to set the standard indicators typical for each type of meat, exceeding which would serve as evidence of the unsuitability of meat as a food.

1. Introduction

Product quality is defined as a set of properties that determine its ability to meet certain needs in accordance with its purpose.

Meat raw materials are perishable products. The technological process of meat products production is complex. This means that a number of requirements have to be observed. [1-4]

It should be borne in mind that the quality of the meat produced can vary widely because of natural factors, cultivation and transportation conditions, pre-slaughter handling, slaughter and primary processing conditions, parameters of cold storage.

Nowadays freezing is the most common method of meat products storing.

There are a partial redistribution of moisture, injury to the product's tissues by ice crystals, and partial denaturation of the protein during freezing. Under the condition of improper freezing, meat loses its taste and nutritional advantages of the product [6-8].
Freezing also involves physical changes that affect a "taste life" duration of frozen meat [9-11]. While ice crystals are forming taking water from the cell fluid the salt and residual metals concentration are increasing. As a result insoluble fat are oxidizing and rancid taste are appearing.

The taste and quality of fish and poultry deteriorates within a few months after freezing, the taste of pork – after 6 months, lamb and veal – after 9 months, beef –after a year.

Currently, the food industry uses a wide range of methods for evaluating the quality and freshness of meat products [13].

Currently known methods for determining the quality and freshness of meat products are quite complex, require a lot of time, expensive equipment and reagents, and can only be used in special laboratories by trained personnel.

One of the promising methods in the field of these studies is an impedance method.

2. Materials and methods

Biological tissues are heterogeneous in their electrical properties. Organic substances, including proteins, fats, and carbohydrates, are dielectrics. The electrolytes contained in the composition of tissue fluids that are good conductors. The membranes of cells have a double phospholipid layer, which has a capacity. This gives the tissues capacitive properties, the presence of which is confirmed by the presence of a shear angle between current and voltage.

Bioimpedansometry is express method. It is based on passing weak alternating currents of various frequencies through the test sample and measuring the electrical conductivity [13-15]. In the future, it determined the dependence of its total electrical resistance (impedance) from the current frequency, which is used to judge the quality of the product.

Biological tissues are composite materials with magnetic and electrical properties. An important property of biological tissues is the dependence of their specific conductivity and relative permittivity on the current frequency [15-20]. In figure 1 shows a graph of the relative permittivity of muscle tissues as a function of the current frequency f. The same dependence on frequency is observed for the electrical resistivity.

During the passage through the tissue of an alternating current that changes according to the harmonic law:

\[ I(t) = I_0 \cos \omega t \]  (1)
The voltage drop on the biological tissue changes according to the law:

\[ U(t) = U_0 \cos(\omega t + \varphi) \]  

(2)

The value that determines the relationship between altering current (AC) power and voltage is the impedance (\( Z \)) - the total electrical resistance of the circuit to AC. This value has two components: active (\( R \)) and reactive resistance (\( X \)). Active (ohmic) resistance is primarily related to the conductivity of internal liquid media, which are electrolytes. Various processes in tissues, accompanied by irreversible energy losses, also contribute to the value of the active component of the impedance. The reactive component is characterized by the capacitance properties of the target tissue. In particular, the capacity of cell membranes that can accumulate an electric charge on their surface [21].

The absolute value (modulus) of the electrical impedance is determined by:

\[ |Z| = \sqrt{R^2 + X^2} \]  

(3)

When an external electric field is applied to the biological tissue, the movement of free charges – ions-occurs.

Changes occurring with the muscle fibers of meat raw materials affect the level of electrical resistance of the tissue. So it is possible to use the impedance method in the food industry in order to determine the quality indicators of meat raw materials [22,23].

The following objects were used as target samples:
- category I beef-muscle tissue with connective and adipose tissue content no more than 6% according to GOST R 54315;
- semi-fat pork-muscle tissue with a fat content of 30-40 % according to GOST R 53221;
- first-class chicken carcass-muscle tissue with a fat content of no more than 20 % according to GOST R 52702.

The main instrument was a bioimpedance meter (BIM), designed to measure the resistance of biological tissues.

The description of the device and the principle of its operation is explained by the functional diagram shown in figure 2.

![Figure 2. Bioimpedance meter functional diagram.](image-url)
The device works as follows. Electrode 4 is inserted into the tissue. The control and information processing unit 10, in accordance with the user’s instructions, determines the order of operation of the device, setting the frequency at which measurements should be made at a certain time. The control and information processing unit 10 sets the frequency of the output signal of the sinusoidal generator 1 entering the input of the electronic switch 2. The electronic switch 2 switches the input signal to one of the arms of the measuring unit 3, which is selected in accordance with the control signals of the control and information processing unit 10, depending on the type of the measured component of the impedance (active or capacitive) and the operating range. In the circuit, a sinusoidal generator 1 – an electronic switch 2– sequentially connected to the resistors of the arm of the measuring unit 3– biological tissue – the common power bus begins to flow current. Stress values at the nodes included in the work of the shoulder of the measuring unit 3 is removed by the multiplexer 5 and are switched to the input of a broadband amplifier 6. Amplifier output AC sine wave signal is supplied to the input of inverter srednetemperaturnogo voltages 7 that performs the detection srednetemperaturnogo voltage values of a sine wave. Then the signal is sent to the analog-to-digital Converter (AIC) 8, where the signal is digitized. Further signal processing is performed in digital form.

A number of experiments were conducted using a bioimpedance meter to determine the number of meat raw materials freezing.

Weak alternating currents of various frequencies were passed through the target sample and the sample impedance was measured. Meat electrical characteristics also undergo changes because the cellular structure of meat changes during storage. When exposed to meat raw materials at low temperatures (multiple freezing and subsequent thawing) cell membranes were damaged and eventually destroyed. The state of the lipid layer of cell membranes changes, the membrane ceases to perform its barrier function, and the selective permeability of cell membranes disappears. The electrical capacity of the tissue sample is reduced. Repeatedly frozen meat is characterized by a high value of electrical conductivity, respectively, a low value of impedance.

3. Findings
In order to visualize the resistance value depending on the number of freezes of the test samples, graphs of the approximating curve of the change in the dependence of the impedance on the measurement number are presented (figure 3).

![Figure 3. Resistance of raw meat tissues depending on the freezing multiplicity (pork).](image-url)
The process of changing the impedance of pork tissues depending on the multiplicity of freezing is described by the next equation:

$$y = 166.05 e^{-0.172x}$$  \hspace{1cm} (4)

A graphical representation of this process is shown in figure 4.

**Figure 4.** Approximating curve of changes in the resistance of pork tissues depending on the multiplicity of freezing.

Similar dependencies were established for other types of meat.

According to the research results, it was found that the amount of resistance is not affected by the place (part of the carcass) in which the electrode is inserted, but the depth of its introduction is affected. For correct measurements, the electrode needles are marked with marks up to the level of which the needle electrode should be inserted.

Based on the graphical display of the results, the impedance indicator decreases depending on the refrigeration time of meat products.

When analyzing the data, it was found that each type of meat raw material has its own range of resistance changes. There is a tendency towards a decrease in electrical impedance with an increase in the refrigeration time of the study samples for all types of meat products.

Research has proved the possibility of using bioimpedansometry in the food industry as an Express method for determining the quality of raw meat that has been processed at low temperatures. This method helps to quickly determine the state of meat and quickly make a decision about its technological purpose despite the fact that research in this way does not require a special laboratory, as well as highly qualified personnel for its maintenance. In addition, the experimental data obtained can be stored in the memory of portable detectors for monitoring meat products, and impedance spectroscopy can be implemented in the form of small devices, which makes it possible not only for industrial use, but also for household use.

The impedance method opens up wide opportunities for determining the meat freshness, correct compliance with storage conditions, compliance with technological modes of processing meat raw materials, in particular, the number of freezes that meat raw materials have undergone.

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