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To cite this article: Irina Asfondiarova *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **497** 012106

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Digital technologies for providing the quality of food products

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Abstract. The Internet of Things (IoT) conception in food industry is actively developing and covers a wide range of tasks: increasing the quality, elaboration of resources-saving technologies, managing working time and production in real-time mode and revealing failures in manufacturing chains. A method of intensification of the industrial process of baking fish molded goods of increased nutritional value by applying an ultrasonic unit is presented in the article; research data on organoleptic and microbiological quality points, chemical composition and energy value, mineral elements are also reported here. High-mineralized fish rows are safe after ultrasonic treatment and they have excellent organoleptic quality indicators. Using ultrasonic equipment with temperature elements will allow not only to intensify the technological process of baking fish rows, to save their original qualitative characteristics but also to control temperature in the center of the product. Applying ultrasonic will also allow finishing complete repeatable processes in the minimum amount of time and reducing processing costs. Using ultrasonic sensors on packaging will help consumers to control the quality in the process of storing.

1. Introduction

Providing and increasing the quality of food products is one of the main aspects of people's healthy life [1].

Development of new food products rich with bioactive substances; improving those which exist and creating resources-saving technologies with the possibility of applying digital transformation with the aim of increasing quality control is an actual direction for every country in the world.

Safety of food products includes a number of procedures and tests at all stages of their production which should be accepted in order to avoid potentially dangerous risks for health. New and efficient solutions in the supply chain are a consequence of constant upgrading of information and communication technologies. Food products quality can be controlled at any point with the help of Internet-equipment connected with the tested equipment, involving food products producers and retail companies at the same time [2].

Healthy nutrition is a determining factor which influences the global food industry. Fish products attract significant attention as a source of protein, vitamins, minerals and fat [3].

During cutting fish raw material, a significant number of waste is formed (heads, spinal columns, fins, scale) [4] which are being processed into protein meal, fish flour, and are used for making new products of increased nutritional value: fish silo, collagen, gelatin and other products [5].



New possibilities in creating products with predetermined flavor and biological characteristics are being revealed: minced fish which is widely used all over the world. Back in the early 1970s, the work for producing fish pastes, surimi, was carried out in New Zealand and Denmark: minced fish was used as raw material for different products and methods were determined, with the help of which their properties could be studied and controlled with measuring instruments[6].

The demand for exact, fast and objective determination of qualitative characteristics of production is currently growing. Computer technologies provide an alternative for automated control with information output on the display. This approach of controlling based on analysis and processing of an image finds different application in food industry [7].

The possibility of using automated equipment in food industry can provide high potential in food industry for increasing security, quality and profitability by means of optimization of monitoring and controlling processes [8].

Over the last years, ultrasonic technology has been widely used in different sectors of food industry [9] and it is also applied as an alternative variant of processing traditional thermal approaches. Ultrasound allows pasteurizing and preserving products by means of inactivation of many ferments and microorganisms at moderate temperature conditions which may improve food quality in addition to providing stability and safety of food production [10].

Ultrasound of low power (high frequency) is used to control the composition and physical and chemical properties of food components and products during their processing which has crucial importance for controlling food properties and improving its quality [11].

Practical significance of ultrasound processing for food industry consists in more efficient micro mixing, faster transmission of energy and mass, reducing thermal and concentration gradients, reducing temperature, faster response to extraction process, increasing productivity and eliminating certain stages of food production processes [12–14].

It is suggested to use the method of baking rows in a cabinet oven with imposition of ultrasonic field for the process intensification. Baking includes many connected processes which take place both inside and on the surface of a food product [15].

Increasing heat-and-mass transfer by means of the capillary and vibration effect leads to more even heat-up in the entire product.

It is necessary to reduce temperature to 150°C and reduce the baking time to 32 minutes because of applying ultrasonic vibrations in the process of baking fish semi-finished products. Also, the temperature on the surface and inside the rows being baked and their humidity should be controlled in the process of baking. Parameters are remote-controlled and regulated with the help of sensors [16].

The aim of this work is intensification of the technology of producing fish molded goods of increased nutritional value with preserving and controlling its original qualitative characteristics in the process of making and storing them with the use of digital technologies.

2. Materials and methods

The object of study is fish rows, control samples without vitamin-mineral premix and increased nutritional value, in raw condition, after baking in a thermal oven with applying ultrasound and without it.

The composition of rows of increased nutritional value includes: minced fish made of pink salmon fillet, a high-mineralized additive (HMA) made of fish heads, bones and fins, hydrothermally processed at 150°C during 5 hours and minced. Also, egg powder, black pepper and salt were added to the minced fish.

The main technological operations of producing fish rows consisted in preparing a HMA and adding it in the quantity of 20 % to the minced fish; mixing the mass obtained with components according to a recipe; packing into 200 g forms for baking, baking in a thermal oven at 180°C for 40 minutes; cooling to 75°C in the center of the product. The finished product was packaged into vacuum bags of lavsan and stored at 2–6°C for 10 days [17].

The method of making fish rows in the ultrasonic field consists in the following. Fish mass is being baked in a cabinet oven, “AngeloPo”, with a fixed ultrasonic generator of “Solovey” series with regulated force of ultrasonic vibrations, which allows obtaining a product with minimum moisture content. Rapid heat transfer with the air in the cabinet oven takes place as a result of small disturbance from the ultrasonic generator of waves in the air which causes the boundary layer tripping. Because of transformation of a small part of acoustic energy into thermal energy, ultrasonic absorption and reducing heat and mass transfer thermal resistivity, the temperature of the product rises to several degrees per minute.

Control and regulation of the temperature mode during baking is performed with the help of a sensor fixed on a flexible leg inside the cabinet oven. The sensing device signal is transmitted to an LCD placed on the external panel of the cabinet oven. From this display, the data is transmitted through Wireless Fidelity on to a duplicate control board located remotely.

The energy value of the products being studied was calculated using Atwater coefficients which take into account the percent of digestibility of nutrient materials of 1 g of a product: protein – 4.0 kcal, fat – 9.0 kcal. The calcium and magnesium content was determined using the method of atomic absorption on the “Yunikam AAS-29” spectrometer, the phosphorus content – using the colorimetric method.

Microbiological safety was determined by the number of mesophilic aerobic and facultatively anaerobic microorganisms.

The quality of rows according to organoleptic indicators was determined using a 20 grade scale taking into account weight coefficients, and also taking into account such indicators as external appearance, taste, smell, consistency, color.

The amount of moisture in the samples of fish rows was controlled using the method of drying to constant mass according to standard practice; the weight fraction of lipids – according to the method based on extraction of fat with petroleum ether in Soksleta apparatus; total protein content – using the Kjeldahl method; ash content – using the method based on eliminating organic substances by burning and determining ash by weighting.

3. Results and discussion

Each operation and further storage of production influences the quality of fish products during their preparation and processing [18].

Knowing the biochemical composition of products is important for understanding their physical, sensing and nutritive properties and also changes which take place during processing [19].

The results of food components content in the rows of increased nutritional value before and after processing are presented in table 1.

Table 1. Chemical composition of fish rows before and after thermal processing.

Components	Fish rows with a HMA in raw condition	Rows (control) after baking	Fish rows with a HMA after baking	Fish rows with a HMA after baking with applying ultrasound
Moisture, %	70.92±0.75	60.54±0.13	61.86±0.17	66.02±0.18
Fat, %	7.30±0.02	5.72±0.02	7.38±0.08	7.66±0.08
Protein, %	14.90±0.09	12.13±0.04	13.25±0.02	14.11±0.02
Ash, %	3.12±0.02	3.08±0.02	3.10±0.03	3.11±0.03
Energy value, kcal/kJ	125.30 / 524.04	116.73 / 488.12	130.50 / 545.82	131.82 / 551.35
Calcium, mg/100g	562.2±0.84	243.00±0.87	561.9±0.85	562.1±0.90

Components	Fish rows with a HMA in raw condition	Rows (control) after baking	Fish rows with a HMA after baking	Fish rows with a HMA after baking with applying ultrasound
Magnesium, mg/100r	68.03±0.66	64.33±0.76	67.53±0.32	67.66±0.34
Phosphorus, mg/100g	421.8±0.82	370.8±0.38	421.0±0.16	421.2±0.17

* HMA – high-mineralized additive.

It can be seen from the table that introducing a HMA into fish rows has significantly increased the content of mineral elements: calcium, phosphorus and magnesium, which, after thermal processing with the use of ultrasound, have changed very little if at all.

It should be noted that during baking high-mineralized rows in a thermal oven without ultrasound less nutritive substances are preserved than during baking with ultrasound. It can be explained by the fact that lower temperatures are applied in the process of baking, the time of processing the product is reduced, and also microbial contamination doesn't increase because bacterial activity is inhibited with ultrasonic waves and it is confirmed by our studies. QMA&OAMO (the quantity of mesophyll aerobic and optional-anaerobic microorganisms) in fish rows before and after baking, including baking with ultrasound, didn't exceed 1×10^6 CFU/g, which demonstrates that the production obtained is safe for consumers.

The profilogram of organoleptic quality indicators is presented in Figure 1.



Figure 1. The profilogram of organoleptic estimation of rows quality before and after ultrasonic processing.

As we see in figure 1, the HMA added into fish rows has not only increased their nutritional value but it has improved their consistency and taste which is confirmed by their excellent level of quality from 91.2 to 95.0 points. The molded production had even refined mass, a likeable creamy-brown color, rich and fine texture, pronounced flavor and taste after thermal processing.

It is important to preserve original properties of new production during storage and create a possibility for controlling temperature conditions and also to notify consumers of the information on storing these products. It is possible only with the use of special sensors which are synchronized with a mobile application.

The scheme of creating a digital technology algorithm of providing the quality of products can be exemplified by fish rows (figure 2).

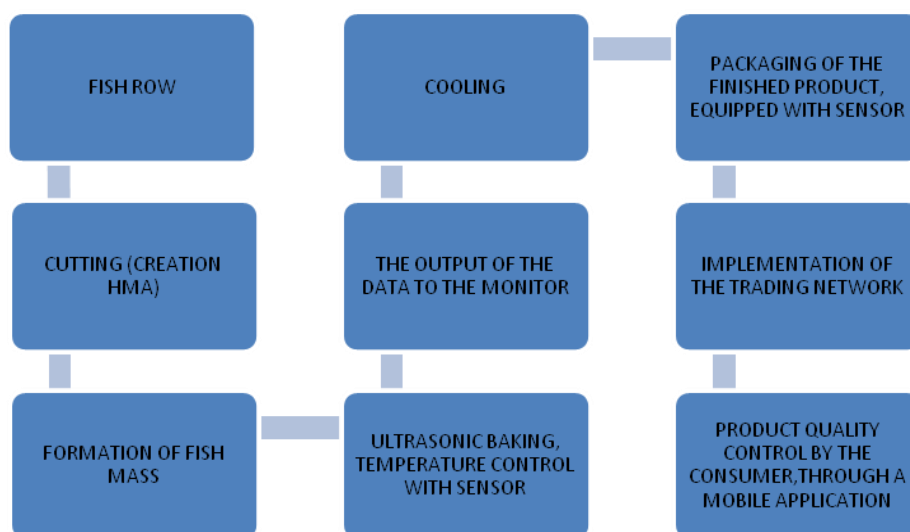


Figure 2. The digital technology algorithm of providing the quality of products.

4. Conclusions and recommendations

Applying an ultrasonic unit contributes to intensification of the production process of baking fish rows of increased nutritional value, safe for human health, improve their organoleptic characteristics and it also allows to preserve nutritive substances almost intact. It has been experimentally determined that applying ultrasonic vibrations allows to reduce temperature and duration of the baking process by 20–25 % when nutritional value is preserved by 8–11 % by means of even and faster baking of the product. Visualization in real time will help to control both the production process of making molded fish products and changes in its quality during storage.

Sensors fixed on the package will allow informing consumers and controlling temperature conditions.

Implementation of the IoT in Russia is at the stage of development as there is a range of problems related to their security, cost recovery, establishing a unified connection between devices, transmitters and sensors. Besides, digitalization of food production, including fish production, should promote both increasing quality control and improving qualitative characteristics with their further preservation.

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