Conference Paper

Convective Drying at Fish Chips Technology

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Abstract

The article presents the overview of the main technological processes in fish structured products dehydration. The rational modes of the technological process of minced fish raw materials with various initial moisture and fat content heat treatment are determined. One of the main tasks of the fish processing industry development which allows increasing the profitability of products and their quality is improving technological processes. The scientifically substantiated choice of resource and energy-saving modes of processing food materials is highly important in this case. It will reduce not only production costs but also emissions of harmful substances into the environment and increase the efficiency of using equipment. It must be taken into consideration that the optimization of dehydration technological processes without identifying their patterns is extremely difficult. Increasing efficiency and controlling technological processes makes sense only on the basis of patterns. The effectiveness of the hydrobionts processing determines the quality and cost of finished products manufacturing while fish processing enterprises working. The development and implementation of highly efficient technologies with the use of resource-saving technical systems, for example, using heat pumps, makes it possible to produce cost-effective high-quality products.

Keywords: dehydration curves, semi-hot drying, critical points, energy-efficient modes, fish chips, minced fish products, heat pump

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1. Introduction

Quite recently fish snacks have become rather popular. These products can be made from fish raw materials or even non-fish materials. However the consistency of such products is dense enough, sometimes tough to provide fast food. An effective solution is the chips manufacturing from minced fish products. It also contributes to the equal and effective salt and spices distribution in the volume of the product as well as the mechanization of the dosing process, etc. Manufacturing of such a product requires a minimum production space. There is no necessity in separating rooms for cooking brine, ripening, etc. Modern processing complexes require raw materials processing methods to reduce production costs, increase the efficiency of the technological equipment use [1-3]. A rise in the production capacity of technological lines and the level of development of a modern enterprise can be achieved with an integrated approach to improving the efficiency of technological processes, equipment and manufactured products of high quality.

The aim of the work is to develop a technology for the high-quality fish products manufacture based on scientifically based energy-efficient modes of fish raw materials dehydration. Certain tasks were solved in order to achieve this goal. They are aimed at dealing with drying fish minced products process and the optimal modes development of raw materials heat treatment under various humidity and fat content. The possibility of supplying the production line with a heat pump was also considered. It will let further increasing the production profitability due to the efficient use of natural low-potential heat sources.

2. Methods and Equipment

The objects of study are the processes of minced fish convective dehydration in the technological line for the production of fish chips. The researches were conducted in the scientific laboratory at Murmansk State Technical University (the department of technological and refrigeration equipment).

Researches were carried out according to the following method -- the mass and specific surface were determined for individual samples. The samples were placed on carriers in an experimental installation for drying food materials (Figure 1).

The experiments were grouped in series. In each series the studied parameter varied within the established limits. Other parameters affecting the process remained constant in time. The product weight loss was determined at specified time intervals. The parameters under research are the temperature of the drying agent in the chamber (varied in the range from 40 to 60 °C); relative humidity of the drying agent (from 35 to 44 %); drying agent circulation rate (from 3 to 5 m/s).

The initial moisture content of fish products from mackerel, sea bass and cod was in the range from 56 to 81 %.

In the course of work the regularities of fish structured products drying were determined depending on the size, mass and chemical composition of raw materials as well as the rigidity of the heat treatment mode. The influence of these parameters on the duration of the drying process was determined:

$$\tau = f(\omega_0, S/m, t, \varphi, \upsilon), \quad (1)$$

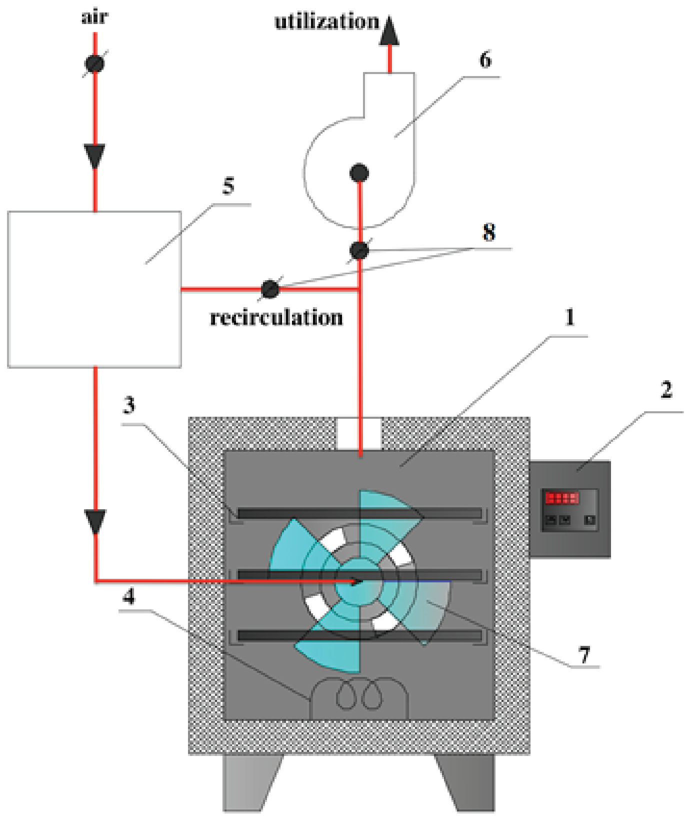

Figure 1: Experimental equipment for drying food materials : 1 -- drying chamber; 2 -- controller; 3 -- drying carriers; 4 - heater unit; 5 -- mixing unit; 6 - exhaust fan; 7 -- circulating fan; 8 - air valves.

where ω_0 -- initial moisture content of the product,%; S/m - product specific surface, m^2/kg; t - drying agent temperature, °C; φ -- drying agent relative humidity,%; v - drying agent circulation rate, m/s.

The heat and humidity characteristics t and φ were combined by a common parameter X_r, representing the rigidity of the heat treatment mode [4]

$$X_r = \hat{t}\left(1 - \frac{\hat{\varphi}}{100}\right). \quad (2)$$

where $\hat{t}$ - average temperature, °C and $\hat{\varphi}$ - average relative humidity in the chamber, %, per process.

3. Results

According to the results of regularities process studies, the kinetics curves of minced fish products dehydration were constructed. Kinetics curves series of minced fish raw materials dehydration with low, medium and high fat content are given as an example (Figure 2).

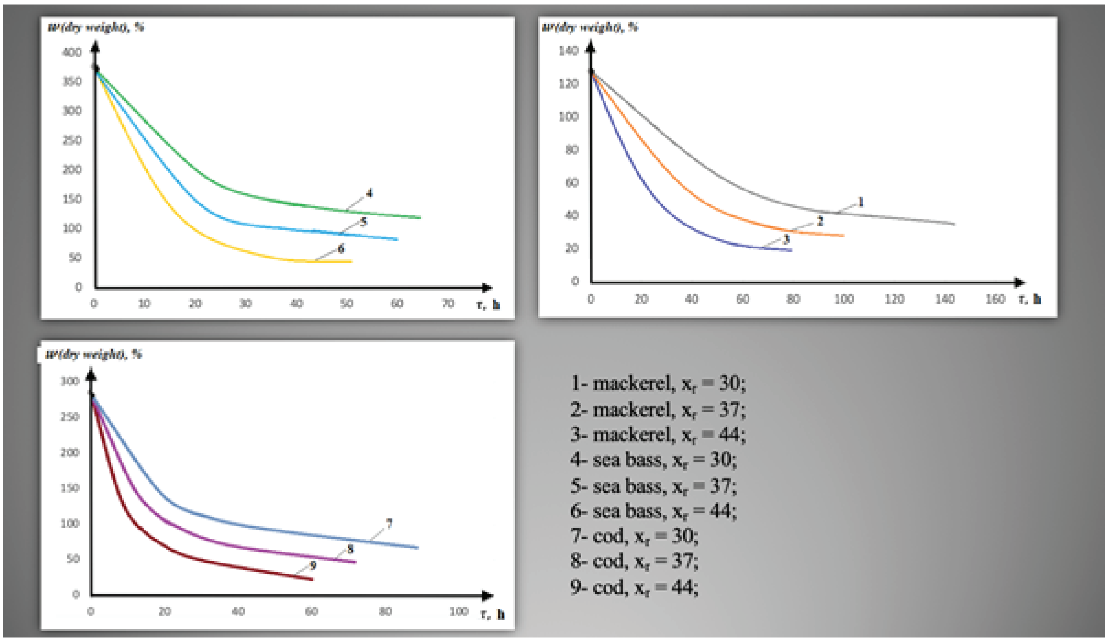

Figure 2: Drying kinetics curves for minced fish products from cod, sea bass and mackerel.

The drying curves (Figure 1) show that the general nature of the process is the same for different types of fish. Increasing in the intensity of the process is significantly affected by a rise in the rigidity of the heat treatment mode. It is worth intensifying the process with reasonable energy consumption. In a number of works, it is noted [1, 4-6] that a decrease in specific energy consumption is more significant in the implementation of a process. This indicator is most important in a competitive environment than reducing the processing time.

We performed the research of the semi-hot drying material modes. It was necessary to choose the optimal modes for the fish chips production. Such modes have a gentle effect in relation to the nutritional value of the finished product also 15-25 % lower by specific energy consumption in comparison with the modes of traditional hot drying. In comparison with the process of cold drying [7 - 9] which lasts from several hours to several days, the process of semi-hot drying product dehydration takes no more than 30-90 minutes depending on the size and mass characteristics of the raw material and the density of the chamber loading.

When products are being dehydrated there are one or more critical points. These points indicate a transition from moisture with a lower binding energy with the material having higher energy [10, 11]. Reaching critical moisture content the product is densified by compressing capillaries of material. The internal structure of the material and its internal properties are changing, the dehydration process slows down.

While fish dehydrating, critical moisture does not depend on operational parameters, geometric dimensions of the material and type of energy supply. They are mainly determined by the chemical composition of the product.

The water content in the fish is significantly higher than other chemical compositions. Therefore it is rational to determine critical moisture through the initial moisture content ω_0, %.

While converting dehydration curves into semi-logarithmic coordinates lgω = f(τ), which are seen as broken lines from a curve and two or three straight lines, critical moisture can be determined (Figure 3).

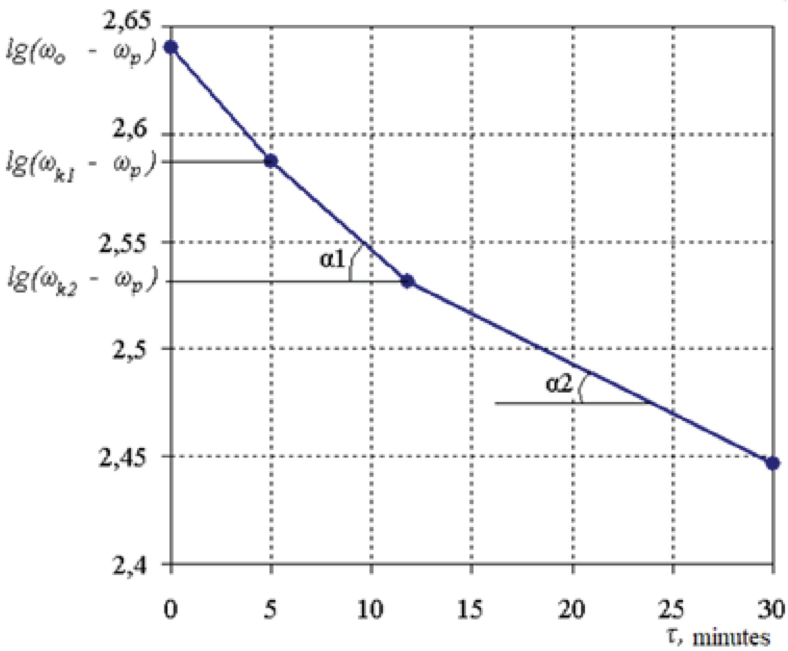

Figure 3: Curve of drying in semilogarithmic coordinates.

Figure 3 shows the first dehydration period - the section from $lg(\omega_o - \omega_p)$ to $lg\left(\omega_{k1} - \omega_p\right)$ and the second period of dehydration - the section $lg(\omega_{k1} - \omega_{k2})$ to $lg(\omega_{k2} - \omega_p)$ and below, consisting of two straight lines. The critical moisture ω_{k1} shows the transition from a period of constant drying rate to a period of falling drying rate. The critical moisture ω_{k2} shows the inner structure changing of product. The internal properties changing leads to the drying rate decreasing [4, 12, 13].

Such dependence for fish dehydration in various processes (drying, smoking and frying) was previously obtained by academician A.M. Ershov and it is determined by the following formulas [4]:

$$\omega_{k1} = 1,069\omega_0^{0,969}. \tag{3}$$

$$\omega_{k2} = 0,784\omega_0 + 2. \tag{4}$$

While drying minced fish products using the above methods for finding critical moisture only one critical point was found. This fact is associated with a difference in the structure of the fish and minced fish tissues and accordingly different water-holding capacity of capillary-porous colloidal materials.

The mathematical processing of the dependences $\omega_k = f\left(\omega_{k0}\right)$ was carried out using the Datafit program. A mathematical dependence is found that is statistically expressed by the following equation

$$\omega_{k1} = 8,1\omega_0^{0,48}. \quad (5)$$

It can be seen from equations (3) - (5) that critical moisture is a function of initial moisture and on the other hand, critical moisture and duration of their achievement on the curves of dehydration kinetics are coordinates of critical points K characterizing the influence of operating parameters, geometric dimensions of the body and chemical composition as well as a change in the internal properties of the product to the intensity of dehydration. It is suggested conducting the semi-hot drying of structured fish products generalization on the basis of dimensionless similarity numbers

$$\frac{\omega}{\omega_{k1}} = \psi\left(\frac{\tau}{\tau_k}\right), \quad (6)$$

Rational modes for the production of structured fish products have been worked out by us. Using semi-hot drying method while maintaining the required values of heat treatment stiffness depending on the range X_r=30-44 depending on the initial moisture content and fat content of the fish is highly important. Based on the results of testing energy-efficient modes, pilot batches of fish chips were done by us (Figure 4).

Choosing the recommended modes for implementation, the results of a positive assessment of the taste panel were taken into consideration.

If the recommended heat treatment mode is not observed, defects in the ready food product appear [8]. For example, for fatty fish raw materials processed with stiffness higher than recommended an overdried, sintered surface is observed. Processing minced fish products in the modes below the specified limits significantly slows down the diffusion of moisture in the tissues.

Regulatory documents have been worked out for the production of fish chips «Zapolyarye» using resource-energy-efficient modes of raw materials dehydration. The technology of fish chips has been tested and implemented at the production site of the fish processing enterprise INTRO LLC, Murmansk.

Figure 4: Ready food products fish chips «Zapolyarye».

The results of our structured fish products semi-hot drying studies process confirmed the high feasibility of introduction a heat pump system into the process for increasing its energy efficiency.

For modernizing the drying installation a water-to-air heat pump unit was designed and assembled (Figure 5).

Figure 5: Heat pump unit for convective drying process.

The unit operates on a scroll refrigeration compressor with a cooling capacity of 4.5 kW. Boiling point is 5 °C, condensation is 50 °C, superheat is 10 °C and subcooling is 0 °C. The system runs on the ozone-friendly refrigerant R407C. It was adapted for year-round operation under conditions corresponding to the use of low-potential heat in conditions of non-freezing Kola Bay. Now it is being planned to work out recommendations for the modernization of the industrial facilities drying chambers operating on the drying

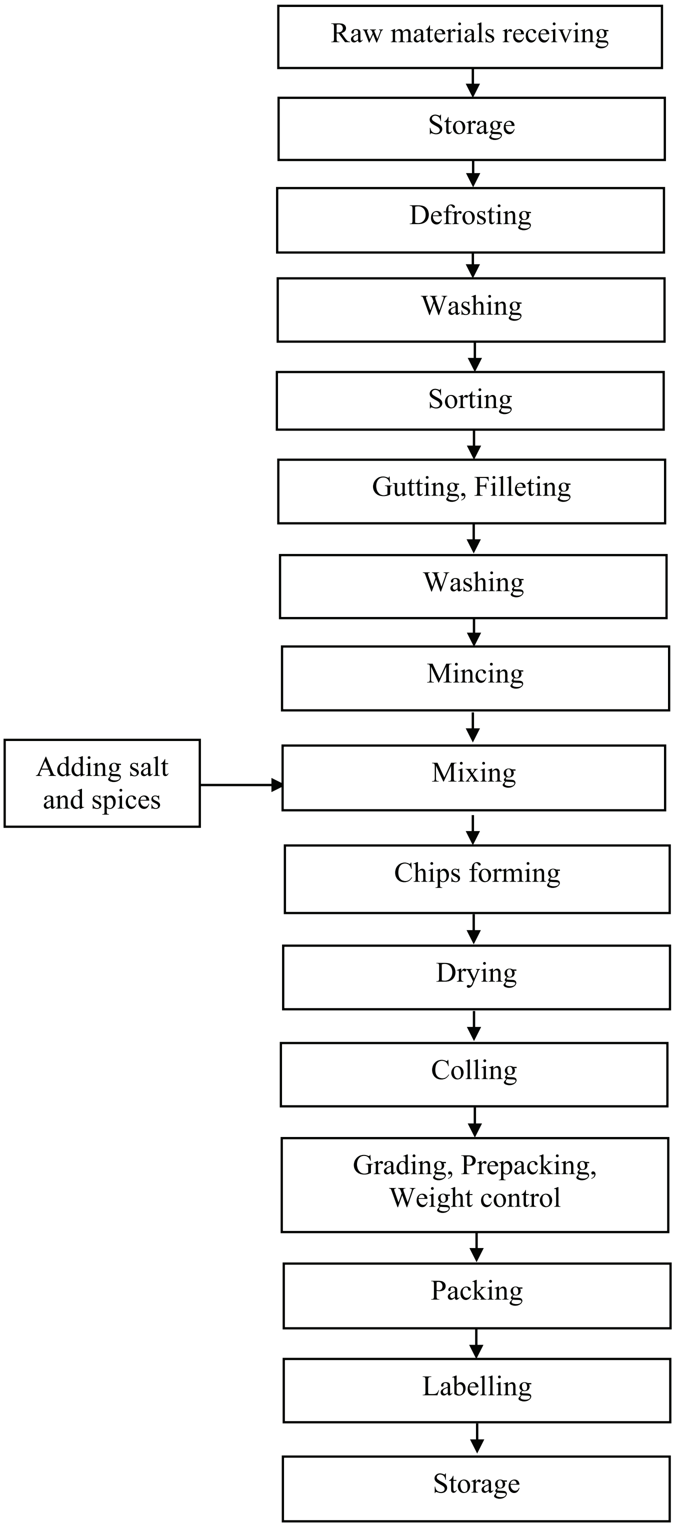

Figure 6: Technological scheme for the fish chips production.

of fish raw materials in the conditions of the Kola coast. The introduction of heat pump systems into the technological lines of the required power and optimal drying conditions will significantly increase the energy efficiency of the technological equipment of coastal fish processing enterprises [14, 15].

4. Discussion

The researchers of the heat treatment of food materials processes note that reducing the specific energy consumption in the process is more significant. This indicator is more important in a competitive environment than reducing the processing time of a product [1, 4-6].

The connection of critical moisture with the initial moisture content of raw materials for the process of minced fish products dehydration was performed by us. This mathematical equation makes it possible to take into account the critical transition from moisture with a lower binding energy with the material to that with a larger one while optimizing energy saving drying modes.

Researches have shown the feasibility of drying fish products from fatty raw materials using mild semi-hot drying modes with minimal rigidity. Drying of fish raw materials with a low fat content for increasing the efficiency of heat and mass transfer processes should be carried out at close to maximum recommended stiffness. The creation of optimal conditions for fish dehydration in thermal processes is mainly based on regularities revealing while processing capillary-porous colloidal materials [4-7, 11- 13].

5. Conclusion

The series of studies were conducted to study the patterns of fish structured products dehydration. Pilot production batches were also made. The main defects of the ready food product appearing while deviating from the specified operating parameters are identified. The rational modes of the technological process of minced fish raw materials with various initial moisture and fat content heat treatment are determined. A technology has been worked out for the production of dried molded fish products (fish chips) using resource-energy-efficient modes of raw materials dehydration. Regulatory and technical documents have been prepared for the implementation of the fish chips «Zapolyarye» technology into production. While designing modern modes of processing raw materials, technological systems were used to produce products that are cost-effective for the enterprise and safe for the consumer. The heat pump was designed and manufactured for using in products convective drying. The heat pump makes heat treatment processes more resource-efficient and energy-saving. A study of the dehydration of various fish raw materials kinetics showed that using half-hot drying energy costs are reduced by 15-20 % compared to drying at high temperatures. The year-round supply of warm Atlantic waters in the Kola region helps the efficient use of heat pumps and additionally reduces energy consumption up to 50 %.

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Conflict of Interest

The authors have no conflict of interest to declare.

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