Automation technologies for fish processing and production of fish products

V I Komlatsky1, T A Podoinitsyna1, V V Verkhoturov2 and Y A Kozub2,3

1Kuban State Agrarian University named after I.T. Trubilin, 13 Kalinin street, Krasnodar, 350044, Russian Federation
2Irkutsk National Research Technical University, Irkutsk, 664074, Russian Federation
3Irkutsk State Agricultural University named after A.A. Ezhevsky, Irkutsk, 664038, Russian Federation

E-mail: kubanagro@list.ru, tatyana_zabai@mail.ru, biovervv@mail.ru, yulia_a72@mail.ru

Abstract. The fish processing industry applies a small number of automation technologies compared to other industries. Their number should be increased despite automated food processing problems and hygiene requirements. Automation and implementation of robots can reduce production costs and improve product quality. The issues of designing automation systems for the fishing industry are analyzed. Automatic control systems can control quality of fish and fish products. Automated systems receive, freeze, sort, cut, wash, salt, dry, smoke, press, cool, package and store fish and fish products. Modern technological tools are equipped with automatic control systems. Some of them include specialized automation and robotic units equipped with microprocessor control systems. Application and implementation of automation systems for processing fish are described. Future trends are discussed.

Due to some peculiarities of animal products, the cooling method should be based on specific technological parameters. The cooling equipment should be applied [1].

In Russia, the fishing industry is slowly developing. Fish tankage production enterprises are an exception. Fish tankage is used by pig and poultry farms. However, the production of industrial fisheries expanded, the number of floating bases with a full fish processing production cycle increased, and the number of shipbuilding and ship repairing enterprises in the fishing industry increased. Modern fish processing and production mechanization and automation methods are being implemented [2].

The main technological processes (TP) are sorting, cooling, freezing, salting, drying, smoking, production of minced and canned fish and technical feed products (fish tankage, feed farce, feed hydrolysates, fat) [3].

These processes are classified by physical and chemical features, heat and mass transfer processes, functional purposes, changes, etc. It makes it possible to isolate the same TPs and use unified technical tools (or solutions) for their automation [4].

In recent years, the automation stage has been developing; fish enterprises have implemented automatic control and management systems. These enterprises are production and economic systems whose automation solves the tasks of monitoring, stabilization, regulation of TP parameters and
operational management, material and technical supply, organization of production and economic activities, technical management of production processes [5, 6].

This automation stage can be successfully implemented using microprocessor control systems. Some automation schemes for individual processing units are presented below.

At present, fish is delivered to enterprises being frozen. Only lake, pond and river fishing farms can deliver live or fresh fish. For its preservation and quick delivery, various technical tools are used. When transporting fish, specialized automobile, railway, river (live fish) and air modes of transport are used. To preserve fish, oxygen-rich pools and various types of containers (open and closed containers, bathtubs, isothermal containers) are used. Water aeration in tanks is widely used for transporting fish using air from a special compressor unit.

The purpose of the study is to identify and solve problems of technological processes in the fishing industry.

The following technological equipment is widely used for salting and marinating fish: fish washing machines (MP-3 washing machines, conveyor-type washing machines, MP-2M, V5-IRM drum-type washing machines, Baader 676 washing machines with a capacity of up to 2 t/h); plants produced by the Central Design Bureau “Azcherryby”; mechanized baths for salting small fish with a capacity of up to 700 kg/h; fish-salting units (RPA-3 salting machines with a capacity of up to 1.5 t/h, mechanized ambulance conveyor-type units, drum-type machines, mechanized lines for salting small fish by the Central Design Bureau “Azcherryba”, etc.); fish loading machines (A1-IPU-2P with a capacity of 25-30 barrels/h), hydraulic presses.

The drying process consists of the following operations: receiving raw materials, sorting, washing, salting, re-washing, stringing and hanging, drying, removing, sorting, packaging, delivering to consumers or storing.

Fillet curing is similar to fish drying. It consists of the following operations: receiving and sorting fish; defrosting; cutting; washing and salting; salt controlling, washing and subsequent salt controlling; twine drying; sorting; packaging products in standard wooden boxes, and storing. Along with curing, drying is also used as a preservation method. However, this method does not eliminate all the microorganisms. The dried product is not sterile [2].

Depending on the temperature regime, there are the following drying methods: cold drying (for producing fresh-dried and salted-dried skinny fish); hot drying (water is removed by air heated to 120-140 and 160-200 °C in special drying plants), sublimation based on the ability of water ice to transform from a solid state to steam bypassing the liquid phase. To accelerate this process, fish is dried in special sublimation plants without oxygen. This reduces the processing time by 6 times.

The smoking method includes the following processes: defrosting; sinking and salting; stringing or laying out on grids; smoking and subsequent cooling; packaging (and freezing after hot smoking) and storing.

During the fish smoking, the following equipment is used:

- smoke generators (N-29-IO2, 255U.288.30-0, PSM by VNIRO) with a capacity of 200-1000 m3/h;
- smoking plants (KP-1, GE-91, KON-5, Y16-AFN, UTOKI, D5-FTG, LS-1, N29-IKE-2, N29-IKE-3, a set of smoking and boiling units, Y15-AFV).

Many units are equipped with automatic control systems. Some of them include specialized automation units with microprocessor control systems.

Automation schemes for fish defrosting equipment are similar to automation schemes for refrigeration equipment used for storing and freezing meat. Let us describe the automation scheme for fish defrosting equipment which has specific features.

For defrosting fish, two-conveyor continuous-type irrigation devices H2-ITA-112 are widely used. Each device is a welded metal structure consisting of a bathtub, irrigators, defrosting and unloading conveyors, an electric drive, a pump, control and shutoff valves. The device is loaded by pushing a block
of frozen fish into one of the cassettes mounted on the defrosting conveyor. Similar blocks with frozen fish are irrigated with water from sprinklers located above the conveyor. Irrigation water is preheated by supplying steam to the irrigation pipe. To ensure uniformity of the defrosting process, fish blocks are turned around. Under its own weight, frozen fish falls onto the canvas of the discharge conveyor, where the defrosting process is completed under the action of water flowing from the defrosting conveyor blocks. At the exit, the fish is rinsed with clean water and conveyed to subsequent operations.

Let us describe a simplified automation scheme for the fish defrosting device, where the following parameters are controlled: a temperature, a flow rate and a steam pressure, a flow rate of irrigation water, a water level. Water supply and discharge are controlled by a level regulator. Steam consumption, irrigation, and water temperatures are regulated by microprocessor modules. The speed of conveyors is controlled by an electric drive ED, a current sensor and a local controller connected to a coordinating microprocessor [5].

It should be noted that fish can be defrosted by high-frequency currents (in microwave units). However, despite high quality indicators and reduced time, complexity of the equipment and cost of electricity, this method has not been widely used. A number of enterprises defrost briquettes of small fish using currents of industrial frequency.

Fish is sorted and washed manually or using simple mechanized tools. At the same time, many enterprises use sorting machines such as ISA-202, H2-ISA-602 and ISR.

Rotary-type machines are used for washing fish. They are horizontal cylinders or cones made of stainless steel which have openings for water. Fish is loaded to the cylinder, and the rotating cylinder mixes it in running water. Conveyor washing machines are a bath in which the conveyor belt with fish moves. The water is constantly changing, and fish is freed from mucus.

Foreign processing enterprises use robotic manipulators that replace low-skilled manual labor.

The automation scheme of the cold-smoking is designed to service N29-IMC. It includes two control loops: based on the signals of temperature sensor 1 in the smoking chamber, regulator 1 controls temperature by affecting the executive device IU1 which changes the volume of steam supplied to the air heater; based on the signals of humidity, speed and optical density sensors, regulator 2 controls the actuator IU2 which regulates relative humidity by changing the volume of steam entering the smoke mixing chamber.

For the automation of cold smoking processes, tunnel-type smoking plants are often used: the smoking chamber is divided into two zones (smoking zone 1 and drying zone 2). The equipment includes a DG smoke generator, a KO irrigation chamber, two heat exchangers TO1, TO2 and two fans B1 and B2. The automated system of fish smoking performs basic control functions (control of the readiness for startup, signaling the status of fans, heaters and control valves, measuring and displaying the temperature and humidity in the chamber) and management (stabilizing the temperature and humidity in the chamber, turning on and off fans, heaters and valves). The relative humidity is measured using the psychrometric method (based on the difference in temperature between “dry and wet” thermometers) and is regulated by changing the flow rate of steam.

Canned food production includes the following operations: defrosting; sorting; cutting; washing; salting; heating (frying, blanching, baking, smoking); packaging and pouring liquid components; rolling up cans; sterilizing.

Fish is stuffed in cans and dosed manually on packaging conveyors. At medium and large enterprises, these operations are performed by special stuffing machines (INA-115, INA-116), which use the volumetric dosing and vibration compaction methods.

The automatic control system (ACS) for dosing contains the following main functional elements: a mass sensor-transducer (IVA-107), a logical analyzer (implemented on the Electronics MC27024 programmable universal controller) and actuators (electro-magnetic type) located in the stuffing machine. Preliminarily, the flow of cans is divided into three groups (underweight, norm, overweight) and the corresponding electromagnetic actuators adjust the mass of each can in accordance with the set value. These actuators are controlled either by signals of the microprocessor controller or the weight control machine (in case of a microprocessor failure).
The method of optimal portion control for filling cans with fish was developed. Accurate and quick receipt of products for packaging or canning is of great industrial importance. This approach involves rapid operational measurement of each fish. A direct measurement is not feasible due to its cost and production rates. An indirect measurement is suitable for the operational measurement of fish weight distribution. A comprehensive structural model of the fish body is based on real data and practical information about its shape. The model is used to obtain reasonable and comprehensive data about fish in a fast and cost-effective way. In case of optimal portion management, portions are made close to the desired net weight according to the cost function [7,8].

Cans are filled before heat treatment. The exceptions are sprats, saury (blanched in oil), and ordinary fish (fried in sauce). Cans are filled with oil, fillings, vegetables by sauce fillers, oil fillers, and salt dispensers equipped with local control systems.

The ratio of fish and sauce depends on technological standards. Preliminary heat treatment is carried out using the following methods: frying, blanching, baking, and hot smoking.

Sterilization is the most critical technological operation. It is a process of heat treatment of products packaged in hermetically sealed containers. Canned food is sterilized in horizontal or vertical autoclaves. The sterilization process involves several stages. At the first stage, steam is forced out of the autoclave; temperature and pressure rise to the required values. At the second stage, the autoclave is heated, constant overpressure is established. Upon completion of the sterilization process in the autoclave, pressure and temperature gradually decrease. The content is cooled with water. Strict sterilization requirements should be met. After cooling, the cans are sorted, washed in an alkaline solution and hot water, dried and sent to the finished product warehouse. The autoclaves are equipped with automation devices.

As an example, let us describe a functional automation scheme for the vertical autoclave equipped with a temperature regulator PRT-2 and a pressure regulator RD-2.

The automation scheme includes a temperature sensor (a gauge thermometer) whose signal is transmitted to the controller and the pressure sensor (MS-P2 gauge) whose output is connected to the controller. The temperature and pressure indicators are recorded by a secondary device. The temperature is supported by the RPT-2 regulator acting on the controlled valves located on the pipelines supplying steam and water. The pressure is regulated by the RD-U regulator acting on the controlled valves installed on the pipelines supplying compressed air and discharging water.

The sterilization control program is controlled by a special software device which can be reprogrammed to another desired sterilization mode in accordance with a fish processing technology.

In the fishing industry, many auxiliary operations are not automated. For their automation, it is necessary to use flexible lines and new production technologies.

There are no systems for automatic identification of landmarks. The share of errors of automatic positioning of landmarks was less than 3%, and the share of standard forecast errors was below 1.5%. This method can be used by food industries [9].

Machine vision methods are a non-destructive, fast, economical, consistent and objective monitoring tool and an assessment technique based on the image analysis and processing using various applications [10].

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