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AUTOMATED CONTROL OF THE PROCESS OF SORTING FRUIT AND VEGETABLE RAW MATERIALS WITH MONITORING ENERGY CONSUMPTION TO INCREASE THE ENERGY EFFICIENCY OF PRODUCTION

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Abstract. *The article proposes an automated control system for the sorting process of fruit and vegetable raw materials with fast algorithms for analyzing the shape of raw materials to isolate poor-quality samples from the general flow with monitoring energy consumption. The automated complex allows you to form optimal values of control influences to improve the quality of the initial product with minimal energy consumption. It is proposed to implement energy consumption control to increase the energy efficiency of production using control and measuring devices in the form of a microcontroller (sensors) and a converter to achieve sustainable development goals. Built-in sensors allow you to monitor energy consumption in real time and predict possible changes.*

Keywords: *sorting, automation, energy efficiency, renewable energy sources, control and measuring equipment, fruit and vegetable raw materials, food industry.*

Introduction. The food industry plays an important role for the world's population, but at the same time it is the largest consumer of energy, which is needed

at all stages of the food chain directly for production, processing and transportation. As is known, food systems account for about 30% of total global energy consumption. About a quarter of all energy is consumed at the production stage, 45% – for food processing, 30% – for retail trade, food preparation. During the processing and storage of raw materials, energy is used for processes such as drying, cutting, grinding, cleaning, including cooling and other forms of processing before distribution, which are very energy-intensive [1]. Therefore, one of the primary tasks of the food industry is to solve the problem of significant total energy consumption. Reducing specific energy consumption should be in line with the concept of the «European Green Deal» and contribute to making production resource-efficient and cleaner. Accordingly, in modern conditions, it is necessary to use alternative energy sources, which will play a decisive role in energy consumption during such energy-intensive operations as drying, grinding, cleaning, and cooling of food raw materials.

Main text. Modern development of the food industry is characterized by the introduction of intensive technologies, among which automation tools occupy one of the leading places. They allow monitoring and optimization of technological processes in real time and predicting potentially expected results [2]. To achieve sustainable development goals, energy consumption is monitored to improve energy efficiency in production. The growing demand for food, coupled with fluctuations in fossil fuel prices, has prompted the search for environmentally friendly alternative energy sources. The feasibility of using renewable energy sources in the food production process will help reduce the use of traditional energy in the context of the energy crisis and the increase in demand for fossil fuels. Recently, much attention has been paid to innovative green energy technologies in the food industry:

– solar energy, namely solar panels – a device that absorbs sunlight and converts it into electrical energy, which is stored in solar batteries attached to the panels;

– wind energy, namely the use of wind at industrial facilities, is becoming a popular trend, as such energy is one of the most affordable and clean;

– automation tools that improve raw material quality control monitor energy consumption to improve energy efficiency.

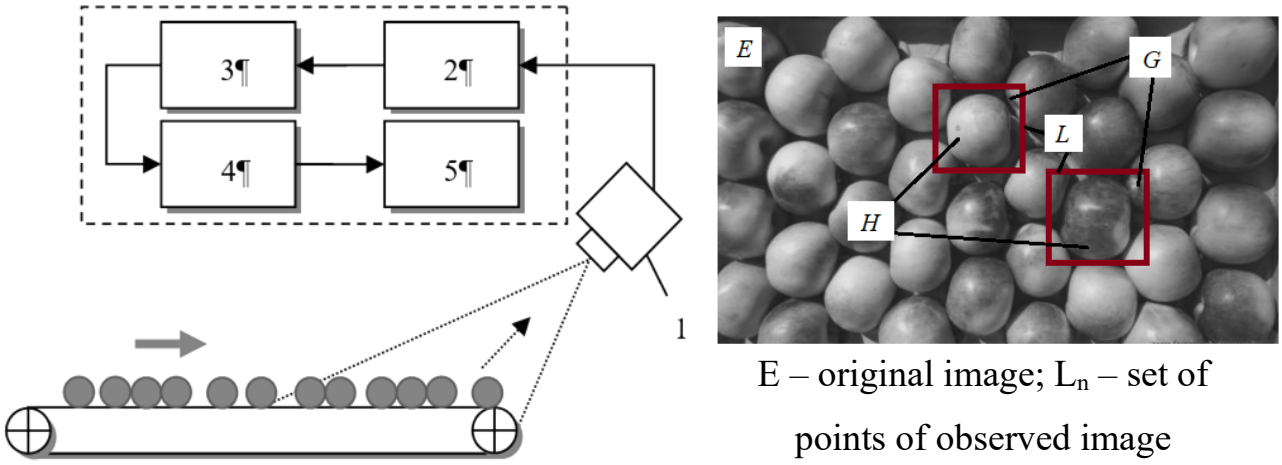
One of the key positions of the sustainable development strategy is to minimize the impact of the food industry on the environment. New technologies open up opportunities to modernize existing equipment by integrating artificial intelligence into production processes, using automated quality control systems and implementing energy-efficient solutions. In today's conditions, enterprises are forced not only to ensure the safety and sustainability of technological processes, but also to constantly improve their economic efficiency and implement innovative technologies to reduce the consumption of water, energy and other resources. A significant effect can be achieved by improving automated process control systems with the inclusion in the structure of the system of an intellectual component of a mathematical apparatus operating on the basis of fuzzy logic algorithms, neural networks, etc.

Automation of technological processes will reduce the amount of waste, improve quality control of raw materials. For fast and high-quality, sorting, less labor-intensive modern technologies have been created, such as machine vision systems. This method is based on obtaining an image of samples, analyzing the images, comparing them with the standard and making a final decision on accepting or rejecting the samples [3]. Using machine vision systems and image processing methods, it is possible to classify plant materials by size, shape and color. Conduct a selection of unsuitable samples that do not meet quality criteria (green skin, sprouts, mechanical damage) and impurities. Among all the sorting criteria, shape is one of the main indicators, since damage and cuts during harvesting and processing add additional types of shapes. Therefore, reliable automatic control systems are needed to increase the speed of production and improve the accuracy and efficiency of the sorting process of plant materials.

Recently, many studies have been devoted to improving sorting processes, using various technologies and highlighting the most important characteristics by which the sorting process can be carried out: by shape [4], by size [5]. However, there is a need to improve the recognition of not only external defects (green skin, sprouts, bruises, mechanical damage), but also internal defects (black core, water core, frost damage, internal cavities). Among all the most important characteristics by which the sorting process is carried out, is the shape of the object, since damage and cuts during

harvesting and processing can add additional types of shapes. Therefore, it is relevant to develop a generalized structure of the visual control system of the flow of plant materials on the sorting device using technical means and technologies for digital image processing. Analysis of the shape of the object based on machine vision systems and identification of samples that do not correspond to the specified shapes for extraction from the sorting device with monitoring of energy consumption through the use of control and measuring equipment.

An automated control system for the sorting process of fruit and vegetable raw materials with fast algorithms for analyzing the shape of raw materials to isolate low-quality samples from the general flow is proposed (Figure 2).



E – original image; L_n – set of points of observed image fragments; H_n, G_n – set of points from a stream

Figure 1 – Generalized structure of the visual control system for the flow of fruit and vegetable raw materials

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Figure 1 shows*: 1 – video camera; 2 – system for converting video into a sequence of photographic images; 3 – system for improving image quality; 4 – image object recognition system; 5 – initial interface of the system.*

Using video camera *1*, a video signal is generated that transmits the dynamics of the movement of objects entering the field of view of the video camera. To increase the area of the section of the flow of objects monitored by the video camera, its optical

axis is located at a certain right angle to the plane of movement of the conveyor belt. Based on the video signal, converter *2* generates a sequence of raster images corresponding to the frames of the input video signal. Changes in the characteristics of the flow, ambient air, technological and random factors cause distortion of photographic images. The function of improving the quality of images is implemented by the corresponding system *3*. After removing distortions and noise, the images are sent to the data recognition system *4*.

The automated complex allows you to form the optimal values of control influences to improve the quality of the output product with minimal energy consumption. It is advisable to control energy consumption using control and measuring equipment in the form of a microcontroller (sensors) and a converter [6]. The system of control and measuring instruments used for measurements has an input in the form of the actual value of the measured quantity, and the output in the form of the measured value of the variable. To achieve sustainable development goals, it is necessary to control energy consumption to increase energy efficiency of production.

An automated system for controlling the sorting process of fruit and vegetable raw materials with fast algorithms for analyzing the shape of raw materials for isolating poor-quality samples from the general flow with monitoring energy consumption using control and measuring equipment is proposed. The automated complex allows you to form optimal values of control influences to improve the quality of the initial product with minimal energy consumption. It is advisable to control energy consumption using control and measuring equipment in the form of a microcontroller (sensors) and a converter.

Summary and conclusions. It is noted that, the food industry plays an important role for the world's population, but at the same time it is the largest consumer of energy, which is needed at all stages of the food chain directly for production, processing and transportation. During the processing and storage of raw materials, energy is used for processes such as drying, cutting, grinding, cleaning, including cooling and other forms of processing before distribution, which are very energy-intensive. Therefore, one of the primary tasks of the food industry is to solve the problem of significant total energy

consumption. Reducing specific energy consumption should be in line with the concept of the «European green deal» and contribute to making production more resource-efficient and cleaner. Accordingly, in modern conditions, it is necessary to use alternative energy sources, which will play a decisive role in energy consumption in the process of such energy-intensive operations as drying, grinding, cleaning and cooling of food raw materials.

It is believed that, to achieve sustainable development goals, energy consumption must be controlled to increase energy efficiency of production. An automated control system for the sorting process of fruit and vegetable raw materials with fast algorithms for analyzing the shape of raw materials to isolate low-quality samples from the general flow is proposed with monitoring of energy consumption through the use of control and measuring equipment in the form of a microcontroller (sensors) and a converter. They allow for real-time control of energy consumption and forecast potential changes.

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