Automation of the drying process of agricultural raw materials to obtain products of high nutritional value

I V Altukhov, S M Bykova, G V Lukina and V D Ochirov
Irkutsk State Agrarian University named after A.A. Ezhevsky, p. Molodezhny, Irkutsk region, Irkutsk district, 664038, Russia

E-mail: altukhigor@yandex.ru

Abstract. The purpose of these studies is to create an automated system for the drying process of agricultural raw materials. This system should be capable of providing biotechnological conditions for heating a single product to preserve especially valuable biological components in this product. Environmental problems of modern society determine the objective of functional nutrition of a person, as the basis of a healthy lifestyle. To solve this problem, it is necessary to obtain products of high nutritional value, with a maximum content of active substances. Each plant product contains not only vitamins and minerals, but also elements that determine its special value. During storage, these components are lost due to biological characteristics and storage conditions. To preserve them for a long period and create a product of high nutritional value, certain conservation methods must be used. Such methods include drying. Products dried in a special way are able to maintain up to 95% of their valuable indicators. An analysis of modern drying methods for plant raw materials showed that the pulse infrared-convection method more closely meets the requirements of biotechnological heating conditions and is therefore suitable for obtaining products of high nutritional value. This method has a sterilizing effect, which allows to increase the shelf life of finished products. The creation of an automated control system for pulse infrared - convection radiation made it possible to obtain products of high nutritional value for long-term storage.

In agricultural production, the urgent issues of raw material production are not limited to the problem of obtaining quality products that meet the requirements of customers, along with this issue there is an urgent need to increase shelf life and a wide range of its application. [1, 2]

For preservation for a long period, various conservation methods are used, but drying of agricultural raw material allows us to provide both long shelf life and to obtain products of high nutritional value. All known drying methods used in industry have their advantages and disadvantages. [3, 4]

The infrared-convection method mostly meets the list requirements. This method allows you to use a new element base of radiation sources and create pulse infrared radiation, which has the ability to penetrate material to a certain depth and increase the temperature gradients. As a result, moisture from the inner layers enters the surface, where it is removed by a convection method. [5,6]

To implement this method, laboratory “Energy Saving in Electrotechnologies” compiled the initial requirements and terms of reference for the design and manufacture of a unit for drying agricultural raw materials. [7]

Certain recommendations were taken into account and were being corrected in the course of work before starting the design of the production - experimental unit: [8]
1. To carry out preliminary experiments on heating given raw material in laboratory conditions to determine the technical parameters of the unit (power, size, optimal thickness of the raw material layer; optimal value of energy illumination; spectral nature of radiation; drying time, etc.).

2. To provide a sufficient range and reserve of radiation power for various types of products.

3. To ensure the possibility of automatic control by IR irradiators and change of the distance between infrared emitters and the material.

4. To ensure volumetric irradiation, as well as radiation to fall primarily perpendicular to the surface of the material.

5. For the internal casing of installations, sheet aluminum or aluminum foil should be used (reflection of infrared radiation over 90%); this increases the uniformity of irradiation and the efficiency of the installation, which is of particular importance when irradiating objects with a low absorption capacity or with a complex surface shape.

6. Possibility of quick and easy replacement of emitters and convenient cleaning of emitters and reflectors.

7. Automation control should include compliance with the drying regimes and the fulfilment of biotechnological conditions.

8. The inclusion of individual emitters should be separate. The pulse-discontinuous energy supply modes should be used for the optimal choice of the irradiation mode to the characteristics of the processed raw material.

After forming the ball requirements, a production and experimental unit was made, shown in figure 1. Pulse ceramic heating elements of types ECS, ECP, ECH, ECX, ECZ were the sources of infrared radiation in the unit.

![Figure 1](image-url)

**Figure 1.** Production Experimental IR – unit: 1 - drying chamber, 2 - centrifugal fan, 3 - cassette holder, 4 - removable, panel IR irradiator, 5 - cassettes with raw material, 6 - temperature sensor, 7 - control panel, 8 - heat-insulating material, 9 - flashlight, 10 - viewing window, 11 - sealed door, 12 - handle, 13 - door holders, 14 - metal casing.

The automatic control system of infrared radiation sources supports the necessary temperature mode and the mode of infrared radiators operation. This allows to reduce electricity consumption.

The device operates as follows. Raw material is placed on trays in a certain layer and then placed into the drying chamber. Depending on the type of material being processed, heat radiators are installed. The control mode of infrared radiation sources is selected taking into account the type of product, its initial moisture content and biological characteristics. The temperature in the chamber is maintained by the control system and thermocouple. Evaporated moisture is removed by fan. After a certain time, the products are removed from the drying chamber.
IR irradiators are placed so that the principle of volumetric irradiation is respected. The design of the installation makes it easy to replace them. Figure 2 shows the electrical circuit of the dryer.

Operation of the dryer circuit: when circuit breaker QF1 is turned on, signal lamps HL1 - HL3 illuminate, these lamps signal that machine QF1 is on and all three phases are energized. Next, we turn on switch SA1. The circuit works both in manual and automatic modes.

Automatic mode: At the beginning SA1 is switched into position “P” on the programmer (TSAP OBEH TPM) [9]; the temperature value that is required during the drying process is set; then SA1 is switched into position “A”, the contact of the programmer is closed, the intermediate relay KL receives power and contacts KL1 - KL3 are closed. The KM1 magnetic starter receives power through contact KL1, the starter’s contacts KM1 are closed, the heating element EK1 and the warning lamp HL4 receive power, then the KM2 magnetic starter receives power through contact KL2, its contacts KM2 are closed, the heating element EK2 and the warning lamp HL5 are supplied, CT time relay coil receives power through contact KL3, CT contact opens.

After the value of the set temperature has been reached, the programmer’s contact is disconnected, the intermediate relay coil KL loses power, its contacts KL1 - KL3 return to the original position, coils of the magnetic starters KM1 and KM2 lose power; their contacts KM1-KM2 return to the original position, heating elements EK1, EK2 and signal lamps HL4 - HL5 lose power, the time relay coil loses power, the time mechanism starts: CT contact is closed in 9 seconds; the coil of magnetic starter KM3 receives power, its contacts KM3 are closed, fan motor M and the warning light HL6 receive power.

Then, as soon as the controlled temperature decreases to the lower limit of the set temperature values, the programmer contact will be closed, the KL coil will receive power, its contacts KL1 - KL3 will be closed, the KM1 - KM2 magnetic starters’ coils will receive power, the KM1 - KM2 contacts will be closed, the heating elements EK1, EK2 and signal lamps HL4, HL5 will receive power. The CT time relay coil will receive power, the CT contact will part, the KM3 magnetic starter coil loses power, the KM3 contacts part, the fan motor M and the HL6 warning lamp lose power. These cycles are repeated until the product is ready. Temperature control is carried out using the programmer (DAC Aries TPM 251). [9] The functional diagram of the controller is shown in Figure 3. The ORM
program (Owen Process Manager) was used for a visual display of the process parameters on the PC screen, monitoring and data archiving.

Before starting work in pulse-discontinuous mode, the values of the settings for the temperature of heating of the raw material $t_{\text{max}}$ and $t_{\text{min}}$ are set. The survey of temperature sensors is set taking into account the necessary measurement accuracy.

The drying process lasts until the desired moisture content of the raw material is reached according to the predetermined indicators. The temperature values of raw material and IR irradiators under various modes are archived on a PC. To connect the device with a computer, the ОВЕН AC3 adapter is used, [9] converting RS-485 interface signals into RS-232 and vice versa (figure 4).

![Figure 3](image3.png)  
**Figure 3.** Functional diagram of the controller ОВЕН ТРМ [9].

![Figure 4](image4.png)  
**Figure 4.** Drying temperature control system.

The presented automatic management system of agricultural raw material drying and the developed unit allow us to fulfill the technological requirements of biotechnological heating conditions and obtain products of high nutritional value.

**References**

[1] Altuhov I, Shamarova N, Suslov K, Gerasimov D, Shushpanov I, Lombardi P and Komarnicki P 2019 Stabilizing the control of a plant material drying process in off-grid power systems *Elektroenergetika* 1 363-67

[2] Altukhov I V, Buyanova I V, Tsuglenok N V, Krieger O B and Kashirsky E B 2019 *Foods and Raw materials* 1 151-60

[3] Altukhov I V 2016 The technology of obtaining concentrated sugar-containing products with the use of pulsed infrared processing and drying of roots and tubers (Irkutsk)

[4] Tsuglenok N V 2004 *Technological forecasting* (Krasnorsk)

[5] Tsuglenok G I and Loam G I 2003 *Methodology and theory of a system for researching energy-technological processes* (Krasnoyarsk)

[6] Khudonogov I A and Ochirov, V D 2010 Influence of IR energy supply modes on the qualitative and quantitative indicators of dried carrot root crops *Vestnik of AltGAU* 8 73-7

[7] Plaksin Yu M and Azarskova A V 2001 *Theoretical Foundations of Radiant Heat Transfer in Infrared Installations and Their Calculation* (Moscow: MGUPP)

[8] Karpov V N and Rakutko S A 2009 *Energy Saving in Optical Electrotechnologies of the AIC.*
Applied Theory and Particular Techniques (SPb.: SPbSAU)

[9] OBEH: equipment for automation Available from: http://www.owen.ru/