The development of microwave installations for separating the fluff from skins of rabbits in the agricultural enterprises of low power

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Abstract. The article is devoted to the development of technology and technical means designed to weaken the retention force of hair in the dermis of rabbit skins due to selective dielectric heating of hair bulbs under the influence of an ultra-high frequency electromagnetic field (UHFEMF). Microwave technologies and more than 20 installations with UHFEMF sources and non-traditional resonators have been developed that provide continuous collection of fluff from rabbit skins. Resonators have been tested that ensure the separation of downy raw materials from the skin of rabbit skins in a continuous mode when implementing a set of reasonable design and technological parameters. Novelty of technical solutions of developed technologies and microwave installations with non-traditional resonators, such as: cylindrical (2655770, 2651594, 2680543, 2682890); semi-cylindrical (2018101622, 2703918); toroidal (2674605, 2699709); coaxial (2655748, 2651593); biconic (2715341, 2018117136) proved by patents of the Russian Federation. A technical specification has been developed for creating a radio-hermetic microwave installation with low-power magnetrons and a biconic resonator, which ensures the separation of down raw materials from rabbit skins in a continuous mode at low operating costs.
1. **Introduction**

Analysis of research results on the implementation of methods for processing animal and animal skins allows us to identify a priority microwave technology for collecting fluff from rabbit skins.

*The scientific problem* is to reduce operating costs for collecting fluff from rabbit skins while maintaining quality at low-capacity agricultural enterprises.

*The aim* of the work is to separate the decontaminated down raw materials from rabbit skins by developing technology and ultra-high-frequency continuous installations with low operating costs and maintaining electromagnetic safety.

The existing technologies of primary processing of animal and rabbit skins are reflected in the works of many authors [2, 4-6, 11]. Many scientists are engaged in the implementation of the basics of the theory of electromagnetic fields and waves in the development of innovative technologies and technical means [1, 7-9].

2. **Materials and research methods**

Analyzing various approaches to collecting hair from animal skins and studying the specific features of the impact of the ultra-high frequency electromagnetic field (UHFEMF) on raw materials, namely selective heating of raw materials components, depending on their electrophysical parameters, we developed a scientific innovation idea. At the same time, taking into account the accumulated experience of the research team of the university, the results reflected in the works of foreign and domestic scientists, we have developed more than 20 installations and technologies that implement the main criteria for designing microwave installations. The effective design of the working chamber of microwave installations was chosen by analyzing the parameters of the electrodynamic system with non-traditional resonators: spherical, cylindrical, coaxial, toroidal, ellipsoid, biconic, etc.

We calculated and visualized the distribution of the electromagnetic field and the power flux density in the developed non-traditional resonators using the CST Microwave Studio program, as well as evaluated their own q-factor. Theoretically, we calculated the intrinsic q-factor of the developed unconventional resonators as the ratio of double capacity to their surface area, taking into account the skin layer.

For experimental research, laboratory samples of low-power magnetron installations (OM75S 31, M24FA-410A, etc.) with air cooling and corresponding design versions of resonators were made.

Three-factor experiments of type 23 on the theory of active planning were performed with the help of laboratory installations and effective modes of operation of continuous microwave installations with non-traditional resonators were identified. Qualitative indicators were evaluated by studying the physical and chemical parameters of skin and its bacterial contamination.

3. **Results and discussion**

The method of implementation of innovative technology and technical means intended for processing rabbit products is shown in Figure 1.

The problem of the number of rabbits based on the introduction of scientific and technological progress remains unresolved. In small-scale agricultural enterprises, the waste-free technology of rabbit production is not sufficiently developed today. Having carried out monitoring of technological and technical problems, and ways to solve them, we found that it is not possible to achieve high-quality dressing of rabbit skins with minimal costs under the conditions of rabbit farms. We propose to collect fluff from the skins of rabbits that have increased down productivity, for example, from rabbits of the «White giant» breed, and not to dispose of the skins. The use of down not only reduces the cost of meat products, but also provides additional sources of raw materials for the felt industry, while it can be used in the production of granular feed from combined raw materials of plant and animal origin. Therefore, the development of innovative technology and technical means using ultra-high frequency electromagnetic field (UHFEMF) energy to separate downy raw materials from rabbit skins at reduced operating costs is actual.
Research of the problem in rabbit breeding

Research of the scientific and technical potential of the region

Monitoring of technological and technical problems, and ways to solve them

Research of technological processes and development of design documentation for innovative technical means

Identification of small-scale agricultural enterprises as potential consumers of innovation

Classification of innovative technologies and developed installations for collecting fluff from rabbit skins by the level of novelty

Determination of the level of technologies for production and processing of rabbit products

Implementation of innovative technology and installations for collecting fluff for agricultural commodity producer

**Figure 1.** The method of implementation of innovative technology and technical means intended for processing rabbit products in the farms

Taking into account scientific and technical potential in the region and in Russia by promising industries «Rabbits» (the demand for rabbit meat in Russia 300 thousand tons per year), studies of technological processor data fluff from the skins of rabbits and developed design documentation for microwave installation with different working chambers (resonators). The developed installations with non-traditional resonators implement the following criteria:

1. The unit provides continuous operation while maintaining electromagnetic safety for service personnel.
2. The intensity of the electric field in the volume resonator is greater than the critical one, at which the viability of the bacterial microflora of the vegetative form stops in the raw material.
3. The working chamber, which includes resonators, provides repeated exposure to UHFEMF with a process life of less than 0.5.
4. The performance of the microwave installation is regulated by using several low-power air-cooled magnetrons and changing the power of each generator.
5. The configuration of the volumetric resonator ensures maximum intrinsic q-factor and uniform distribution of the electric field in the raw material, taking into account the depth of penetration of waves.
6. The dose of UHFEMF exposure to raw materials is adjusted depending on the size of rabbit skins. The duration of the impact is regulated by the speed of movement of transporting mechanisms, and the specific power – the volume of loading and power of generators.
7. The installation contains nodes that ensure the absorption of brine or sourdough mezdra skin and combing, collecting fluff raw materials.
8. With repeated exposure to UHFEMF, the skin with a mezdra fabric impregnated with brine or sourdough is endogenously heated no more than 45–50 °C.
9. The intensity of heat generation is controlled by regulating the power of microwave generators depending on the volume of loading.
10. Humid air is removed while maintaining the radio-tightness of the installation.
11. The beyond the waveguides limit the emission to the required limits during transfer and unloading skins.

A model of the mechanism of the technological process of separating down from rabbit skins is shown in Figure 2. An innovative idea lies in the weakening of the retention force of hair in the hair follicles due to selective endogenous heating of the dermis of the skin, the mezdra side of which is impregnated with a special sponge or when the mezdra, smeared with vegetable oil, is covered with moistened rock salt. Homogenized fermented mixture (sourdough) in UHFEMF under the influence of endogenous heat reduces the strength of hair retention in the bulb, their separation from the dermis occurs in a few minutes, depending on the state of the original skin. Features of mustard powder are
based on the hydrolyzing effect of acids formed from starch, a significant content of fat in it, and the action of enzymes in the skin.

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**COLLECTING SETS OF RAW WITH THE SKINS OF RABBITS**

Soaking the mezdra side of the skins with a certain concentration of brine or sourdough (a homogenized fermented mixture of rye flour, water, yeast, mustard powder and salt)

Selective endogenous heating of multi component raw materials (hair, skin, mezdra tissue, hair bulbs, brine or sourdough) in UHFEMF

Weakening of the hair retention force in the bulbs due to selective endogenous heating, disinfection of down raw materials in high-tension EP and collection using combing nodes and a pneumatic pump. Quality control

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**Figure 2.** A model of the mechanism of the technological process of separating down from rabbit skins

Histomorphological assessment of the degree of dewatering of rabbit skins, the mezdra side of which is covered with vegetable oil and moistened rock salt, showed that when exposed to UHFEMF, the hair bulb is destroyed. The epidermis layer is completely loosened, resulting in a weakening of the retention force of the hair in the dermis, and with a slight pressure on the suction of the pneumatic pump is separated quite easily. At the same time, the strength properties of down raw materials are preserved.

Two technologies have been developed to implement this microwave technology.

1. Collection of decontaminated downy raw materials in the process of rotation of boxes with skins, the mezdra side of which is impregnated with brine or sourdough in resonators containing pegs. The principle of operation of the unit is based on ensuring the weakening of the retention force of down in the hair follicles in the process of selective exposure to UHFEMF, combing the fluff fibers while preserving their marketable appearance, collecting them and transporting them pneumatically. For example, this technology is implemented by a microwave installation (Figure 3) with a semi-cylindrical resonator and mobile tubes for collecting fluff from rabbit skins (patent No. 2699194) [1, 10].

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**Figure 3.** Microwave installation with a semi-cylindrical resonator and mobile rules for collecting fluff from rabbit skins: a) installation; b) dielectric rule

The resonator chamber is formed by a horizontally positioned semi-cylinder and a rectangular tray. The tray is mounted for movement and rotation around its axis dielectric pravilki (with the possibility of movement and rotation around its axis), made in the form of a frame assembled from rods, forming the shape of a truncated cone, which are attached to the rims of appropriate diameter, and the center pravilki laid-axis (Figure 3 b). The ends of the rule axes are located in the retainer rollers located above the conveyor chains installed in the skids. The skids are mounted on top of each other in
parallel, along the side surfaces of the pallet.

2. Collection of decontaminated downy raw materials in the process of continuous exposure to UHFEMF on expanded skins in the form of plates with moistened mezdra brine or sourdough. Most of the developed microwave installations implement this technology as the most effective. For example, in a conveyor microwave installation, the fluff is separated from the unfolded rabbit skins (Figure 4).

![Figure 4](image_url)

**Figure 4.** Conveyor microwave installation: 1 – coaxial resonator; 2 – magnetrons; 3 – perforated dielectric drum; 4 – dielectric pegs; 5 – slot for a pneumatic pump; 6 – dielectric rollers; 7 – slot for unloading the skin; 8 – dielectric rollers; 9 – sponge bath; 10 – table for laying skins; 11 – electric drive of the drum, 8 rollers and 6 rollers; 12 – hatch with an observation window; 13 – external cylinder; 14 – inner cylinder, 15 – toothed crown

The conveyor microwave installation contains a horizontally located coaxial resonator 1, represented as a system of two coaxially arranged outer 13 and inner 14 cylinders with common bases, with radii differing by more than a quarter of the wavelength, and a length equal to a multiple of half the wavelength. The outer cylinder has three slots along the side surface and 4 dielectric flexible pegs on the inner surface. In the annular space between the cylinders, a dielectric perforated drum 3 with dielectric pegs is coaxially installed. The size of the annular gap between the dielectric pegs corresponds to the thickness of the skins. Magnetrons 2 are installed on the side surface of the outer cylinder with a 120-degree shift along the perimeter. On one end side of the resonator there is an electric drive 11 of the drum 3, transporting rollers 8 and dielectric rollers 6, and on the other – a hatch 12 with an observation window. Along the perimeter of the drum 3 there is a toothed crown 15. The slot 5, which is located in front of the rollers 6, is connected through the air outlet to the pneumatic pump. A storage tank is attached to the other slot 7, and between these slots along their radial rollers is installed so that they cover the gap between the dielectric pins. Under the transporting rollers 8, located in front of the third slot, a bath 9 is installed so that the lower leading roller is immersed in the sponge, and a table 10 is installed at the level of the gap between them. The average perimeter of the coaxial resonator 1 should be a multiple of half the wavelength.

Removal of hair from rabbit skins immediately after slaughter is possible by soaking with brine 5% concentration and exposure to UHFEMF dose equal to 0.2 kWh/kg. After more than 2 hours after slaughter, it is more effective to spray a sourdough from a fermented mixture of rye flour, water, yeast, mustard powder or rock salt on the mezdra side of the skin, when moving through the resonator.

The manufactured and tested microwave installation with an unconventional resonator for separating the hair from the skin of rabbits is shown in Figure 5, and the technical characteristics of the installation are shown in Table 1.
Table 1. Technical characteristics of microwave installation

| Parameter                                         | Value           |
|---------------------------------------------------|-----------------|
| Power consumption of four generators, kW          | 4,8             |
| Plant capacity, kg / h; PCs/h                     | 15–20; 34–45    |
| Power of the conveyor motor, kW                   | 0,25            |
| The speed of movement of the conveyor, m/s        | 0,015–0,2       |
| Pneumatic pump power, kW                          | 0,25            |
| The power of the fan for cooling the magnetron, kW| 0,25            |
| Power consumption of the microwave installation, kW| 5,55            |
| Specific energy costs, kWh / kg                   | 0,3             |
| Overall dimensions, m                             | 1,2×1,0×2,15    |

4. Conclusion

Studies of the pattern of distribution of the EP tension in non-traditional resonators show that in a cylindrical resonator, the EP is evenly distributed over the entire working area. The tension reaches 4 kV/cm, and the q-factor is within 7000, in a toroidal one – 7 kV/cm. The q-factor is 9000, in a biconic one – up to 6 kV/cm, and the q-factor is 7000.

A truncated biconic resonator with a volume of 350 l with a q-factor of 9000 with a magnetron power of 3200 W will provide an electric field strength of 1.2–1.5 kV/cm in a volume of up to 55 l in the area of the cone bases and reduce the total microbial number by half.

The symmetrical biconic resonator, which has a sufficiently high intrinsic q-factor, is able to implement the main criteria for designing microwave installations, namely: continuity of the technological process due to open vertices, ensuring electromagnetic safety and high EP intensity sufficient for disinfection of downy raw materials; to increase the efficiency of the installation to 0.7. With a capacity of 35–45 PCs/h, the power consumption of 5.55 kW, energy costs for the technological process of separating down from rabbit skins and collecting is 0.3 kWh/kg.

Acceleration of the weakening of the retention force of hair in the shit of skins can be carried out by exposure to microwave UHF EMF, if the mezdra side is impregnated with a homogenized fermented mixture of rye flour, water, yeast, mustard powder, or rock salt on top of vegetable oil.

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