Artículo de investigación

Microwave technologies and devices separating fur from rabbit skin

Tecnologías de microondas y dispositivos que separan la piel del cuero del conejo
Tecnologias e dispositivos de microondas que separam a pele da pele de coelho

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Abstract

The purpose of this work is the development of microwave technology and de-vices separating fur from rabbit skins in a continuous mode at reduced operating costs.
They developed the method for the action of the ultrahigh frequency electro-magnetic field (UFEF), which provides the reduction of fur fiber holding power in the meat fabric of rabbit skins with simultaneous combing and gathering. They calcu-lated the mathematical dependences describing the dynamics of multicomponent raw material heating with the change of dielectric and physicomechanical parameters in the process of UFEF. They calculated and visualized the electromagnetic field distri-butions in the developed resonators, on the basis of which they substantiated the ef-fective parameters of the electrodynamic system: the maximum property, the quality of resonators and the electric field strength. They substantiated the complex of struc-tural and technological parameters of devices with new structural design of working chambers by a multi-criteria evaluation of the technological process for the separation of fur from rabbit skin. They manufactured and tested

Resumen

El propósito de este trabajo es el desarrollo de la tecnología de microondas y los dispositivos que separan la piel de los cueros de conejo en un modo continuo a costos operativos reducidos.
Desarrollaron el método para la acción del campo electromagnético de frecuencia ultraalta (UFEF), que proporciona la reducción del poder de retención de la fibra de la piel en el tejido de carne de la piel de conejo con el peinado y la recolección simultáneos. Calcularon las dependencias matemáticas que describen la dinámica del calentamiento de materias primas de componentes múltiples con el cambio de los parámetros dieléctricos y fisicomecánicos en el proceso de la UFEF. Calcularon y visualizaron las distribuciones del campo electromagnético en los resonadores desarrollados, sobre la base de los cuales fundamentaron los parámetros efectivos del sistema electrodinámico: la propiedad máxima, la calidad de los resonadores y la intensidad del campo eléctrico. Ellos sustentaron el complejo de parámetros estructurales y tecnológicos de los dispositivos con un nuevo diseño estructural de las cámaras de trabajo mediante una evaluación de múltiples

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the microwave device under production conditions for the separation of fur from rabbit skin, and adjusted the op-erating modes, which allow to reduce operating costs. They evaluated the technical and economic efficiency of microwave technology introduction for the processing of fur and the devices for rabbit farms; they developed practical recommendations for the operation of microwave units to separate fur from rabbit skins.

Keywords: Rabbit skin, the holding strength of fur fibers in skin, micro-wave technology, volume resonators, electrodynamic parameters, ultra-high frequency device.

criterios del proceso tecnológico para la separación de la piel del cuero del conejo. Fabricaron y probaron el dispositivo de microondas en condiciones de producción para la separación de la piel de la piel de conejo, y ajustaron los modos de operación, lo que permite reducir los costos operativos. Evaluaron la eficiencia técnica y económica de la introducción de la tecnología de microondas para el procesamiento de pieles y los dispositivos para granjas de conejos; desarrollaron recomendaciones prácticas para el funcionamiento de las unidades de microondas para separar las pieles de los cueros de conejo.

Palabras claves: piel de conejo, la fuerza de sujeción de las fibras de piel en el cuero, tecnología de microondas, resonadores de volumen, parámetros electrodinámicos, dispositivo de frecuencia ultraalta.

Resumo

O objetivo deste trabalho é o desenvolvimento de tecnologia e dispositivos que separam a pele de peles de coelho em um modo contínuo a custos operacionais reduzidos microondas.
Eles desenvolveram o método para a acção do campo electromagnético de alta frequência ultra-(UFEF), que fornece pele de coelho carne tecido de pele para retenção de fibras de energia reduzido com cabelo e recolha simultânea. Calcularam as dependências matemático para descrever a dinâmica do aquecimento materiais multicomponentes com a mudança de dieltricos e parâmetros fisicomecánicos no processo de UFEF. Eles calculado e visualizado as distribuições de campo eletromagnético em ressonadores desenvolvidos, com base na qual fundamentar os parâmetros reais do sistema electrodynamic: a propriedade máximo, a qualidade dos ressonadores e intensidade do campo elétrico. Eles sustentadas parâmetros estruturais e tecnológicas complexas dos dispositivos com um novo design estrutural das câmaras de trabalho através de uma avaliação multi-critérios do processo tecnológico para a separação de couro pele de coelho. Eles fabricado e testado o dispositivo de micro-ondas, sob condições de produção para a separação da pele da pele de coelho, e modos de operação ajustados, reduzindo assim os custos operacionais. Eles avaliaram a eficiência técnica e econômica da introdução de tecnologia de microondas para o processamento de dispositivos fazendas de peles e de coelho; desenvolveu recomendações práticas para a operação de unidades de microondas para separar peles de peles de coelho.

Palavras-chave: pele de coelho, a força de aperto das fibras na pele de couro, tecnologia de microondas, de volume ressonadores parâmetros eletrodinâmicas, dispositivo de UHF.

Introduction

Rabbit breeding is a promising branch of animal husbandry, and the unsatisfied demand for rabbit meat is considerable in Russian Federation and amounts to more than 300 thousand tons per year. They gather more than 5 thousand tons of rabbit fur all over the world annually, of which about 4.5 thousand tons are produced in China. In accordance with the existing program "The Development and the Increase of Rab-bit Breeding Products in Russian Federation during 2014…2020", the increase of rabbit breeding products and the further effective use of existing capacities is relevant. The technological cycle involves the cultivation of livestock on rabbit farms, slaugh-ter, cutting and finished product (meat, skin, fur, giblets) sale (Balakirov & Tinaeva, 2007). The leaders of rab-bit breeding have developed a whole range of effective technologies aimed at maxi-mum economic indicators (Strekalov & Strekalov, 2014). However, there is a lot of manual labor in rabbit skin processing line and, consequently, quite high

operating costs. Therefore, the scientific and technical task of the research is the development of the technology and the tech-nical means for the separation of fur from rabbit skins using ultra-high frequency electromagnetic field source (UFEFS), which reduce operating costs.

Issue study level. A great contribution to the theory of electromagnetic fields and the development of innovative electrical technologies was made by Atabekov G.I., Bessonov L.A., Borodin I.F., Bunimovich V.I., Vasilyev A.N., Vendinym S.V., Ginzburg A.S., Kisunko G.V., Netushil A.V., Neiman M.S., Prischeb L.G., Strebkov D.S., Tarushkin V.I. and many other authors (Glushakov et al, 2001; Novikova et al, 2016; Shamin & Belova, 2017; Ershova et al, 2017; Dorokhov, 2010). The analysis of their research results allows to determine the main trends of microwave technology improvement, including the separation of fur from rabbit skins.

The aim of the study is to preserve the quality of fur by microwave technology and unit improvement for the separation of fur from rabbit skins in a continuous mode at reduced operating costs.

Main scientific tasks:

1. To develop the method of rabbit skin separation by UFEF exposure at reduced operating costs and the structural schemes of devices ensuring the separation of fur from skin.
2. To substantiate the parameters of the electrodynamic system by the calculation of the electromagnetic field distribution in the developed resonators within the transient mode using the CST Microwave Studio program, which make it possible to substanti-ate the effective designs of the resonators ensuring the maximum quality and electric field strength.
3. To determine mathematical dependencies that allow to reconcile the construction and technological parameters with microwave unit operation modes to weaken the strength of fur fibers in the meat fabric of rabbit skins.
4. To substantiate the complex of structural and technological parameters and mi-crowave unit operation modes based on regression models taking into account the multi-criteria evaluation of fur separation technological process from rabbit skins.
5. To develop, to create and to test the microwave units under production con-ditions that ensure the separation of fur from rabbit skin in a continuous mode; to as-sess the technical and economic efficiency of the device introduction in the rabbit farm; to develop scientifically based practical recommendations on the operation of microwave units for the separation of fur from rabbit skins.

The object of the study is the technological processes that ensure the weakening of fur holding power in rabbit skin and its collection. They also studied the experi-mental samples of microwave units that implement the technology of rabbit skin meat fabric soaking with ferments, the selective heating of multicomponent raw materials during the process of moving through the resonators of a new structural design in continuous mode taking into account electromagnetic safety.

The subject of the research is the regularities of UFEF impact on two-component raw materials in the resonators of different configurations to determine the operating modes of units with effective electrodynamic parameters.

Concept. Guided by the theory of electromagnetic waves and the basics of fluff fiber holding power weakening in skin, they solved the scientific and technical prob-lem - the development and the justification of multi-generator radio-sealed microwave unit parameters for the separation of fur from rabbit skin in a continuous mode.

Materials and Methods

The scientific studies were conducted using the mathematical devices of elec-trodynamics and the theory of the electromagnetic field of ultrahigh frequency. Three-dimensional modeling of microwave unit design was carried out via the pro-gram Compass-3D V16. According to the program CST Studio Suite 2015 they cal-culated and visualized three-dimensional pictures of the electromagnetic field distribu-tion in the developed unconventional resonators. They performed the multi-criteria evaluation of UFEF impact process on raw materials through the regression models obtained on the basis of active planning theory concerning three-factor

experiment of 23 type in the programs Statistic 12.0 and Excel 10.0. The qualitative indicators of fur were evaluated through physico-chemical and microbiological indicators in special laboratories.

Results and Discussions

It is important to control the quality of agricultural machinery products sup-plied by the agro-industrial complex, so it is necessary to pay attention to the reliabil-ity of systems and devices during operation (Novikova et al, 2015).

The basic technology of rabbit skin processing includes the following process-es: fleshing, degreasing, dressing, aging, tanning, lubrication and drying (Bondarenko, 2003). Tanning improves skin elasticity and increases the tensile strength. The skin is cleaned from the subcutaneous fat and muscle layer, the subcutaneous tissue is removed and dress-ing is performed. The process consists of treating the skin with a special salty acid so-lution to clean the core layer from adhesives and increase the strength and the softness of the skin. After that, the skin is stretched to the rules, dried, impregnated with a fat solution to prevent them from drying out and cracking. Next, the skins are rolled up and left for 12 hours for aging, and then they are subjected to final drying in a stretched form at room temperature. This technology of fur processing does not pro-vide the satisfactory quality always. In order to increase the shelf life of fur and the acquire new technological properties they use other methods of drying. For example, rabbit skins are dried in chambers at the temperature of 40 ... 45 °C, the air relative humidity of 45 ... 50%, the air speed of 0.5 ... 1 m/s for 3 ... 4 hours, with the aging for 4 ... 6 hours. But even with this technology of drying, the skin tissue remains coarse (Ivashov, 2001).

Due to the very low sale cost of dried rabbit skins of meat breed (less than 100 rubles / piece), most rabbit breeding farms dispose the hides with thick fur or send them to the plant for the production of protein feed. At that it should be remembered that the slaughter of rabbits is carried out before the period of their molt, and it is pos-sible to collect 1 kilogram of fur from 3-5 rabbits at the selling price of 250 rubles/kg. Rabbit meat price is in the range of 300-400 rubles/kg (Tsygankov, 2003). Therefore, the separation of fur from rabbit skins for use as the raw material in the textile, knitwear and felt in-dustry is a promising technology (Bondarenko, 2003; Kopusov, 2001).

The development of microwave technology and a multi-generator unit with low-power air cooling magnetrons for the separation of fur in a continuous mode in-cludes the following sequence:

- the study of technical conditions for rabbit fur and the electrophysical pa-rameters of its components;
- the justification of the configuration and the parameters of non-conventional resonators;
- the selection of related mechanisms ensuring the movement of raw materials in a working chamber;
- the justification of the electric field strength and the resonator quality;
- the calculation of microwave generator power, depending on the unit required performance;
- the substantiation of UFEF influence modes on fur;
- the choice of control means and the means of technological process control;
- the drawing up of an operational-technological scheme with a set of measures excluding the defects in the process of unit continuous operation (Lin, 2006; Tinaev, 2004).

Microwave technology provides (Dautov et al, 1996; Didenko, 2003; Semenov, 2008):

- selective, non-contact and self-regulating heating depending on the dielectric parameters of skin, meat tissue, and fur at the frequency of 2450 MHz;
- a high efficiency of microwave energy conversion into thermal energy with the correct combination of magnetron number and location in the resonators of non-traditional configurations that ensure the movement of raw materials and UFEF uni-form exposure;
- low energy losses in a working chamber when a single fan is used to cool several magnetrons, cuts, matched with the wavelength, to ensure the electromagnetic safety when raw materials are moved through the resonator in a continuous mode;

- the high accuracy of heating rate control for fur and the control of UFEF exposure dose.

It is known that the block diagram of microwave devices contains seven main elements:

1) a power source that converts the mains voltage into a high voltage required for the magnetron operation (a high voltage rectifier or a step-up transformer with a voltage regulator, and heat feeding device, etc.);
2) microwave generator that converts the power of the network frequency into the microwave range power;
3) transmission lines and microwave energy input devices in the resonator chamber;
4) the electrodynamic system of the resonator chamber, which provides a given distribution of microwave energy in its volume;
5) the auxiliary elements that contribute to the achievement of raw material uni-form heating;
6) the devices that provide unit radio leaktightness;
7) remote control unit (Grigoriev, 2007; Drogaytseva, 2011; Kovalchuk, 2003; Kolomeitsev & Komarov, 2006).

Our developments are aimed at the resonator chamber improvement with high intrinsic quality to achieve a uniform distribution of high voltage electric field in it, and the selective heating of raw material components for continuous operation mi-crowave unit radio-tightness provision through the use of special slots and transcend-ent waveguides that perform the functions of inlet and outlet nozzles (Drogaytseva, 2011; Zhdankin et al, 2016).

This article provides the descriptions of the three microwave technologies for rabbit skin processing and the principle of the corresponding unit operation with non-traditional resonators. This is the drying of rabbit skin in UFEF; the collection of fluff in the process of rule rotation with the skin in the resonators; the collection of fluff in the process of UFEF exposure on skin, the meat side of which is soaked with fer-ments (homogenized with the fermented mixture of rye flour, water, yeast, mustard powder and salt).

1. Fur drying. In order to preserve the quality of hair and skin, the microwave technologies are suggested for fur material drying. Currently, there is a need to devel-op microwave units with low-power magnetrons and the frequency of 2450 MHz with air cooling for the processing of fur in rabbit farms.

They developed the microwave units with different configurations of working chambers for fur drying stretched on radio-transparent rules: with cylindrical mobile resonators for continuous operation; with toroidal and coaxial resonator for periodic operation. A microwave unit with cylindrical movable resonators for fur drying is presented in the form of a cylindrical shielding tube installed with an inclination. There are non-ferromagnetic disks inside the pipe. There are radio-transparent perfo-rated spheres between these disks, made of two hemispheres, where they placed the radio-transparent rules with raw material. Microwave generators and exhaust fans are placed with the alternation along the side surface of the shielding tube. End pipe bases perform the functions of inlet and outlet pipes. The dryer of fur with a coaxial resona-tor is characterized by the fact that a non-ferromagnetic diffraction cylinder is located coaxially in the cylindrical shielding case, the base of which is the annular case of the radial fan. The annular space between the housing and the cylinder forms a coaxial resonator. The generators are spaced evenly around the perimeter of the shielding housing side surface. The fan inlet is directed inside the cylinder, and the outlet is di-rected to the coaxial resonator, where the rules with hides are suspended on the car-ousel hanger.

The developed microwave rotor type fur dryer of continuous operation (Fig. 1) contains a cylindrical shielding body 1, inside which a cylindrical non-ferromagnetic drum 9 with perforated compartments (rotor 2) is located coaxially. The compart-ments perform the function of resonators 3 with trapezoidal section, when they will be under the emitter of the microwave generators 8. The average perimeter of the an-nular space between the shielding housing and the non-ferromagnetic drum is equal to the multiple half of the wavelength. Then, an electromagnetic field is excited in the volume with a trapezoidal section if the generators are installed on the upper base of the shielding housing. The rotor rotates from the electric motor 4, installed under the lower base of the

housing, where the discharge nozzle 6 is attached. The depth of the compartments (resonators 3) is vertically greater than the width of the trapezoidal ra-diotransparent rule lower base, and the radial depth of the resonators is greater than the height of the radio transparent rule. There is a loading nozzle on the upper base of the body, microwave generators and exhaust fan 10 are also installed there. The noz-zles (6, 7) perform the functions of the extreme waveguides. For this their dimensions are matched with the wavelength.

The technological process of fur drying and disinfection is the following one. Turn on the exhaust fan 10 and the motor 4 of the rotor 2. Direct radio-transparent rules with fur to the compartments 3, so that they pass through the loading nozzle 7. During the filling of the compartments 3 with rules, turn on microwave generators 8 sequentially. The speed of resonator movement with raw materials depends on drying duration. At that, UFEF is excited and the fur raw material is heated endogenously and selectively in the compartments where the emitters from microwave generators 8 are directed. In the process of resonator movement, the raw material is exposed to multiple impacts, since several microwave generators are located around the perimeter of the rotor. Moreover, the duty cycle of the process, i.e. the ratio of UFEF exposure duration to the cycle duration should not exceed 0.5. Only then the internal pressure and the temperature of the endogenous heating will be equalized throughout the raw material structure. At the end of the rotor 2 turn, the dried fur is discharged through the outlet nozzle 6. If during one rotation of the rotor 2, with such an amount of mi-crowave generators, it is not possible to achieve the required quality of drying for this type of fur, then it is necessary to provide the second rotor turn with the closed outlet nozzle. The slope of the perforated plates to the drum shell 9 provides a reliable unloading of the rules with the fur from the compartments.

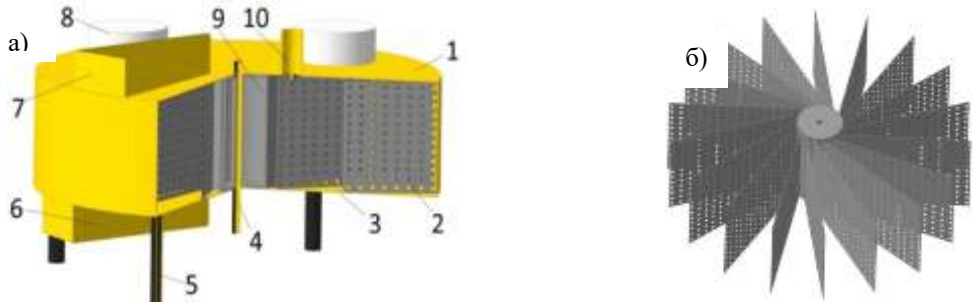

Fig. 1. Microwave rotary type dryer for fur: a) front view, sectional view; b) non-ferro-magnetic rotor with perforated compartments; 1 – shielding case; 2 - non-ferromagnetic rotor with perforated compartments; 3 - trap-ezoidal section resonators; 4 - drum shaft; 5 - mounting frame; 6 - outlet nozzle; 7 - inlet nozzle; 8 - microwave generators; 9 - drum; 10 - exhaust fan.

The dryer performance can be adjusted by changing the rotor outer diameter, the number of compartments, the number of generators and their power by the power of the exhaust fan 10. Adjusting the size of the compartments and the power of the microwave generators, you can ensure a high electric field strength in the resonator, which contributes to the destruction of microorganisms and skin parasites, since their loss factor is greater than that of fur and leather. The degree of raw material disinfection by exposure depends on the critical electric field strength, i.e. when the power density of the microwave energy loss in raw material will be greater than the energy loss at the critical electric field strength due to heat transfer from the sample surface (skin parasites, microorganisms).

- Collection of fluff in the process of rule rotation with the skin in cylindrical resonator chambers.

We have developed a microwave multiresonator device to separate fur from rabbit skins. The principle of the device operation is based on holding power weakening in skin during the selective exposure of UFEF, the combing of fur fibers with the marketable state preservation, their collection and pneumatic transportation. To implement this technology, they analyzed the dielectric and physico-mechanical parameters of fur components. They show that the dielectric

permeability of skin and fur is ten times different, therefore, it is possible to weaken the retention of fibers in skin during dielectric heating at 2450 MHz (Shamin et al, 2017). Physical and mechanical characteristics of skin: humidity 46 ... 47%, fat content 28.5 ... 29%, density 300 kg/m3 (Zhdankin, et al, 2017).

The unit (Fig. 2) contains a cylindrical shielding housing 1, located vertically. There is an air outlet 8 inside the housing. There are vertically arranged cylindrical resonators 2 along the perimeter of the housing, the upper bases of which are represented by the cover 13 of the housing. Each cylindrical resonator 2 has coaxially located removable dielectric cylinders 3 without bases and rotating dielectric cone-shaped rules 5. The cone-shaped rules 5 are mounted on the shafts containing the driven sprockets 11. A pneumatic line section is installed on the bottom side of each cylindrical resonator 2 element, their configuration allows to join them, forming a common pneumatic line 12. Dielectric pegs 4 are attached to the inner surface of removable dielectric cylinder element, so that their length decreases along the cylinder height, creating the space for the vertical placement of the rule 5 with the skin the fur of which is arranged outside. There is the perforation along the lower perimeter of the forming dielectric cylinders. The driven sprockets 11 are included in the clutch with the leading sprocket 9, located under the base of the shielding housing 1 on the shaft. The shaft is installed in the center of the air duct. The air duct is connected to the exhaust fan, and the vents 10 are joined to it from each magnetron 6. Radiation from each magnetron 6 is directed to two waveguides 7 installed in two adjacent resonators 2 on the side of the duct 8.

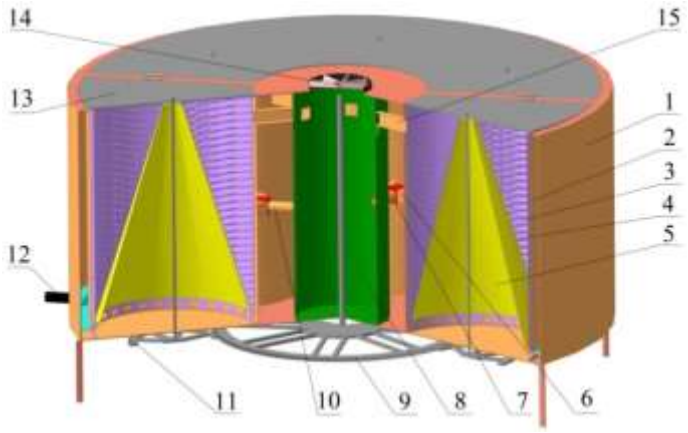

Fig. 2. Microwave multiresonator device for the separation of fur from the rabbit skins: 1 - shielding case; 2 - cylindrical resonator; 3 - removable dielectric cylinder; 4 - dielectric pegs; 5 - dielectric cone rules; 6 - magnetrons; 7 - waveguides; 8 - air duct; 9 - leading sprockets; 10 - ventilation hoses from magnetrons; 11 - driven sprockets; 12 - pneumatic pipe; 13 - covers; 14 - exhaust fan; 15 - ventilation pipes between the resonators and the duct.

This will reduce the overall dimensions of the device, although the use of individual magnetrons will increase the power of the radiation flux in the resonator, therefore, it will accelerate the process of fluff fiber holding power weakening. But at the periodic operation of the unit with individual magnetrons, which increase the book value, the economic efficiency decreases. At that the duration of the pause is much longer than the duration of raw material processing. Ventilation sleeves 7 from the magnetrons 6 and the ventilation pipes 15 from the resonators 2 are connected to the air duct 6 containing the exhaust fan 14 with an electric motor. The elements of the generator electronic unit, the start-protection equipment and process control system are located in the control cabinet.

The technological process is as follows. Open the covers 13, pull out the removable dielectric cylinders 3 containing the dielectric pegs 4. Pull the rabbit skins onto the dielectric cone rules 5 with fur facing out. Reinstall the removable dielectric cylinders 3 into the cylindrical resonator 2. Close both covers tightly. Using start-protective equipment, turn on the electric motors of the exhaust fan 14, which provides

cooling for the magnetrons 4, the motor of the pneumatic conveyor intended for fur moving through the perforations of the dielectric cylinders and the bases of the resonators into the pneumatic conduit 12, and then into the cyclone where the fluff is collected. After that, turn on the electric motor, on the shaft of which the driving sprocket 9 is located, which enters the clutch with the driven sprockets 11. At that, all cone-shaped dielectric rules 5 with rabbit skins begin to rotate. Next, turn on all microwave generators (magnetrons 6) for a certain period of time. Warm air from the magnetrons 6 during their operation and the resonator chambers is removed through the ventilation sleeves 10, the ventilation pipes 15 and the common air outlet 8 using the exhaust fan 14. UFEF occurs in the cylindrical resonator 2, the selective heating of skin and fur takes place proportional to their dielectric parameters. In the process of the cone-shaped dielectric rule rotation, the combing of fur fibers takes place using the dielectric pegs for fluff fibers, the holding strength of which is weakened due to the selective dielectric heating of skin. With the exhaust fan, the fur is sucked through the perforations of the removable dielectric cylinders 3, through the channels of the pneumatic duct, which are located at the base of the resonators 2, then it is transported by the means of the pneumatic duct to a cyclone located outside the device. The resonator electric field is high enough to reduce the bacterial contamination of fluff. The possibility of the heating temperature increase of the skin surface layer allows you to weaken the fur holding strength by several times. When the holding period is expired, the microwave generators 6 and the electric motor 9 of the rule 5 drive are turned off, after which the dielectric rules 5 cease the rotation. Then you can open the cover 13 of the shielding housing, since the lock will be turned off. After that, you should get the removable dielectric cylinders, remove the skins without fur from the rules and put them in a waste container. Then you place a new batch of rabbit hides on the rules 5 with fur facing out. Then you install the removable dielectric cylinders with pegs in the corresponding resonators. Close the covers 13, start the electric motor to drive the rules, turn on the microwave generators 6. The greater the rotational speed of the rules, the higher the kinetic energy of the peg impact on the fluff fibers and the more efficient the removal process. The unit works in a periodic mode and allows to combine the selective endogenous heating of the hide skins and the combing of the fluff fibers; collection and disinfection; the pneumatic transportation of fur to cyclone.

They analyzed the economic efficiency of such a microwave unit use in a rabbit farm to collect fluff from rabbit skin (Table 1).

Table 1. Economic indicators of the microwave unit introduction with three sources of electromagnetic radiation and six cylindrical resonators for the collection of fluff from rabbit skin.

Indicators	Values
Book value, rub.	75000
Unit capacity, pcs / h	40
Power consumption, kW	6,2
Electricity consumption, kWh / pcs.	0,155
Operating costs for the processing of fur, rubles / month	39747,6
Fur collection cost from rabbit skins, rubles / pcs.	9,46
The price of non-processed meat breed rabbit hide, rubles / pcs.	10
The cost of rabbit fluff collected from the skins, rub / kg	80
Sale price of 3 category fluff, rub / kg	250
Profit, rub / kg	170
The amount of collected fluff, kg / month	1050
Capital costs, rub. / (kg / month)	71,43

The profit from the use of microwave multiresonator unit for the separation of fur from rabbit skins with the capacity of 40 pcs/h is in the range of 180 thousand rubles / month.

- The collection of fluff in the process of rabbit skin movement, moistened with sodium chloride solution through a semi-cylindrical resonator. There is the device (A.S. No. 20254) using the machine for wool cutting, where the skin is fed by the means of spring table cushion under detachable comb knives, driven by separate drives. There is an old way of fluff removal from rabbit skin (A.S. No. 40499), which provides for the preliminary moistening with table salt solution, due to its rubbing into the skins from the inner side. But this method is suitable only for a raw hide. The known methods of animal hide hair separation using salts, alkalis, sulfides and enzyme preparations are long and the fur quality is low and therefore these methods do not satisfy the rabbit farms.

The fluff collection technology proposed by us is implemented by the device that provides the weakening of hair retention strength in the skin due to selective dielectric heating and the rubbing of ferments into the skins on the flesh side (Fig. 3). The unit provides the movement of the stretched rabbit skin using the roller conveyor through a semi-cylindrical resonator located horizontally, with the slots along the ends. Microwave generators are located on the side surface of the resonator. There is a bath with saline solution or ferments in front of the resonator, where the rotating roller is located. This will allow to wet the skin with ferments from the core. Then the skin falls into the resonator via the roller conveyor. When the skin is in UFEF, the strength of the hair coat weakens and the fluff is easily pulled out from the fermented skin using a plucking drum with spikes. Plucked fluff is sucked by an exhaust fan. The skin without fur is removed from the other end of the semi-cylindrical resonator. The technological process of fluff holding power weakening in the skin during the process of selective dielectric heating and soaking the flesh with a saline solution, the combing of fluff fibers and pneumatic transportation takes place in the following way. Pour the ferment into the bath 8. Turn on the electric motor, which drives the roller conveyor 6, the transmission mechanisms of which are closed by the cover 7, and the roller 9 - with an absorbent coating. Turn on the exhaust fan for sucking the fluff through the pneumatic line 1. Turn on the electric motor of the dielectric plucking drum 4 with the pegs 3, the revolutions of which can be adjusted.

The skin, removed in the form of a stocking from a rabbit carcass, should be cut lengthwise and unrolled in width, routed between the roller 9 and the pressure roller 10, so that the flesh side of the skin contacts the absorbent roller 9 with fur facing out.

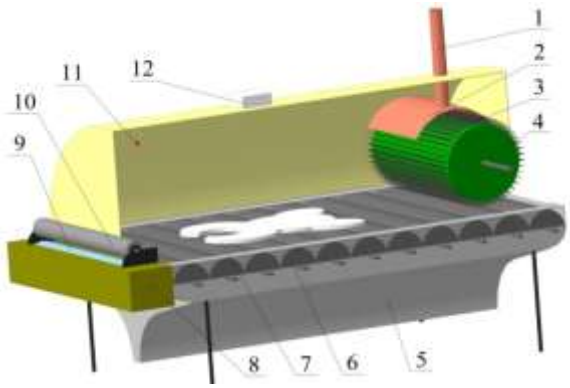

Fig. 3. The device for the separation of fur from rabbit skin in UFEF: 1 - pneumatic conduit; 2 - dielectric umbrella; 3,4 - spiked drum for plucking; 5 - non-ferromagnetic pallet; 6 - roller conveyor of non-ferromagnetic material; 7 - the cover over the gears; 8 - bath for ferments; 9 - roller; 10 - pressure roller; 11 - semi-cylindrical non-ferromagnetic dome; 12 - microwave generators.

At that, the flesh side of the skin is soaked with warm saline solution, which destroys the hair follicles (these are skin capsules, inside which the hair roots are located). Next, the skin is moved

to the roller conveyor. Then turn on the microwave generators. In the process of moving via the roller conveyor 6, the skin is selectively exposed to the electromagnetic field impact of ultra-high frequency (UFEF) in a semi-cylindrical resonator (11, 6). At that, the strength of hair retention in skin is weakened due to a significant difference in the dielectric characteristics of hair, follicles, dermis, etc., as well as due to the salt solution, which also heats up in UFEF.

It should be noted that the strength of hair is different on different topographic areas. The skin with a weakened retention force of skin hair is tightened under the dielectric pluck drum 4, where the fluff is combed out with using the pegs 3 and sucked through the pneumatic conduit 1 into a special cyclone unloader by the exhaust fan. In the process of movement with a non-ferromagnetic roller conveyor 6, the fat is melted from the flesh side and salt is poured in, all this is drained through the slots between the rollers into the non-ferromagnetic pallet 5, from where it is removed through the drain hole. The processed skin is pushed out of the roller conveyor 6 from the semi-cylindrical resonator through the discharge gap into the accumulation container. The technological process is continuous. At that the environmentally safe power flux density should not exceed 25 μW/m2, with an 8-hour unit operation. If the slots for the supply of raw materials and waste unloading are less than a quarter of the wavelength (limited by skin thickness equal to 1 cm), then with the correct location of the pressure roller at the receiving slit, the maximum permissible level of power flux density is maintained. Besides, electromagnetic radiation is extinguished in the salt solution through the gap and increases its temperature. At the end of the process, turn off the microwave generators 12, stop the electric motors of the roller conveyor 6 and the roller 9, then the electric motor of the dielectric plucking drum 4. Then turn off the exhaust fan. The width of the roller conveyor must be greater than the width of the unfolded rabbit skin. The dimensions of the semi-cylindrical resonator should be consistent with the wavelength, especially the dome diameter. The length of the pegs 3 should ensure the fluff combing from the skin. The performance of the unit depends on the number of microwave generators, on the type of skins and on salt solution concentration.

Conclusions

They studied the influence of physicomechanical and dielectric characteristics of hide components on the dynamics of their heating in the course of UFEF exposure to evaluate the weakening of hair retention strength in the rabbit skin.

They developed the microwave units with prismatic, coaxial and semi-cylindrical resonators for rabbit skin drying, the separation of fur from rabbit skin. The theoretical substantiation of the structural and technological parameters of unconventional resonators was performed by the resonator self-quality and the electric field intensity calculation using the CST Studio Suite 2015 program and the quality factor calculation as the doubled ratio of the resonator volume, which stores the EMF energy, to the surface area of the resonator taking into account the skin layer.

They performed the improvement of the methodology matching the design and the technological parameters of the microwave unit with operation modes, ensuring new results in the achievement of fur processing continuity, the uniform distribution of the electric field in the resonator and the unit performance variations.

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