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VALIDATION OF MICROWAVE INSTALLATION PARAMETERS WITH MOBILE RESONATORS FOR HEAT TREATMENT OF NONEDIBLE EGGS

Abstract. The use of hatching eggs rejected in the candling process as a protein feed after heat treatment and disinfection is relevant. The aim of the work is to develop and to validate the parameters of the installation, which provides heat treatment and disinfection of rejected hatching eggs, to obtain high-quality protein feed at reduced energy costs. The following objectives were solved: to develop a flow chart of the installation for the impact of the electromagnetic ultrahigh frequency field on a raw material with a cidal effect and providing selective heating of a two-component raw material in a dielectric shell; to develop the constructional design of the ultrahighfrequency installation with resonators having high basic Q-factor and providing high electric field intensity and continuous operation with maintaining electromagnetic safety; to conduct a technical and economic assessment of the use of the worked out installation in farms for processing rejected hatching eggs. The technical problem of the development is to ensure the duty cycle of a continuous process of exposure of the electromagnetic ultrahigh frequency field (EMUHFF) less than 0.5 and electromagnetic safety with a sufficiently high basic Q-factor of the resonator, forming a resonator-beam electrodynamic system. A distinctive feature of the resonators from the known mobile resonators is the use of a biconvex lens made of fluoroplastics to form a uniform field on the object of influence. The installation contains the bezel in the shielding case attached to the ring gear, coupled with the driving gear. To the bezel, the lower hemispheres are attached with the possibility of tipping. Emitters are directed into the upper hemispheres, which are rigidly fixed on the body. With a power consumption of 4.08 kW and a capacity of 12 kg/h, the specific energy costs are 0.34 kW·h/kg, i.e. it is 32% reduction in energy costs compared with the prototype.

Keywords: electromagnetic field, mobile spherical resonators, fluoroplastic lens, rejected hatching eggs, heat treatment and disinfection.

Introduction. Improving the efficiency of microwave installations that provide heat treatment and disinfection of nonedible animal waste with an increase in the forage value of the protein supplement and identifying patterns of the impact of the electromagnetic ultrahigh frequency field on high-humidity multicomponent raw materials to determine the effective operating modes of microwave installations in the food industry are relevant.

It is known that the average percentage of chicken output under current conditions is 84-85% [1]. Analysis of the research results showed that the percentage of rejection of hatching eggs in Russia is 6-10%. Each hatching egg loses 80% of its value if sold as a table egg. In farms, the waste of hatching eggs can reach up to 3%. Such a high percentage of early embryonic mortality is usually associated with

improper storage of hatching eggs.During the entire incubation period, egg candling is performed several times. Biological control of hatching eggs before setting to the incubator and after candling of the hatching eggs after 3 and 7 days makes it possible to identify rejected eggs suitable for use as protein feed after disinfection and cooking. Hatching eggs are rejected in case of:

- disturbances in the development of the embryo and separation of the inner shell membrane;
- appearance of blood rings and frozen foetuses;
- when the yolk exploded and mixed with white;
- marble shell structure (abundance of calcium in the shell);
- shell damage (light streaks);
- large air cell or cell is located on the side;
- the presence of blood clots;
- free movement of yolk, etc.

Such material after candling hatching eggs on average is accumulated in the amount of 3%. The use of hatching eggs rejected in the candling process as protein feed after heat treatment and disinfection is relevant. Therefore, we suggest that the listed incubation wastes should be boiled and disinfected in the electromagnetic ultrahigh frequency field (EMUHFF) at high electric field intensity for the use as a feed additive.The calculation of the number of eggs requiring processing for use in the form of protein feed in farms was carried out. If there are 12 incubation cabinets and 4 hatchers in the hatching egg workshop, each of which has 104 trays, and the average number of eggs in each tray is 120 pieces, then the capacity of one incubation cabinet for 19 days is 12,480 pcs. of eggs, and of 12 incubation cabinets - 149760 pcs. of eggs.According to the fact that 3% of eggs set in the incubator belong to the category of "rejected", therefore, 4493 eggs from 12 cabinets can be processed for the production of protein feed. This means that an average of 1123 pcs should be recycled throughout the day. Therefore, the designed microwave installation with a capacity of 200 pcs/h can process this amount of raw materials in 5.6 hours, and the installation will work 22.5 hours per month.

The specific properties of electromagnetic radiation contribute to the emergence of new field of application of microwave technology, that is the creation of a previously impracticable process of cooking eggs without water.

There is a method and microwave installation for cooking eggs without water. For example, a microwave egg boiler contains a rotating fluoroplastic rotor with cells inside a cylindrical shielding body for transporting eggs through the chambers of microwave ovens [2]

The power consumption of the microwave installation (ultrahigh frequency installation) with four sources and transport mechanism is 5.0 kW; the speed of eggs movement is 1.8 cm/s, the productivity is 150-165 pieces/h, the specific energy cost is 0.5 kW · h/kg [3]. The author proved that with a process duty cycle of close to 0.5, the cooking time is the shortest; when the temperature in the yolk reaches about 70 °C, the shell breaks.With such a constructional design of the working chamber, in the form of a tetrahedral prism with a slit for transporting eggs through the electromagnetic ultrahigh frequency field, the Q-factor of the resonators is very low, therefore, the energy costs are high.

There is a device for sanitizing hatching eggs by the complex effect of electromagnetic radiation [4]. The device contains infrared sources and ultrasonic frequency generators (22 kHz or 110 kHz) located above the dielectric disk with cells for transporting eggs. This device allows to disinfect eggs in a continuous mode, but it does not cook them to get protein feed.

Therefore, the aim of this work is to develop and validate the parameters of the installation, which provides heat treatment and disinfection of the rejected hatching eggs to obtain high-quality protein feed at reduced energy costs.

The following objectives were solved:

1. To develop a flow chart of the installation for the impact of the electromagnetic ultrahigh frequency field on a raw material with a cidal effect and providing selective heating of a two-component raw material in the dielectric shell.

2. To develop the constructional design of the ultrahigh frequency installation with resonators having high basic Q-factor and providing high electric field intensity and continuous operation with maintaining electromagnetic safety.

3. To conduct a technical and economic assessment of the use of the worked out installation in farms for processing rejected hatching eggs.

There are proven technologies and technical means for heat treatment of non-food animal waste in the electromagnetic ultra-high frequency field of (EMUHFF) to increase the forage value of the protein supplement. For the implementation of this technology, installations with ultrahigh frequency (microwave) power supply has been developed [5].

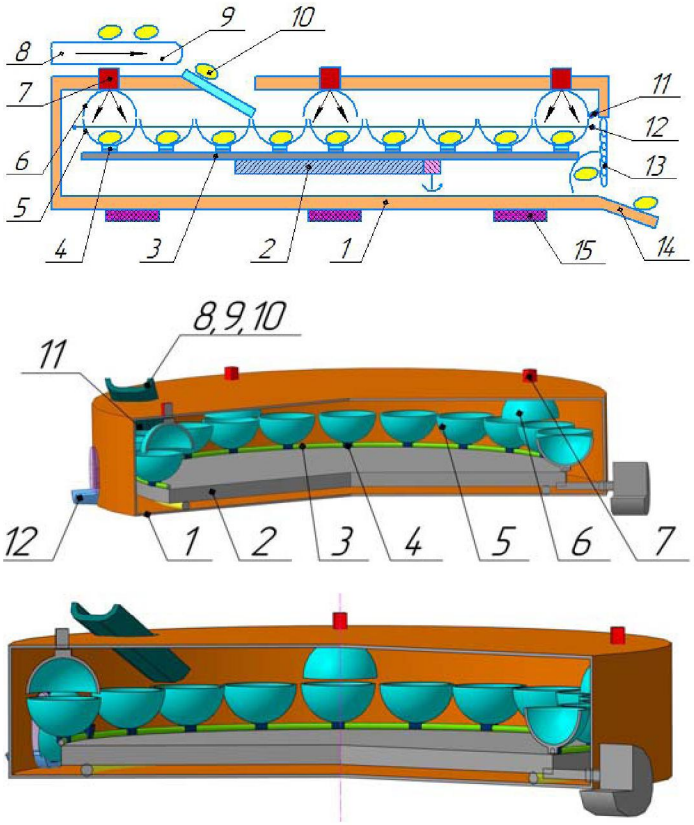
Materials and research methods. Based on the analysis of the constructional design of existing installations that provide cooking eggs without water in continuous mode, working with the use of electromagnetic radiation energy of ultrahigh frequency (EMUHFF), new working chamber with spherical mobile resonators was developed, which allows to reduce the specific energy costs for the process of egg heat treatment.

Research results and discussion. It is known the microwave (ultra-high frequency) emitters that direct the energy to the part of the raw material, which has large dimensions. For this purpose the H - shaped waveguide with an open end is used. There are horn antennas with a corrective dielectric lens in its aperture to create a flat wave or focus the radiation on the raw material. Using fluoroplastic biconvex lens it is possible to form a uniform field on the side of the targeted object [8].

We propose the microwave installation with low-power magnetrons, air cooling for cooking eggs without water in continuous mode, by repeated exposure of the electromagnetic ultrahigh frequency field in the "heating-pause" mode.

The technical problem of the development is to ensure the duty cycle of continuous process of exposure of the electromagnetic ultrahigh frequency field (EMUHFF) less than 0.5 and electromagnetic safety with a sufficiently high basic Q-factor of the resonator, forming a resonator-beam electrodynamic system.

Microwave installation (figure) for heat treatment of eggs in continuous mode: inside a cylindrical shielding body 1 installed on the mounting rack 15, coaxially, along the perimeter of the lower base there is the dielectric bezel 3 attached to the ring gear 2, coupled with the driving gear mounted on the shaft of the electric drive.



Microwave installation for heat treatment of nonedible eggs in continuous mode: a) schematic illustration; b, c) spatial image from different angles; 1 – shielding body; 2 – ring gear; 3 – bezel; 4 – pivot hinge; 5 – lower hemisphere; 6 – upper hemisphere; 7 – magnetron with emitter; 8 – conveyor; 9 – charging tray; 10 – charge hole; 11 – tipper; 12 – dielectric fishing line; 13 – shield grid; 14 – discharge tray; 15 – mounting rack

Lower non-ferromagnetic hemispheres 5 are attached to the bezel 3 using the hinges 4 convexity down, diameter multiple of half the wavelength, covered with guide line 12, the ends of which are connected with the inner side surface of the shielding body 1, where there is a window with shielding grid 13. There is also a tipper 11 in the form of a dielectric rack fixed to the upper base of the shielding body 1 with the possibility of contact and tripping of the lower hemispheres 5 towards its side surface and discharge tray 14.The upper non-ferromagnetic hemispheres 6, equal in diameter to the lower hemispheres 5, rigidly fixed under the upper base of the shielding body 1 convexity up, have opening in the upper points for guiding the emitters of the magnetrons 7 located along the perimeter on the upper base of the shielding body. The upper hemisphere 6 is covered with a *fluoroplastic lens*. On the upper base of the body 1, there is an inspection window and a charge hole, under which the dielectric charging tray 9 is located. The distance between the radiators 7 should be at least two diameters of the hemispheres 6.

The technological process of eggs heat treatment in continuous mode is under the following way. Turn on the driving gear, providing rotation of the gear ring 2 and the dielectric bezel 3 with the lower hemispheres 5. Turn on the conveyor 8, for feeding eggs through the charge hole 10 and the charging tray 9 into the mobile hemispheres 5.

Turn on the microwave generators, after that the rays of electromagnetic waves using the upper hemispheres will be directed to the lower hemispheres, where the eggs stand. In this case, the microwave generator operates in a resonant-beam electrodynamic system. That is, the upper hemispheres 6 contain fluoroplastic lenses and operate in the mode of the beam electrodynamic system. Fluoroplastic lens with a diameter equal to the diameter of the hemisphere 6, provides radiation focusing.At the moment when the upper 5 and lower 6 hemispheres are situated coaxially relative to each other, a spherical resonator is formed. Herewith, electromagnetic rays from the emitters 7 are sent to the lower hemispheres 5, bounce back off their surface, a standing wave is formed, there is a heat treatment of raw materials. The presence of several microwave generators and their non-synchronous operation give an averaging out of the total waves reflections, which leads to a good degree of distribution of the electric field in the working chamber and, consequently, to the uniform heating of the raw material.

Moreover, in effective rotation speed of the electric motor, the eggs in the lower hemispheres fluctuate, which also increases the uniformity of heating of the eggs components. By placing the magnetrons at regular intervals, taking into account the fact that these intervals should be much larger than the diameter of the hemispheres, it is possible to achieve wave interference and prevent the eggshell from breaking. Studies show that the best distribution of the electric field intensity in spherical mobile resonators with a slit is achieved at hemisphere diameter of 12.24 cm and interval of up to 1.0 cm.

Such a constructional design of spherical resonator with mobile hemisphere and stationary sphere with fluoroplastic lens allows to transfer up to 80% of the energy emitted by the magnetron to the raw material, and up to 55% without fluoroplastic lens. [9].

Technical specifications of the microwave (ultrahigh frequency) installation are shown in table.

Technical specifications of the microwaveinstallation

Item	
Capacity, pcs/h kg/h	 200 12
Magnetron power, kW	3.2
Fan power for magnetron cooling, kW	0.25
Drive power of the ring gear, kW	0.63
Microwave installation power, kW	4.08
Specific energy costs, kW·h/kg	0.34

Technical and economic assessment of the use of the developed installation in farms for processing rejected hatching eggs was carried out. Operating costs for heat treatment of eggs in microwave installation in continuous mode for 1 month according to the conceptual design include the costs of wages, energy, maintenance and repair of the installation, depreciation allocations, other expenses.

Accordingly, the mathematical model is developed for the latter, matrices of product markers from genuine to falsified are proposed. Variants of poor-quality, and also surrogate products as possible intermediate links are considered for completeness of the information [6].

The microcontroller synchronizes with the external network and calculates the sine period [7].

Taking into account the average salary of the operator servicing this installation, in the Nizhny Novgorod region, the salary will be 106.25 rubles/hour. Taking into account the payment of personal income tax and contributions to the PFR, the FCMIF,and the SIF and the working time of 32 hours, the *wages* will be 4,862 rubles.

The power consumption of the developed microwave installation is 4.08 kW, then the cost of *electricity* per month will be 4.08 kW · 22.5 h · 7.3 rub/kW*h = 670.14 rubles. *Depreciation* for 1 month from the book value of the construction (72 thousand rubles) is 1,200 rubles, and deductions for *current repairs* - 1,440 rubles.

Taking into account other expenses of 408.6 rubles/month, general production costs of 1287 rubles/month, the total amount of operating costs is 4862 + 670.14 + 1200 + 1440 + 408.6 + 1287 = = 9867.74 *rubles/month*.

The producing cost of the operating costs for heat treatment of rejected hatching eggs in the microwave installation is 9867.74 / 4493 = 2.2 *rub/pcs*.

The price of the hatching eggs is 25-35 rubles/pcs. Taking into account the fact that eggs rejected after candling after 3-7 days lose 80% of their value, the wholesale price of raw materials on 03.10.2018 averaged 3-5 rubles per piece. Then the cost of raw materials will be 4493 pcs/month · 4 rubles/pcs = = 17 972 rubles/month. The cost of heat-treated and decontaminated rejected eggs according to the conceptual design will be 4+2.2 = 6.22 rubles/piece. If the heat treatment of eggs weighing 60 g, an average of 270 kg/month, the producing cost of protein feed is 6.22/0.06 = 104 rubles/kg. The wholesale price of egg feed for chickens is 400 rub/kg. When selling produced protein feed from rejected hatching eggs by means of exposure to EMUHFF at a price below the market - 250 rubles/kg, the additional income will be 150 rubles/kg.

Conclusion. When using spherical resonators with mobile hemispheres and fluoroplastic lenses in stationary hemispheres, forming the resonator-beam electrodynamic system, the specific energy costs are reduced by 32% compared to the prototype with the use of one fan for cooling four magnetrons mounted directly to the resonators, with the electronic units located in the control cabinet. The producing cost of the heat-treated rejected eggs is 104 rubles/kg.

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ТАҒАМДЫҚ ЕМЕС ЖҰМЫРТҚАЛАРДЫ ТЕМПЕРАТУРАЛЫҚ ӨҢДЕУГЕ АРНАЛҒАН ҚОЗҒАЛМАЛЫ РЕЗОНАТОРЛАРЫ БАР МИКРОТОЛҚЫНДЫ КОНДЫРҒЫНЫҢ СИПАТТАМАЛАРЫН НЕГІЗДЕУ

Аннотация. Термиялық өңдеуден және залалсыздандырудан кейін ақуызды жем ретінде овоскопиялық процесс барысында жарамсыз инкубацияланған жұмыртқаны пайдалану маңызды болып табылады. Жұмыстың мақсаты инкубация жұмыртқаларын термиялық өңдеу және дезинфекциялауды қамтамасыз ететін, төмендетілген энергия шығынын азайтқан жоғары сапалы протеинді азық алуға мүмкіндік беретін қондырғының параметрлерін әзірлеу және негіздеу болып табылады. Міндеттер шешілді: бактерицидтік әсері бар шикізатқа жоғары жиілікті электромагниттік өрісіне әсер ету және диэлектрлік қабықшасында екі компонентті шикізатты іріктеп алуды қамтамасыз етудің технологиялық схемасын жасау; жоғары электр өрісінің

беріктігі мен электромагниттік қауіпсіздікті сақтай отырып үздіксіз жұмысын қамтамасыз ететін жоғары сапалы, жоғары деңгейлі резонаторлармен микротолқынды қондырғылардың конструкциялық конструкциясын әзірлеу; шаруа қожалықтарында жарамсыз жұмыртқаларды қайта өңдеу қондырғыны пайдалануды техникалық-экономикалық бағалау жүргізу. Дамудың техникалық міндеті электронды-магниттік өрістегі (ЭМПСВЧ) 0,5-тен кем және резонатор-сәулелі электродинамикалық жүйені қалыптастыратын резонатордың жеткілікті жоғары өзіндік сапасымен электромагниттік қауіпсіздіктің үздіксіз технологиялық үрдісінің жұмыс циклын қамтамасыз ету болып табылады. Белгілі жылжымалы резонаторлардан резонаторлардың айырықша ерекшелігі әсер ету объектісінде біртұтас өріс қалыптастыру үшін фторопласттан жасалған қосдөңес линзасын пайдалану болып табылады. Қондырғы қорғау корпусында алдыңғы тегершігімен тісті тәжге байланысқан сақинасы бар. Сақинаға төменгі жартысферамен бекітілген, олардың аударылуға мүмкіндігі бар. Сәуле таратқыш денеге қатаң бекітілген жоғарғы жарты шарға бағытталған. Энергияны тұтыну кезінде 4,08 кВт және сыйымдылығы 12 кг/сағ, нақты энергия тұтыну - 0,34 кВт/сағ, яғни, прототибімен салыстырғанда энергия шығынын 32% төмендету.

Түйін сөздер: электромагниттік өріс, жылжымалы сфералық резонаторлар, фторопластикалық линза, жарамсыз инкубациялық жұмыртқа, термиялық өңдеу және заласыздандыру.

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ОБОСНОВАНИЕ ПАРАМЕТРОВ МИКРОВОЛНОВОЙ УСТАНОВКИ С ПЕРЕДВИЖНЫМИ РЕЗОНАТОРАМИ ДЛЯ ТЕРМООБРАБОТКИ НЕПИЩЕВЫХ ЯИЦ

Аннотация. Использование отбракованных в процессе овоскопирования инкубационных яиц как белкового корма после термообработки и обеззараживания актуально. Целью работы является разработка и обоснование параметров установки, обеспечивающей термообработку и обеззараживание отбракованных инкубационных яиц, для получения качественного белкового корма при сниженных энергетических затратах. Решены задачи: разработать технологическую схему установки для воздействия электромагнитного поля сверхвысокой частоты на сырье, обладающего бактерицидным эффектом и обеспечивающим избирательный нагрев двухкомпонентного сырья в диэлектрической оболочке; разработать конструкционное исполнение сверхвысокочастотной установки с резонаторами, обладающими высокой собственной добротностью, обеспечивающими высокую напряженность электрического поля и непрерывный режим работы при сохранении электромагнитной безопасности; провести технико-экономическую оценку применения разработанной установки в фермерских хозяйствах для переработки отбракованных инкубационных яиц. Технической задачей разработки является обеспечение скважности непрерывного технологического процесса воздействия в электромагнитном поле сверхвысокой частоты (ЭМПСВЧ) менее 0,5 и электромагнитной безопасности при достаточно высокой собственной добротности резонатора, образующего резонаторно-лучевую электродинамическую систему. Отличительной особенностью резонаторов от известных передвижных резонаторов является использование двояковыпуклой линзы из фторопласта для формирования равномерного поля на объекте воздействия. Установка содержит в экранирующем корпусе ободок, прикрепленный к зубчатому венцу, сцепленному с ведущей шестерней. На ободок прикреплены нижние полусферы с возможностью опрокидывания. В верхние полусферы, которые жестко закреплены на корпусе, направлены излучатели. При потребляемой мощности установки 4,08 кВт и производительности 12.кг/ч. удельные энергетические затраты составляют 0,34 кВт·ч/кг, т.е. на 32% происходит снижение энергетических затрат по сравнению с прототипом.

Ключевые слова: электромагнитное поле, передвижные сферические резонаторы, фторопластовая линза, бракованные инкубационные яйца, термообработка и обеззараживание.

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