

ORIGINAL PAPER

**DIGITAL TECHNOLOGIES IN AGRICULTURAL PRODUCTION: IMPLEMENTATION BACKGROUND, CURRENT STATE AND DEVELOPMENT TRENDS**

*IVAN A. STAROSTIN, PhD (Eng), Senior Research Engineer*

starwan@yandex.ru

*MARINA E. BELYSHKINA*<sup>✉</sup>, PhD (Ag)

bely-mari@yandex.ru<sup>✉</sup>, ORCID: <https://orcid.org/0000-0003-2876-1031>

*NAREK O. CHILINGARYAN, PhD (Eng), researcher*

narek-s@list.ru

*ALEKSEI YU. ALIPICHEV*

al\_new2003@mail.ru

Federal Scientific Agroengineering Center VIM; 109428, Russian Federation, Moscow, 1<sup>st</sup> Institutskiy Proezd Str., Bld 5

**Abstract.** Digital technologies have been deeply integrated into our lives and found their application in all areas of human activity, including agriculture. Technological progress, the development of infrastructure in the IT industry, wider access to the Internet, a high level of education and growing computer literacy of the population contribute to the popularization and introduction of digital technologies in agricultural production. The review of the use of digital technologies in the agricultural sector has shown that existing software tools help plan the work of an agricultural organization, monitor the state of production, manage the farm, and sell products on virtual trading platforms. Most software products are able to store data in the cloud, and farmers can access the system via their personal account from any device with Internet access. There are also a number of programs on the market that allow farmers to plan, analyze and control the crop or livestock production. Leading manufacturers of agricultural machinery and equipment are actively integrating digital technologies into their products. It is now possible to manage a fleet of vehicles used in the fields, and implement unmanned control. Use can be made of tractors equipped with automatic systems for driving along rows or laid paths, turning, and monitoring process parameters. The authors propose a set of digital control means to be used in agricultural production, based on the application of technologies of the Internet of things, cloud data storage, big data processing, and artificial intelligence. It is the technologies that digital agriculture will be based on, which use robotic monitoring tools to collect information and transmit it to "cloud data storage". It is processed there and directed to the control system, which develops the optimal solution and transmits the control signal to the robotic actuators. In this regard, the development of agricultural machinery should be focused on the robotic tools designed for monitoring and performing technological operations. The most difficult task is to develop a control system, since it must have elements of artificial intelligence and replace humans in agricultural production.

**Key words:** digital agriculture, big data, agrobot, Internet of things, unmanned agricultural machinery, robotic technical means.

ORIGINAL PAPER

**RESEARCH RESULTS OF THE MODIFIED WORKING TOOL OF THE COMBINED ROTARY MOWER**

*NIKOLAY V. ALDOSHIN, DSc (Eng), Professor<sup>1</sup>*

naldoshin@yandex.ru, <https://orcid.org/0000-0002-0446-1096>

**ALEKSANDR S. VASILIEV**, PhD(Eng), Associate Professor<sup>2</sup>

vasilevtgsha@mail.ru

**ANDREY V. KUDRYAVTSEV**, PhD(Ag), Associate Professor<sup>2</sup>

akud@tvgscha.ru

**VYACHESLAV V. GOLUBEV**, DSc (Eng), Professor<sup>2</sup>

vgolubev@tvgscha.ru

<sup>1</sup> Russian State Agrarian University - Moscow Timiryazev Agricultural Academy; 127550, Russian Federation, Moscow, Timiryazevskaya Str., 49

<sup>2</sup> Tver State Agricultural Academy; 170904, Russian Federation, Tver, Sakharovo settlement, Vasilevskogo Str., 7

**Abstract.** Currently, there are practically no mechanization tools on the market that combine grass removal (mowing) and the levelling loosening of the upper soil layer, while cutting the root systems contained in the soil in one pass. The purpose of the study was to provide a theoretical rationale of the modified design of the working tool of the combined rotary mower, as well as to conduct its laboratory and field studies. Complex theoretical, laboratory and field studies were carried out using the equipment of the Department of Technological and Transport Machines and Complexes, the Department of Technology of Processing and Storage of Agricultural Products of Tver State Agricultural Academy and recognized methods of experimental research. In the course of theoretical studies, the main parameters of the new working tool were determined, which enabled two technological processes to be carried out in one pass: grass mowing and cutting with loosening of the top soil layer (0...10 cm). On the basis of the obtained data, a workable model of the working tool was designed. When tested in laboratory conditions, regardless of the operating modes and the initial state of the cultivated soil, improved agrophysical properties were observed in terms of absolute humidity and saturation with root residues. It was found that the most optimal level of absolute humidity for the impact of the working tool on soils of light-loamy granulometric composition was 20%, while the best structural and density indicators were observed at all values of soil saturation with root residues; they averaged 2.24 units and 1.26 g/cm<sup>3</sup>. It has been established that at low operating speeds, it is advisable to use a higher rotation speed of the working tool (at 150 rpm), at the same time, with an increase in speed, the speed of rotation should be reduced (to 110 rpm). As a result of field experiments, convincing data were obtained on the feasibility of using a new working tool that provides effective mowing of grassland vegetation (the purity of the stem cut is 95.6%) and loosening of the surface layer of the soil (0...10 cm), increasing the structural coefficient by 26.8% while optimizing the density and grinding of root systems. The next stages of the study include developing and manufacturing a workable design of a combined rotary mower prototype that ensures the optimal energy intensity of performance and the required quality of technological processes.

**Key words:** working tool, mowing, surface tillage, improvement of forage lands, soil structure.

## ORIGINAL PAPER

### ANALYTICAL FEASIBILITY STUDY OF THE AUTOMATIC CONTROL SYSTEM OF TILLAGE DEPTH

**ALEKSEI S. DOROKHOV**, RAS Corresponding Member, DSc (Eng), Professor<sup>1</sup>

dorokhov@rgau-msha.ru, <https://orcid.org/0000-0002-4758-3843>

**ALEKSEI V. SIBIRYOV**, DSc (Eng), Senior Researcher<sup>1</sup>

sibirev2011@yandex.ru

**ALEKSANDR G. AKSENOV**, PhD (Eng), Leading Researcher<sup>1</sup>

**MAKSIM A. MOSYAKOV**<sup>✉</sup>, PhD (Eng), Senior Researcher<sup>2</sup>

Maks.Mosyakov@yandex.ru<sup>✉</sup>

<sup>1</sup> Federal Scientific Agroengineering Center VIM; 109428, Russian Federation, Moscow, 1<sup>st</sup> Institutsky Proezd Str., Bld. 5

<sup>2</sup> Russian State Agrarian University - Moscow Timiryazev Agricultural Academy; 127550, Russian Federation, Moscow, Timiryazevskaya Str., 49

**Abstract.** The authors have carried out analytical studies on the development and rationalization of a system for automatic controlling the depth of tillage, a block diagram and an algorithm for a linear positional control system, as well as offered a design scheme to develop a control algorithm. A mathematical model describing the control object that regulates the tillage depth has been determined, provided that the motion trajectory of the moving parts of the driving links and the actuator rods of the automatic system controlling the tillage depth is perfectly traced. A structural diagram of a linear system of positional control of the soil tillage depth has been developed, which is a mechanism for adjusting the support wheel with an acting disturbance on the control object, changing the distance between the O axis of the wheel rotation of the tillage machine power tool and the rotation axis of the support wheels of a soil cultivation machine. A design scheme to develop a control algorithm for changing the tillage depth has been obtained. To determine the required accuracy and modes of using hardware in various phase states of the soil layer, a basic set of hardware was identified and analyzed to ensure that it meets the requirements for controlling the tillage depth of the working elements. They include a sensor for determining the penetration depth of the working element; microcontroller (setting and control of regulated force impact on the soil, i.e. vertical movement of the electric cylinder rod); electric cylinders (linear actuators). To test the developed algorithms for the functioning of the automatic control system for adjusting the travel depth of the working elements for presowing soil cultivation, it is necessary to conduct experimental studies in laboratory and production conditions.

**Key words:** tillage, tillage depth, table beet, onion, moisture, density, soil, algorithm.

## ORIGINAL PAPER

### ANALYSIS OF USING MODERN PLANT CULTIVATION UNITS IN CITY FARMING AND ITS DEVELOPMENT PROSPECTS

**MIKHAIL N. EROKHIN**, Full Member of the Russian Academy of Sciences, DSc (Eng), Professor  
*n.erohin@rgau-msha.ru*, <https://orcid.org/0000-0001-6573-0950>

**DMITRY M. SKOROKHODOV**, PhD (Eng), Senior Lecturer  
*d.skorokhodov@rgau-msha.ru*, <https://orcid.org/0000-0002-6315-4184>

**ANASTASIA N. SKOROKHODOVA**, PhD (Eng), Senior Lecturer  
*red-green216@mail.ru*, <https://orcid.org/0000-0002-5451-810X>

**ALEKSANDR A. ANISIMOV**, Assistant Professor  
*alanis152@mail.ru*

**ROMAN A. POTEKIN**  
*P8070070@yandex.ru*

Russian State Agrarian University – Moscow Timiryazev Agricultural Academy; 127550, Russian Federation, Moscow, Timiryazevskaya str., 49

**Abstract.** City farming is a modern area of agriculture. It is currently becoming more and more promising due to the growing proportion of the population living in large cities. The successful development of city farms largely depends on the improvement of its technical systems and modular devices, in which a microclimate is created that ensures the rapid growth of crops without the use of plant protection chemicals. The modern devices for growing plants in an urban environment are discussed in the papers. The authors consider some factors influencing the growth of plants under the conditions of an intensive cultivation system, the main of them including: technological, plant parameters, ambient temperature, air humidity, and lighting. To ensure the necessary microclimate conditions within the agrotechnical requirements for various crops in industrial and personal city

farms, modern means and methods of automatic control and management are should be installed. To ensure microclimate conditions within the agrotechnical requirements for each crop, it is necessary to separately develop a cultivation technology in a city farm with the introduction of special implements for cultivation based on design analysis. To ensure the technological improvement of city farming systems, it is necessary to develop and improve systems for automatic irrigation, application of fertilizers and growth regulators, monitoring the functional state of plants online, harvesting and controlling its quality. An important area for the development is the modular designing of such devices, which will significantly reduce the amount of design work and shorten the design time, increase the quality and reliability of equipment due to the preliminary development of unified units and their manufacturing technology. When organizing the serial production of modules, the terms of assembly work, the cost of manufacturing machines and lines will be reduced, which will significantly reduce the cost of equipment. The authors conclude that the formation of modular-designed technical systems, balanced in terms of the component composition and productivity of specific elements of technological blocks will ensure the maximum efficiency of the production of demanded types of plant products in an urban environment.

**Key words:** city farming, designing, modular designing, modules for growing plants.

## ORIGINAL PAPER

### DESIGNING A MIXER OF PROTEIN, MINERAL AND VITAMIN ADDITIVES

*EVGENIY V. AVAKIMYANTS, Junior Research Engineer*

*VLADISLAV V. GORDEEV, PhD (Eng), Key Research Engineer*

cow-sznii@yandex.ru

Institute for Engineering and Environmental Problems in Agricultural Production (IEEP) – Branch of FSAC VIM, Saint Petersburg, Russia

**Abstract.** To ensure the effective use of protein-mineral-vitamin supplements in the diets of dairy cows, a mixer design has been developed for their preliminary mixing before adding to the main mixing process. Based on the structural-morphological analysis, alternative structural elements of the mixer design have been considered and conventional symbols were assigned to them. A morphological matrix of solutions has been compiled to offer a set of alternative options. The mixer drive was chosen by the ability to ensure high speed, rotational speed control, user-friendly operation and cost. The design uses an electromechanical drive combined with a V-belt drive. This solution meets all the specified requirements and allows protecting the drive from possible overloads. The working tool was chosen based on the requirement to contact the material actively throughout the chamber volume and to avoid the formation of stagnant zones. A blade mixer with variable blade positioning was found the most effective tool for the high-speed mixing of bulk materials. The designed mixer will be operating at a continuously varying speed in the range from 500 to 1500 min<sup>-1</sup>. This will offer the advantages of high-speed mixing while reducing the influence of negative factors on the final mixture quality. The resulting decision matrix will allow determining the most promising areas for further designing, which makes it possible to improve the quality of the developed technical means.

**Key words:** mixer, feed additive, mixing, feed mix, feeding, structural and morphological analysis.

## ORIGINAL PAPER

### RESULTS OF RESEARCH TO ASSESS THE EFFECT OF PRE-SOWING UV TREATMENT AND ARTIFICIAL LIGHTING MODES DURING LUPINE GERMINATION ON VITAMIN FEED

*VLADIMIR YU. STRAKHOV* ✉

strakhov.94@list.ru✉

**SERGEY V. VENDIN**, DSc (Eng), Professor

elapk@mail.ru; <https://orcid.org/0000-0002-0482-6657>

**YURIY V. SAENKO**, DSc (Eng), Associate Professor

yuriy311300@mail.ru

Belgorod State Agrarian University named after V.Y. Gorin; 308503, Russia, Belgorod region, Belgorod district, Mayskiy, Vavilova Str., 1

**Abstract.** One of the ways to increase the nutritional value of feed is the use of a biologically active additive based on sprouted grain. The positive use of sprouted grain of wheat and barley has been reliably established. At the same time, the possibilities of using sprouted grain of lupine are considered much less frequently. The authors have described technique and presented the results of experimental studies on assessing the effect of pre-sowing UV treatment and artificial illumination modes during lupine germination on vitamin feed. The time of UV treatment aimed at disinfection before germination and the time of grain illumination with a phytolamp during germination were chosen as the variable factors, and the length of the shoots was chosen as the response function. The range of seed illumination was from 4 to 10 h, and the UV irradiation time was from 60 to 300 s. The germination period was 5 days. Samples exposed to natural light served as control. According to the experimental data, a regression equation was obtained that describes the effect of UV disinfection and illumination time during growth on the length of the shoots, and graphical dependences of the change in the response function in the intervals of variation of the influencing factors were constructed. Experimental data have shown that an increase in the time of UV disinfection of seeds has a positive effect on the length of the shoots. It was revealed that on the fifth day of germination, the maximum length of shoots (25 mm at 11 mm in control samples) was obtained with preliminary UV disinfection of germinating seeds for 300 s and 4-hour artificial illumination with a phytolamp. The expediency of using this technique when germinating lupine seeds for vitamin feed for animals has been experimentally confirmed.

**Key words:** sprouted grain, lupine, vitamin feed, UV disinfection, artificial lighting, dose, sprout length.

## ORIGINAL PAPER

### DETERMINATION OF PARAMETERS OF THE WORKING IMPLEMENT OF A ROOT CROPPER

**MIKHAIL G. ZAGORUIKO**, PhD(Ag), Associate Professor<sup>1</sup>

zagoru-jko.misha2013@yandex.ru; <https://orcid.org/0000-0001-7826-3773>

**VALENTIN V. VASILCHIKOV**, PhD(Ag), Associate Professor<sup>2</sup>

vasilchikovvv@sgau.ru; <https://orcid.org/0000-0002-1521-3071>

**YURI V. KATAEV**, PhD(Ag), Associate Professor<sup>1</sup>

ykataev@rgau-msha.ru; <https://orcid.org/0000-0003-0832-3608>

**ANGELA K. MAMAKHAY**, specialist, MSc student<sup>3</sup>

mamakhaeva@mail.ru; <https://orcid.org/0000-0002-8582-108>

<sup>1</sup> Russian State Agrarian University - Moscow Timiryazev Agricultural Academy; 127550, Russian Federation, Moscow, Timiryazevskaya st., 49

<sup>2</sup> Saratov State Agrarian University named after N.I. Vavilov; 410012, Russian Federation, Saratov, Teatralnaya Sq., 1

<sup>3</sup> Federal Scientific Agroengineering Center VIM; 109428, Russian Federation, Moscow, 1<sup>st</sup> Institutskiy Proezd Str., 5

**Abstract.** The main condition for feed preparation is to ensure the high quality of the finished product. At the same time, it is necessary to increase the efficiency and durability of the feed chopper

by optimizing its design parameters, taking into account the physical and mechanical properties of the processed material. The authors studied the technological principle of crushing root and tuber crops. The paper considers the operation of an industrial rotary feed chopper when processing beets and carrots. The experiment planning method is applied. The strength characteristics of the grinder elements were checked during design (selection of the shape and sharpening angle of knives) and verification calculations for strength (assessment of the strength characteristics of knives). The authors show the influence of the main geometric parameters of the working implement of the grinder - the knife inclination and the sharpening angle of the knives - on the preparation of high-quality feed. It was revealed that the sharpening angle of the grinder knives should be calculated depending on the friction coefficient of the initial material against the grinder body, as well as the type and properties of the supplied material. Based on the data obtained during the laboratory experiment and simulation modeling, in order to achieve greater versatility with the feed chopper, a combined shape of the cutting edges of the knives was chosen – that with a straight and serrated cutting edge of the chopper. Samples of cutting edges at 30x magnification, obtained using an instrumental microscope MMI-2, showed that the optimal shape of the knife is a wedge with a double escapement.

**Key words:** forage, root and tuber crusher, multifactor experiment, optimization, simulation.

## ORIGINAL PAPER

### MILK COOLING UNIT BASED ON THERMOELECTRIC MODULES

**VLADIMIR V. KIRSANOV**, DSc (Eng), Chief Research Engineer<sup>1</sup>

kirvv2014@mail.ru

**YURI G. IVANOV**, DSc (Eng), Associate Professor<sup>2</sup>

iy.electro@rgau-msha.ru<sup>2</sup>

**LYUDMILA N. VERLIKOVA**, Assistant Professort<sup>2</sup>

lverlikova@rgau-msha.ru

**VLADIMIR N. KRAVCHENKO**, PhD (Eng), Associate Professor<sup>2</sup>

vkravchenko@rgau-msha.ru

<sup>1</sup> Federal Scientific Agroengineering Center VIM; 109428, Russia, Moscow, 1<sup>st</sup> Institutskiy Proezd Str., 5

<sup>2</sup> Russian State Agrarian University – Moscow Timiryazev Agricultural Academy; 127550, Timiryazevskaya Str., 49, Moscow, Russian Federation

**Abstract.** The tendency to increase the consumption of personalized nutrition opens up new prospects for the industrial production of milk from an individual cow with preserved useful components inherent in a specific animal species, the composition of fat, protein, lactose, and taste. A milking installation is composed of robots for individual milking of cows with automatic control of milk quality indicators. At the same time, milk corresponding to the parameters of high quality enters the thermoelectric plate-type cooler - heater, then into the packing machine, where it is bottled into containers to further proceed to the refrigerator. Thermal modules as a cooling element are chosen due to their high speed and the ability to accurately control the set temperature. At the same time, water is heated through the hot heating system of the thermal module, which is used for the technological needs of the farm. The work aims at developing and justifying the parameters of an energy-saving thermoelectric system for cooling native individual milk from a cow and heating water in milking robots for the production of personalized food products. The authors present a technological line scheme with milk cooling directly during the milking process. Analytical relationships are given for calculating the parameters of a thermoelectric cooling system according to two options - the milk flow rate and the parameters of the cyclic supply of one-time equal portions of milk. The proposed technology and method for milk cooling in the flow using thermoelectric modules as part of milking robots makes it possible to develop a new technology for the production of high-quality dairy products according to individual orders of consumers.

**Key words:** robotic milking, thermoelectric milk cooler, personalized dairy products.

## ORIGINAL PAPER

### APPLICATION OF SAND AS BEDDING IN BOXES WITH AN LOOSE CATTLE KEEPING AS EXEMPLIFIED BY “ULANOVO” FARM

**SERGEY P. KAZANTSEV**, DSc (Eng), Professor

kspts@bk.ru

**MIKHAIL I. SOLOVIEV**, PhD (Ped)

rsolrmihail@yandex.ru

**OLEG M. MELNIKOV**, Senior Lecturer

ommelnikov@mail.ru, <https://orcid.org/0000-0003-3202-8799>

Russian State Agrarian University - Moscow Timiryazev Agricultural Academy; 127550, Russian Federation, Moscow, Timiryazevskaya Str., 49

**Abstract.** The paper describes the experience of using sand as a bedding material gained by the Ulanovo cattle-breeding farm for 2800 heads located in the Medyn district of the Kaluga region. Removing manure from the passage, maintaining a sufficient level and evenness of sand in the bed require an integrated approach to mechanization of this process in accordance with the requirements for creating comfortable conditions in the boxes. The authors have analyzed the efficiency of the machines and equipment used in the livestock farm. It was found that the Mensch V4500 self-propelled machine was more reliable and efficient when removing manure from the aisles as compared to the Fligl trailed tanker of the VFW 18 000 model. The average daily operating time was 17.1 hours, which is optimal for a farm with 2,800 heads. Mechanized sand bedding shall be preferably made by the trailed W3385 gritter than the self-propelled Mensch M3620 model, although it is more maneuverable, easy to operate and highly productive. But the use of a self-propelled model with a daily load of 5.4 hours is ineffective for a given livestock population. The technology of using sand as bedding in the Ulanovo farm has shown its effectiveness associated with an increase in the productivity of animals, a decrease in mastitis cases, and a decreased disposal rate of animals due to limb diseases. Despite these advantages, this technology has not found wide application in Russia due to the high cost of imported machines and the lack of domestic analogues that provide manure removal and sand introduction into the boxes.

**Key words:** free-stall cattle keeping, livestock farms, manure cleaning, sand bedding in boxes, type of bedding in boxes, operating efficiency of manure cleaning machines.

## TECHNICAL SERVICE IN AGRICULTURE

### ORIGINAL PAPER

#### MECHANICAL PROPERTIES OF HEAT-STRENGTHENED STEEL 65G SURFACE-REINFORCED WITH HARD-ALLOY SURFACING

**ALEKSANDR M. MIKHALCHENKOV**<sup>✉</sup>, DSc (Eng), Professor

mihalchenkov.alexandr@yandex.ru<sup>✉</sup>

**NATALIA D. ULYANOVA**, PhD (Econ), Associate Professor

ulyanova@bgsha.com

**SERGEY A. FESKOV**, PhD(Eng)

feskovwork@gmail.com

**ALEKSANDR A. GUTSAN**

gagauz0326@gmail.com

Bryansk State Agrarian University; 243365, Russian Federation, Bryansk region, Vygonichi district, Kokino, Sovetov Str., 2A

**Abstract.** Increasing the service life of soil-cultivating equipment parts by the use of surfacing reinforcement of working surfaces has found a fairly wide application. However, the studies carried out on this problem were focused on parts, the metal of which had not been subjected to preliminary heat hardening. Meanwhile, in recent years, the components of the working tools of agricultural implements are almost completely hardened by heat treatment. This is especially true for imported products. Information on the reinforcement of parts that have undergone this kind of processing is extremely scarce, and sometimes contradictory. Therefore, the research task was to study the properties of heat-strengthened steel 65G after its surface reinforcement. During the experiments, as the base metal, use was made of spring sheets made of 65G steel with a hardness of about 45 HRC. T-590 electrodes were used as the surfacing material, intended for surfacing of parts operated in an abrasive environment. The reliability of the results obtained was guaranteed by a large number of measurements. Mechanical properties were evaluated by HRC hardness. As a result of experiments, it was found that the hardness value of 44-47 HRC for leaf springs taken out of service makes them suitable for use as repair materials. When surfacing one roller, the initial hardness of the base metal remains at the same level; surfacing two rollers leads to a decrease in HRC by 9 units. Three zones are distinguished in the area between the rollers. The use of reinforcing rollers on the surface of heat-treated steel 65G increases its service properties due to their high hardness, a decreased contact path of the abrasive particle with the working surface and forms a “fluidized” layer of a moving abrasive medium between the rollers.

**Key words:** mechanical properties; hardness; thermal hardening; steel 65G; surfacing reinforcement; hard alloys.

## POWER SUPPLY AND AUTOMATION OF AGRICULTURAL PRODUCTION

### ORIGINAL PAPER

#### USE OF THE S-40 DRYER IN TWO-STAGE DRYING OF CORN GRAIN

*MIKHAIL G. ZAGORUIKO, PhD(Eng), Senior Research Engineer*

zagorujko.misha2013@yandex.ru

*SERGEY A. PAVLOV, PhD(Eng), Key Research Engineer*

sapavlov777@mail.ru

Federal Scientific Agroengineering Center VIM; 109428, Russian Federation, Moscow, 1<sup>st</sup> Institutskiy Proezd Str., 5

**Abstract.** The paper provides rationale for safe modes and methods for calculating a two-stage drying technology with partial recirculation of grain, in which the grain is under-dried by 2...3% to the standard humidity in a grain dryer, and the hot grain is cooled by active ventilation with outside air, while drying it to the standard humidity. The safe mode of two-stage drying in S-40 provides for partial recirculation of grain with moisture removal close to the standard, and the moisture content of the recirculated mixture not exceeding 18%. The recirculation coefficient calculated based on this condition is used to determine the temperature of the recirculating grain mixture, taking into account the reversible component in the shaft dryer. The minimized recirculation ratio provides for the permissible unevenness in drying and minimal fracturing. The recirculation drying process was analyzed according to the standard method, but with the adjusted values of moisture removal and temperature of the grain mixture. Economic tests of the S-40 dryer were carried out using a two-stage technology on corn grain. It has been experimentally established that the S-40 dryer with a recirculation coefficient of 2 and a moisture pick-up of 4% per cycle when drying corn grain with a moisture content of 23.5 to 15.6%, at a drying agent temperature of 95°C, provides a throughput of 10 t/h (without refrigeration). Cooling was carried out in the warehouse. No significant changes in the quality of dried and cooled grain have been established: the starch content and fracturing practically did not change; the unevenness of the dried seeds did not exceed the original requirements. The expediency of using the S-40 direct-flow dryer in the recirculation mode has been experimentally established.

**Key words:** drying, corn grain, recycling, two-stage technology, calculations.

## ORIGINAL PAPER

### DESIGN OF ELECTRIC AIR OZONATOR FOR LIVESTOCK KEEPING HOUSES

**ALEKSANDR N. MANUYLENKO** ✉, *postgraduate student*

manuilenko.shura@yandex.ru ✉

**SERGEY V. VENDIN**, *DSc (Eng), Professor*

elapk@mai.ru, <https://orcid.org/0000-0002-0482-6657>, Researcher ID: Q-8148-2017

Belgorod State Agrarian University named after V.Ya. Gorin; 308503, Russia, Belgorod region, Belgorodsky district, settlement Maysky, st. Vavilova, 1

**Abstract.** One of the most important tasks of animal husbandry is establishing and maintaining normalized microclimate parameters in closed livestock keeping houses: temperature, humidity, speed of air flows, illumination, gas composition of air, and suspended dust particles. Failure to comply with established zootechnical and veterinary-sanitary standards in a closed room, (other things being equal) can lead to a decrease in productivity, increased feed consumption per unit of production, the rapid development of pathogenic microbes, and the spread of infections. The design of an electric air ozonizer based on a corona discharge and an air ozonation system is proposed to ensure high-quality air disinfection in livestock keeping houses in accordance with sanitary standards. A distinctive novelty of the proposed design is the emitter module, made as a ceramic base, on which tungsten electrodes are fixed in the form of a grid with a honeycomb cell. The advantages of the proposed design of an electric air ozonizer include the reliability of operation due to shutdown in case of an emergency, protection against overheating and critical concentration of ozone inside the room in one place due to a weather vane, ozone and temperature sensors, and a central control unit. The proposed design of the electric ozonation system will increase the efficiency of disinfection and disinsection of air in industrial livestock buildings, and will also ensure a more uniform concentration of ozone throughout the room volume due to the location of ozonizers and their improved operation of the emitter in terms of performance and uniformity. Preliminary evaluative experimental studies to test the performance of the proposed electric air ozonator in a livestock keeping house with an area of 1600 m<sup>2</sup> have shown that its design reduces the amount of microflora in the air from 27520 to 240 colonies/m<sup>3</sup>, while increasing ozone concentration to 0.035 mg/m<sup>3</sup>, as well as reduces the content of harmful gas impurities of hydrogen sulfide from 0.16 to 0.0003 mg/l; ammonia - from 0.13 to 0.05 mg / l; carbon dioxide - from 10 to 0.2 mg/l.

**Key words:** air, livestock keeping house, disinfection, ozone, electrical ozonation, structural diagram, ozonation control.

## THEORY AND METHODOLOGY OF PROFESSIONAL EDUCATION

### ORIGINAL PAPER

#### INTERNATIONAL SOCIETY FOR ENGINEERING PEDAGOGY: HISTORY AND DEVELOPMENT TRENDS

**PETR F. KUBRUSHKO**, *DSc (Ed), Professor, Corresponding Member of the Russian Academy of Education*

pkubrushko@mail.ru; <https://orcid.org/0000-0002-2142-1037>

**LIUDMILA I. NAZAROVA**, *PhD (Ed), Associate Professor*

nazarova@inbox.ru; <https://orcid.org/0000-0001-8469-8052>

**DIANA O. EPRIKYAN**, *Assistant Professor*

eprikyan\_d@bk.ru

**Abstract.** The paper analyzes the history of the establishing and development of the International Society for Engineering Pedagogy IGIP – one of the first international organizations specializing in the theory and practice of training TVET teachers (TVET stands for technical and vocational education and training). Engineering pedagogy is presented as a part of TVET pedagogy, which considers the training of professional personnel in various specialties and areas. Engineering pedagogy dates back to the 1950s. It was centered around the International Society for Engineering Pedagogy IGIP established in 1972 in Klagenfurt (Austria) under the leadership of Adolf Melecinek. Russia joined this movement in 1995. In a number of engineering universities, IGIP Centers were established and have been successfully operating since then. TVET teachers improve their professional and pedagogical qualifications and, if their level of training and professional experience is confirmed to the IGIP standards, teachers are awarded the title of “European Lecturer at an Engineering University”. The development trends of the International Society for Engineering Pedagogy in Russia are primarily associated with its integration into the system of continuous vocational (TVET) teacher training in the context of the digital transformation of society. It is necessary to systematically update the tasks set for IGIP. A new international standard (third generation) of the minimum pedagogical training required for university teachers has been developed. Cooperation with other partner organizations is being established. The IGIP publication system was revised (a new iGEP journal was established – International Journal of Engineering Pedagogy). Annual IGIP Symposiums contribute to integration processes in professional education and promote academic mobility. The centers for engineering pedagogy are accredited according to the international IGIP standard. An important task of the International Society for Engineering Pedagogy is not only the modernization of the scientific and methodological foundations of university engineering pedagogy in accordance with the urgent tasks of professional education, but also the improvement of the methodology of engineering and technical education as a whole as a system that has invariant components of the teaching content structure and variable components differentiated by training levels and areas.

**Key words:** International Society for Engineering Pedagogy – IGIP, technical and vocational education and training (TVET), TVET teacher, engineering education, TVET teaching activity.