INNOVATIVE MAINTENANCE AND FEEDING OF WEANING PIGLETS BASED ON NEW TECHNICAL MEANS
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ИННОВАЦИОННОЕ СОДЕРЖАНИЕ И КОРМЛЕНИЕ ПОРОСЯТ-ОТЪЕМЫШЕЙ НА ОСНОВЕ НОВЫХ ТЕХНИЧЕСКИХ СРЕДСТВ

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ABSTRACT
A set of equipment for an innovative animal management system based on advanced technological solutions is presented. The equipment set includes a pen for housing postweaning piglets, a vibration feed distributor, and a self-feeder. Rationale behind the use of the small-group nested housing technique for postweaning piglets is presented, and the viability of development of a new feed distributor and self-feeders is discussed. Information on experimental studies of a new (vibration-based) type of feed distributor is presented to demonstrate its operating efficiency and adequate performance.

РЕЗЮМЕ
Представлен комплект оборудования для инновационной системы содержания на базе использования современных технических средств. Комплект оборудования включает в себя станок содержания поросят-отъемышей, вибрационный раздатчик кормов и самокормушку. Дано обоснование необходимости применения технологии мелкогруппового погнездного содержания поросят-отъемышей, показана целесообразность разработки нового типа раздатчика кормов и самокормушки. Представлены материалы экспериментальных исследований нового (вибрационного) раздатчика кормов, подтверждающие его работоспособность и достаточную производительность.

INTRODUCTION
In 2018, Russia has reached threshold values of the food self-sufficiency target of the Russian Federation in terms of meat production; meat output grew (mainly owing to pig farming) by 14.4%. The industry is actively employing advanced machinery and industrial digital technologies (*Izmailov A.Yu., 2019; Latruffe et al., 2017; Wasserstein R. L., Lazar N.A., 2016*).

Livestock and poultry production volumes amounted to 10,629.4 thousand tons (Table 1).

Table 1
Production volumes of main types of livestock products and pig farming products in the Russian Federation (thousand tons)

Product name	1990	2000	2010	2016	2017	2018
All categories of producers						
Slaughtered livestock and poultry (slaughter weight)	10111.6	4445. 8	7166.8	9800.2	10391.4	10629.4
including pigs	3480.0	1578.2	2330.8	3368.2	3537.6	3744.2
Agricultural organizations						
Slaughtered livestock and poultry (slaughter weight)	7603.5	1786.5	4342.3	7515.2	8043.9	8349.7
including pigs	2290.6	435.8	1228.0	2716.8	2917.3	3186.4

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Product name	1990	2000	2010	2016	2017	2018
Household farms						
Slaughtered livestock and poultry (slaughter weight)	2507.0	2579.5	2612.6	2045.3	1973.3	1911.8
including pigs	1188.9	1107.2	1040.1	590.9	558.7	514.1
Family-operated farms, farming enterprises and self-employed entrepreneurs						
Slaughtered livestock and poultry (slaughter weight)	1.1	79.8	209.9	292.2	305.3	321.9
including pigs	0.5	35.2	69.0	47.2	44.2	43.7

Source: Federal State Statistics Service for 2010-2017, includes data of the All-Russian Agricultural Census of 2016.

A major area where resource saving technologies are being introduced is the sphere of comfortable animal housing and reduction of feed consumption that, on the average, account for 60% of total pork production costs. Optimal and biologically sound management of pigs with consideration to their genotype, is the basis for efficient use of resources (*Kostlivý V., Fuksová Z., 2019; Laure Latruffe et al., 2017; Madau Fabio A. et al. 2017*).

Comprehensive feeding of pigs with well-balanced feed is a critical factor in effective utilization of the genetic potential of animals. One of the particularities of pig feeding is that these animals have a very high growth rate, as compared to other livestock species. Thus, careful preparation of feed, as well as providing animals with high quality and safe feeding compounds, is required. All of the nutrients of the feed should be balanced not only in terms of the required consumption volume, but also in terms of balance of the nutrients, which should be optimized with respect to the proteins/calories composition of the diet (*Syrovatka V. I. et al., 2019*).

Affected by adverse factors during the piglet rearing stage, animals may become overstressed which may result in stock underdevelopment, disorders, and, consequently, high death level.

The adverse effects mentioned above are the most crucial for the initial stage of a pig's development, i.e., for postweaning piglets. For the above-mentioned reasons, pig breeding enterprises should strive to create comfortable housing and feeding conditions, most importantly – in rearing pens. According to the existing technological process, piglets are moved into houses where they are grouped in three or four nests, with up to 30 animals in a pen. This results in stress. When feeding a large group of piglets, there is not enough space to accommodate all of them, which leads to conflicts between animals.

MATERIALS AND METHODS

Based on studies of various sources when researching the issue of eliminating the drawbacks of the postweaning piglet feeding process, it was determined that the nested small-group rearing method of piglets should be used, with the number of animals not exceeding 10 to 12 per one pen. To achieve this objective, a set of equipment was developed which uses a conceptually new type of distributor and self-feeder.

This study uses the methods of system analysis, mathematical statistics, regulatory documents; it also reviews the trends in technology and facilities used for management and feeding pigs; uses the technique of summarization of ranking scores. Some information in this study is presented in the form of tables (*Choi L., 2016; Ivanov, Yu. Mironov V.V., 2018; Morozov N.M., Rasskazov A.N., 2019).*

STUDY RESULTS

Figure 1 shows the flow chart of the innovative system of postweaning piglets’ housing and feeding based on advanced technological solutions.

The basis of the innovative system of housing and feeding postweaning piglets is the equipment providing small-group nested stress-free housing of animals. The conceptually new process solution for feed distribution and the self-feeder are technologically and structurally integrated into the pen system.

The pen for small-group nested housing of postweaning piglets accommodating up to 12 animals has the area of 6.9 m^2 (Fig. 1, Item 1), and is equipped with a self-feeder, a brooder intended as the piglet rest area, and suckle feeders. To ensure ease of animal management, the entrance gate is located within the front wall of the pen, close to the self-feeder. There is some free space in the pen near the self-feeder sufficient for at least four piglets. The brooder is located in the left part of the pen, and is adjacent to the rear wall. It accommodates up to 12 piglets. Floor area of the brooder is at least 1.2 m^2.

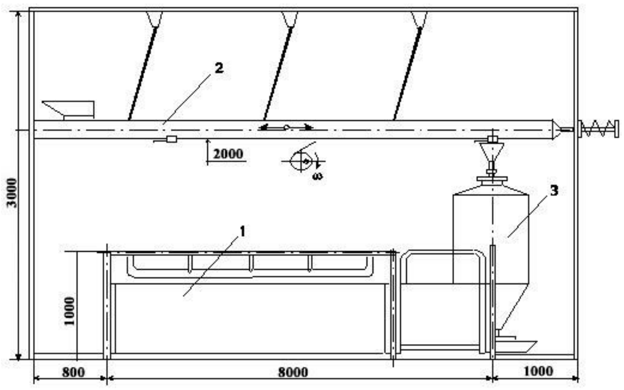


Fig. 1 - Process scheme of the innovative system of postweaning piglets' housing and feeding based on advanced technological solutions

1- pen for small-group nested housing of postweaning piglets; 2 – feed distributor; 3-self-feeder

General view of the pen for small-group nested housing of postweaning piglets is shown in Figure 2.

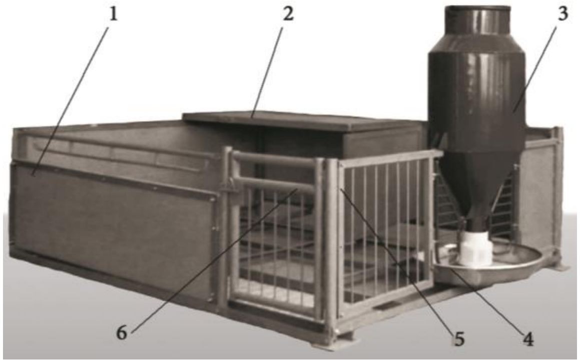


Fig. 2 - Pen for nested housing of postweaning piglets

1-pen front wall; 2-pigled brooder cover; 3-feed supply hopper; 4-round self-feeder trough; 5-contact grille; 6-gate

Pen fencing is made of 200 mm wide and 35 mm thick plastic panels. The top of the panels has a locking profile, and their bottom has the respective slot. The design of the panel ensures its durability, and makes it possible to treat the panels with disinfectants. Panels comprising a wall are assembled into panes of the required height: 600 mm high in the front, and 800 mm high on the sides and in the rear. The panels are reinforced along the perimeter by a metal frame made of angle bars with the dimensions of 45x45x5 mm, and a 40x45 mm plate. The frame has four bolt holes for securing the walls to the support poles.

In order to improve the efficiency, the self-feeder (Fig. 1, item 3) is located at the partition between two adjacent pens, and supplies both of them. The self-feeder is equipped with a supply hopper which holds two days' worth volume of feed; a round trough divided into four partitions is located in each of the pens. Beside the self-feeder, there are two suckle feeders.

The structural diagram of the self-feeder is shown in Figure 3.

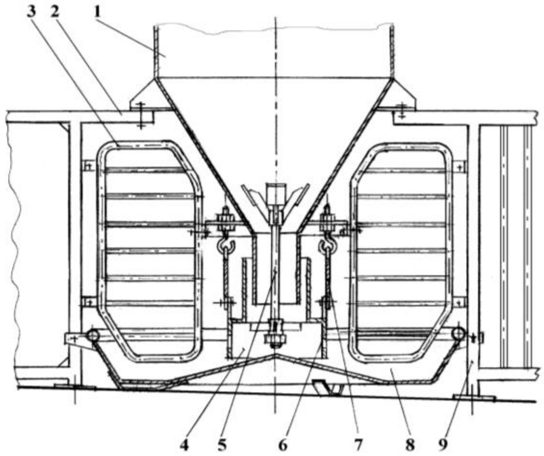


Fig. 3 - Mechanism of the self-feeder

1-hopper; 2-pen partition; 3-removable partitions; 4-discharge neck, 5-agitator; 6-slots; 7-flexible suspension; 8-round trough; 9-contact grille

Hopper *1* is intended for storage of a certain reserve volume of dry feed; the discharge neck *4*, being a movable part, makes it possible to regulate the rate of feed supply from the hopper into the round trough *8*.

The discharge neck *4* is the main working body of the self-feeder. Animals actuate its slotted shell ring (by moving the ring within the gap between the cylindrical pipes) and thus the feed in the trough *8* is replenished. To achieve this, the discharge neck unit is attached to the hopper using flexible elements to allow movement, and there is an adjustable gap between the discharge neck and the bottom of the trough.

The upper part of the discharge neck has the same form as the matching part of the hopper, while the neck internal diameter is 30 mm larger. This gap makes it possible for the discharge neck to move in all directions, and ensures that feed is always present in the trough *8*. To prevent bridging of feed within the cone-shaped bottom part of the hopper, the discharge neck *4* is equipped with the flap agitator *5*.

To attract animals to the self-feeder, the lower part of the discharge neck has a slotted shell ring. The ring slots fill with feed, but their width is not sufficient for feed to spill into the trough *8* spontaneously.

The conceptually new vibration feed distributor (Fig. 1, item 2) was developed to deliver feed to self-feeders. This device has a number of advantages over the existing feed conveyors.

Presently, the main method of feed distribution mechanization lies in the use of stationary feed transportation and distribution systems, based on various engineering solutions.

Systems employed to transport feed from bunkers to pig houses and distribute it within include chain-disc conveyors and screw-type (spiral) conveyors.

A common drawback of these technologies is that they employ a working body (a chain with discs, a helix or a screw), which forces the feed to the pig feeding location. The chain-disc, helix or screw system operate under a high load and are prone to intensive wear due to active interaction with the feed.

Alternative technologies to transport feed within the pig breeding facility are thus required that would have none of these disadvantages.

Research dedicated to the development of equipment for the transportation and distribution of feed based on new technological solutions resulted in the development of a conceptually new system of feed delivery to piglets.

A promising line of development of feed distribution systems is the vibrating transportation system.

Unlike chain-disk or screw (spiral) conveyors, the vibrating feed delivery chute has no moving parts.

Main requirements to vibrating conveyors are the capacity to prevent sticking of the feed, as well as to select parameters of vibration and the angle of inclination of suspension links and the piston.

Main advantages of vibrating conveyors as compared to chain-disk or screw (spiral) type conveyors are: improved working conditions in the pig house, reduced soiling owing to the fact that this feed delivery system is enclosed, absence of contamination of the feed and its loss to spillage, low wear of the feed delivery chute due to the absence of rubbing parts and simple design. Apart from the above advantages, metal needed to manufacture them and their energy consumption are lower, reliability of the system is higher while its operational costs are reduced.

A study of principles of this granular material transportation method enabled us to develop a valid process scheme and determine the location of the actuating mechanism of the feed distributor.

According to the theory of vibration-based transportation of granular materials, the line of the shaking force which sets the system in vibration, should pass through the centre of the system's mass (centre of attraction) to exclude secondary torsional oscillations that affect the material transportation process adversely.

The process scheme of the vibration piglet feed distributor was developed with due account to these requirements.

The process scheme is shown in Figure 4.

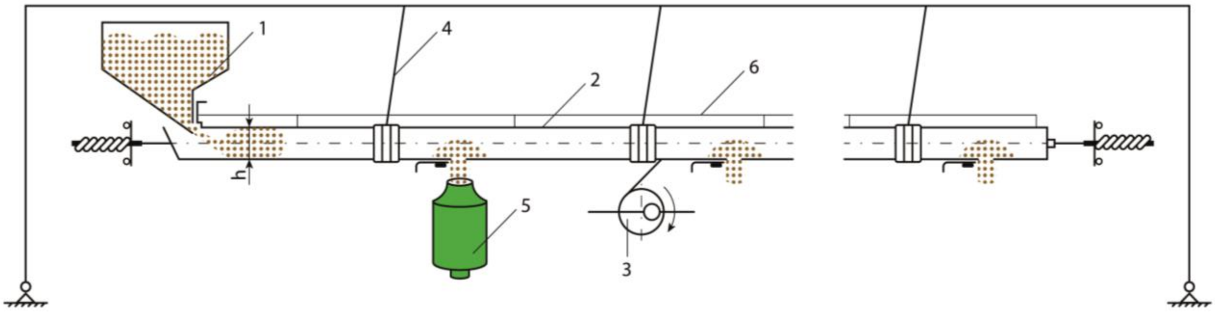


Fig. 4 - The technological scheme of the modernized vibrating feed distributor

The feed distributor includes intake hopper *1*; feed delivery chute *2*; actuator *3*; suspension links *4*; self-feeder *5*; and rectangular reinforcement tube *6*.

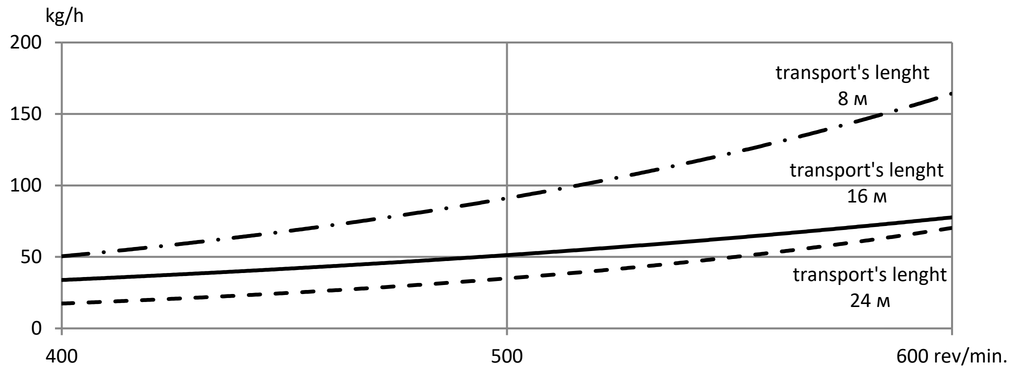
The intake hopper is intended to deliver feed into the delivery chute, which has the form of a cylindrical pipe 24 m long and 100 mm in diameter. The actuating mechanism is comprised of a cam which rotates to create vibration with a certain amplitude (in our particular case, two cams (10 and 20 mm) were used. Suspension links are located at a certain angle to the vertical line, and facilitate feed shaking within the feed supply chute.

The advance of dry feed into the self-feeder hopper is achieved by the feed distributor of the new design by means of vibrating feed delivery chute.

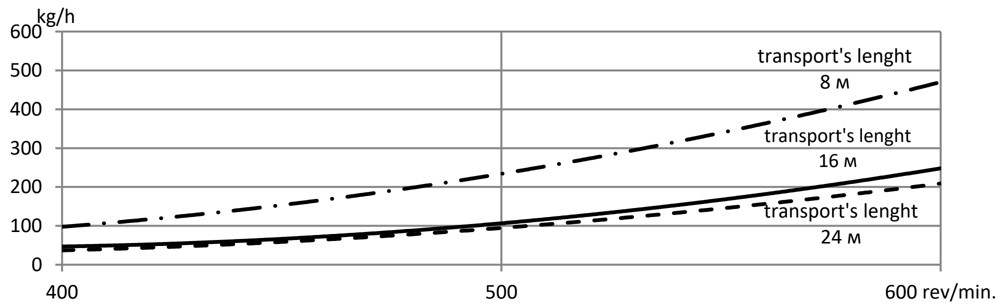
Dry feed is transported within the vibrating feed chute throwing up tossed granules and moving them towards discharge apertures.

On the basis of the process scheme of the vibrating feed distributor, design documentation was developed, and the feed distributor was manufactured and assembled. This enabled experimental studies of the vibration feed distributor.

These studies, conducted on loose and pellet feed, enabled us to determine the dependency of the feed distributor performance from the speed rate of the electric motor, the feed transportation distance, and the amplitude of the vibration mechanism oscillation (Fig. 5 a and b).



a) loose feed



b) pellet feed

Fig. 5 - Dependence of the vibrating feed distributor’s capacity on the number of electric motor’s revolutions (eccentricity of 10 mm)

The diagram demonstrates that, in case of loose feed (Fig. 5 a), the transportation distance of 8 m, and the electric motor’s speed within the range of 400 to 600 rpm, the performance of the feed distributor increases more than threefold, with the transportation distance of 16 m -- just over twofold, and with the transportation distance of 24 m it is more than four times higher.

For pellet feed (Fig. 5 b), the change of performance with the change of the electric motor speed rate at various feed transportation distances is as follows.

With the electric motor speed rate changing from 400 to 600 rpm and the transportation distance of 8 m, the performance is four times higher; with the transportation distance of 16 and 24 m, the performance is more than five times higher.

Similar experimental studies with an eccentricity equal to 20 mm were carried out. The vibrations' amplitude increasing due to a larger eccentricity using contributes to an overall vibrating feed distributor capacity increasing. Similar experiments were carried out with the eccentricity equal to 20 mm. The increased oscillation amplitude due to the higher eccentricity results in a more intensive increase of performance of the vibration feed distributor.

CONCLUSIONS

The set of process equipment for the stress-free nested postweaning piglet management and feeding system would make it possible to minimize stress-related phenomena, ensure livability of piglets, improve average daily weight gain, and stabilize piglet development.

The expected results of application of the equipment are: an increase of postweaning piglet survivability of up to 98%, and achieving 30 to 32 kg of body weight in 85 to 90 days. The experimental studies have shown that the developed vibration feed distributor provides stable feed delivery and the required performance.

Stress-free small-group (up to 12 animals) housing of postweaning piglets improves livability of rearers up to 90 or 93%, and average daily weight gain during the rearing to no less than 400 g per animal per day.

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