Digital technologies in food preparation and distribution

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Abstract. The article considers the analytical review of digital technologies (smart farming) in agro-industry. Such digital technologies include computer programs for calculating the farm animal diet, their advantages and disadvantages are given. The analysis and disadvantages of foreign robotic systems for feeding animals are presented. The results of correlation and regression analysis of the impact of the herd size of farm animals on labor input for their feeding are presented. The impact of the number of feed loading cycles in the hopper and its capacity on the uneven feed distribution by the “Free Stall Feeder” robotic feed distributor using the Mathcad 15 program is shown.

1. Introduction

In the sub-sectors of animal husbandry, there is a variety of animal production technologies. Based on the research conducted by scientists on the methods of keeping and feeding farm animals [1], digital technologies are distinguished. The specific conditions of the digitalization of agricultural production are caused by the impact of various conditions, such as technological, biological, climatic, organizational, economic, and environmental. At the present stage of animal husbandry sub-sectors development, the concept of “digital automated technologies for performing production processes and operations” is introduced, which include animal feeding – the feed mixtures preparation and distribution, etc. [2].

In the field of “smart farming”, it is expected to introduce, in the federal subjects of the Russian Federation, a complete innovative integrated scientific-technical cycle of “end-to-end” type of digital systems “smart agricultural enterprise” and “smart farm”, etc. This digital system is based on modern competitive domestic technologies. A “smart agricultural enterprise” serves as the management subject, and digital technologies in the management of agro-industrial complex serve as management objects, "smart farm" (animal husbandry), etc. are the objects of management [3].

The Global Forum for Food and Agriculture (GFFA) was held in Berlin (the 17 of January 2019th) with the theme “Agriculture Goes Digital – Smart Solutions for Future Farming”. Therefore, the very concept of “digital animal husbandry” is a transition to an innovative methodology that is dictated by the logic of the industry development [4].

The “Digital Economy of the Russian Federation” state program is aimed at modernizing the Russian economy, which was approved by the Decree of the Government of the Russian Federation (28.07.2017, no.1632-D): “…digitized data is a key factor in production in all spheres of socio-economic activity, which contributes to improving the competitiveness of the country, the life quality of the nation, ensures economic growth and national sovereignty”. Sustainable development of the
agro-industrial complex, of increasing food independence and export potential of the country will require a competitive high-tech industry with high labor productivity and low unproductive expenses. At the same time, the country needs a technological breakthrough, an important part of which is digital technologies in the agro-industry [5].

2. Materials and methods

In the Russian market there is a large number of computer programs aimed at calculating rations [6] (table 1), which differ in many criteria (functionality, difficulty in use, and pricing policy) [7].

| Computer program title | Advantages | Disadvantages |
|------------------------|------------|---------------|
| Hybrimin (Germany) [8] | Ration calculation and optimization of any complexity in steps, a wide range of reports and forms for production processes, a simple and convenient interface, a high level of technical support | High cost of license and annual maintenance |
| Bestmix (Netherlands) developed by “Adifo” company, WinPas (Poland) [9] | User-friendly interface, low cost | Dated |
| AminoCow (USA), ProFeed Version 4.5 (Germany) [9] | – | Not adapted for Russia, hence, not applicable enough |
| “Korall”, “KormoResurs” and “Plinor” (Russia) [11,12] | Low cost, consideration of the specific features of keeping and feeding animals, modularity and wide opportunities, the disadvantage – a complicated interface | Complicated interface |
| “Korm Optima Ekspert” (Voronezh) [10] | Unaided input of formulas and coefficients when calculating feed energy, and also allows calculating in one work window the total rations of all age groups of animals of this species from birth to slaughter | – |
| “Feed rations” by “Plinor” company (Saint Petersburg) [10] | Calculations of rations for cattle, has a clear interface, calculations are linked to Russian standards | – |

A. E. Kirnos, on the basis of automation, proposed to use the software and hardware platform “Arduino”, which is assembled on a microcontroller of the “AVR” family. The basis is the “Wiring” (C-like) and is soft hardware with its loader without the use of separate hardware programmers. Based on the functional automation scheme, A.E. Kirnos built the organization of information flows of the livestock enterprise system with a firmware module that is used to manage different types of activities. On the basis of individual blocks, a unified management system for livestock enterprises will be created [13].

“Mullerup A/S” (Denmark) is a part of “GEA Farm Technologies” corporation and produces automated feeding systems for animals [17-21]. The design of the “Mix Feeder” robotic feed distributors of this company allows preparing the feed mixture and distribute it in livestock houses with various animal keeping systems, both in automatic mode under the control of the “MIT” computer and manually.
For the distribution of a premixed feed, “GEA Farm Technologies” produces a standard size range of robotic feed distributors “Free Stall Feeder” – M1600, M2000 and M3000 with a hopper capacity of 1.6; 2 and 3 m$^3$, respectively, which are designed to serve a herd of up to 400 cows and have 20-30 cycles of loading per shift, serve up to 15 groups of animals, the speed of movement when distributing the feed mixture is 16 m/min, automatic (MIT computer) or manual control [23].

For feeding a dairy herd with a population of up to 1000 cows in a yard housing, this company has developed the “MIX&CARRY” system, which consists of a suspended-type robotic feed distributor and an installation for a feed mixture preparation.

The “MVM” feed mixing unit of “GEA Farm Technologies” is a mixer-feeder with vertically mounted working bodies, which is equipped with an electronic weighing system.

One of the most perspective automated feeding systems is “Triomatic” by Trioliet (the Netherlands), the advantage of which is an uninterrupted operation of the feed reserve, and the rest of the operations are performed according to the animal feeding program. This system has a feed preparation department and a robotic feed distributor. The robot dispenses and distributes feed with parameters that allow composing individual rations for cows. The automatic feeding system “Vector” by Lely company allows increasing labor productivity by 10-15% [1].

The “SILOKING” SelfLine System 1000+30 is an automated feeding system in the form of a mixer, manufactured by “Mayer Maschinen Baugesellschaft GmbH”, (www.siloking.com), includes a hopper, a transfer conveyor, a cab, a feed loading device, three augers [16].

The disadvantage of the mixer by “Mayer Maschinen” company is low accuracy and reliability, the inability to control without an operator, performance. Another mixer-feeder under the patent RU No. 2129773 has a hopper with longitudinal mixing screws located along it, a discharge opening with flaps, and a discharge auger. The feeder has the same disadvantages as described above, as well as a low feed mixing speed.

Based on the above analytical review of robotic feed distributors, we will determine the influence of the herd size of farm animal from labor effort on its feeding by robotic feed distributor, for example of the “Free Stall Feeder” brand by conducting correlation and regression analysis in the language of Mathcad 15 in view of the recommendations presented in the work of [22], based on the original data, given in the work of [14,15].

### 3. Results and discussion

The results of correlation and regression analysis of the impact of the herd size on the time spent on feeding farm animals by a robotic feed distributor, as well as the impact of the technological parameters of the “Free Stall Feeder” robotic feed distributor on uneven feed distribution, are presented in tables 2 and 3, respectively.

| Indicator title                                      | Time spent on feeding (min/day) |
|------------------------------------------------------|---------------------------------|
| Squared correlation ratio                           | 0.975 (97.5%)                   |
| Correlation ratio                                   | 0.98                            |
| Correlation ratio error                              | 0.08                            |
| Calculated value of the correlation ratio significance test | 12.36                         |
| Student’s t-test table value                         | 3.182                           |
| Confidence interval for the correlation ratio        | 0.987±0.255                     |

Analysis of the data, presented in Table 2, shows the herd size affects the labor costs when feeding farm animals by a robotic feed distributor on the farm for a day and is 97.5. Since the calculated value is greater than the tabular values of Student’s t-test, the null hypothesis is rejected and the curvilinear relation in the logarithmic form is evident (figure 1).
Table 3. The correlation and regression analysis of the impact of technological parameters of, for example, the “Free Stall Feeder” robotic feed distributor on uneven feed distribution

| Indicator title                                      | Number feed loading cycles in the hopper | Hopper capacity, m³ |
|------------------------------------------------------|------------------------------------------|---------------------|
| Squared correlation ratio                            | 0.9877 (98.8%)                           | 0.9816 (98.16%)     |
| Correlation ratio                                    | 0.994                                   | 0.991               |
| Correlation ratio error                              | 0.055                                   | 0.068               |
| Calculated value of the correlation ratio significance test | 17.92                                   | 14.61               |
| Student’s t-test table value                         | 3.182                                   | 3.182               |
| Confidence interval for the correlation ratio        | 0.994±0.176                             | 0.991±0.216         |

Figure 1. The dependence of the herd size on the time spent on farm animal feeding by a robotic feed distributor on the farm

Analysis of the data presented in Table 3 shows the uneven feed distribution by a “Free Stall Feeder” robotic feed distributor is affected by the number of feed loading cycles in the hopper and by its capacity, which is 98.8% and 98.2%, respectively. Since the calculated value is greater than the tabular value of the Student’s t-test, the null hypothesis is rejected and the curvilinear relation in the form of a quadratic polynomial is evident (figure 2).
Figure 2. The dependences of technological parameters of, for example, the “Free Stall Feeder” robotic feed distributor, on the uneven distribution of feed: a - its hopper volume; b - the number of loading cycles

4. Conclusions
The disadvantage of most foreign and domestic computer programs is the high cost of licenses and annual maintenance, a complicated interface, and some foreign programs that are not adapted for Russia.

The farm animal herd size affects the labor costs per day for its feeding by a robotic feed distributor, for example, of the “Free Stall Feeder” type, which are 97.5%, and their curvilinear relations were obtained in the form of a logarithmic one.

The equations of the dependence in a parametric form:

\[ y = 144.06 \ln(x) - 515.74. \]

These equations allow determining the labor costs for feeding farm animals by a robotic feed distributor.

The feed distribution unevenness by a “Free Stall Feeder” robot is affected by the number of feed loading cycles in the hopper and by its capacity, the equations of graphical dependencies of which have the form:

\[ y = -0.0272x^2 + 1.7873x - 15.679, \]

and

\[ y = -0.0029x^2 + 0.236x + 8.72, \]

respectively.

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