Scientific Papers. Series D. Animal Science. Vol. LXV, No. 1, 2022
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

SIMULATION OF PIG PRODUCTIVITY UNDER FEED CONSUMPTION

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Abstract

The aim of the research is to develop a computer model that makes it possible to predict the productivity of pigs based on the data on their consumption of the exchange energy of feed and the amount of feed loss during storage and operation of technological equipment. Based on the known results, regression relationships have been established between the value of the exchange energy of the given feed and the average daily gain in the live weight of animals, as well as the cost of feed per kilogram of gain. Due to the loss of feed nutrients and the feed itself during the storage of feed in warehouses, during preparation and delivery to animals, as well as throwing away part of the feed when it is eaten by animals, the amount of nutrients consumed by the animal and the accounting of feed consumption do not match.

Key words: *animal weight, feed effect, metabolic energy, pig weight gain model.*

INTRODUCTION

Pig breeding is one of the oldest branches of agriculture, when animals were kept on pasture in the process of growing. To reduce the cost of meat production, this method of keeping pigs is sometimes used now, using the walking method of production (García-Gudino et al., 2021). However, obtaining a large volume of meat products requires the use of modern equipment and technologies. Timely and accurate assessment of the body weight of an animal when raising a pig affects the assessment of profit in its production, allowing decisions to be made on the timing of fattening animals to reduce labor and feed costs (He et al., 2021). Improving the technology of pork production is aimed at increasing the absorption of nutrients and reducing feed consumption (Pomar et al., 2021). Feeding is an important operation in the life of an animal, ensuring the efficiency of animal husbandry. The level of provision of an animal with nutrients significantly affects its behavior and the rate of weight growth (Jia et al., 2021; Misiura et al., 2021). Modern research in pig breeding has several directions.

In particular, the influence of feeding conditions on the state of health of the animal is revealed, and through this, on the indicators of its productivity (Misiura et al., 2021). Another focus is on the impact of different diet formulation methods in providing pigs with the required amount of nutrients while minimizing nutrient excretion and greenhouse gas emissions. In particular, it was found that the reduction of crude protein improves the absorption of available energy due to a decrease in energy losses for protein deamination. Due to growing concern for the environment, selection in pig breeding for nitrogen excretion is being studied. A number of researchers (Monteiro et al., 2021) consider the assessment of the life cycle of an animal to be a more promising indicator. Relationships between production traits and the impact of life cycle assessment of individual reared pigs on finishing (feed consumption per kilogram of body weight gain) were studied (using a modeling approach). Double and precision feedings were compared. This indicator appeared to be the best indicator of the impact on the life cycle assessment with a very high and positive correlation (r> +0.99) for both feeding programs. Some work is focused on studying the effect of supplements or changing the norm of individual nutrients. The aim of the study (Ewaoluwagbemiga et al., 2021) was to evaluate the behavior of animals during feeding with dietary protein restriction. A significant correlation coefficient was found between the predicted and observed values of protein (0.50), metabolic energy (0.70) and lipid (0.90).

The results of the researches show the relationship between the dynamics of feeding and the behavior and body weight of the animal. A model was used in which several breeds of animals, their age, feeding (behavior and feed intake) were used as factors. The results (Kavlak et al., 2021) show that the social interactions of animals in a group have a significant indirect genetic effect on the feeding, behavior and feed conversion rate of the pig, but not on the average daily weight gain and fat thickness. In an automatic feeding station for pigs, the features of animal behavior and interaction with other individuals were studied (Angarita et al., 2021) by recording the indicators of individual feeding of an animal. The results showed that both direct and social effects influenced the duration of eating at a single-site feeder. Animals that spent more time at the feeder per day

Investigated the effect of feeding frequency (one /M1/, three /M3/ and five /M5/ times a day) with the same daily feeding rations. The results of these studies show that the number of feed deliveries per day affects the digestion and absorption of proteins and fats in pigs, and does not affect the weight gain of animals. Final body weight, average daily weight gain in the M3 and M5 groups were significantly higher than in the M1 group, but the specific feed consumption was significantly lower than in the M1 group.

The researches consider the problems of animal productivity modeling. The limitations of the possibility of linear prediction and double exponential smoothing are noted. Often, uncertainty and correlation in the estimated features are not sufficiently taken into account. Alternative approaches to predicting individual growth or consumption response based on non-linear models (allometric, monomolecular, rational) and Bayesian methodology were developed and evaluated to fit the model to the original data and the ability to generate probabilistic forecasts. It was found that a good fit does not guarantee an accurate forecast, which has a quantitative value in the medium and long term. Forecasts from non-linear models gave more accurate results compared to the reference linear models.

An analysis of the methods used to model the studied livestock processes showed that pig breeding does not use methods typical of technical sciences (Bormotov et al., 2020; Bormotov et al., 2022), but mainly regression modeling and correlation or dispersion analysis are used. An exception is the work (Plaksin et al., 2021), where the simulation was performed on the basis of a theoretical analysis. This mathematical model takes into account the change in the consumption of the prepared feed mixture depending on the age of the suckling pigs during the operation of the technological equipment. Models that make it possible to comprehensively predict the productivity of pigs have not been identified.

The aim of the research is to develop a computer model that makes it possible to predict the productivity of pigs based on the data on their consumption of the exchange energy of feed and the amount of feed loss during storage and operation of technological equipment.

MATERIALS AND METHODS

The research methodology included a regression analysis of the known production data for growing pigs for fattening to obtain adequate dependencies. The correlation coefficient of the initial and calculated values for the models was R=0.9321-0.9843. Based on the established functional dependencies, the indicators were modeled in the mathematical package MathCAD to determine the forecast of their values, taking into account the magnitude of feed losses during the operation of technological equipment.

RESULTS AND DISCUSSIONS

An analysis of the results of the economic activity of pig-breeding enterprises (Tronchuk et al., 1990) made it possible to establish in tabular form the relationship between the amount of metabolic energy during fattening of pigs and the value of animal weight gain, feed costs per kilogram of live weight gain and the duration of pig rearing. The specified information allows us to evaluate the results of the economic activity of the enterprise and identify existing trends, however, they are insufficient for numerical modeling of the performance indicators for raising pigs. At a minimum, it is required to establish regression expressions that numerically show the relationship of these indicators. The established regression models

(Figure 1) were obtained on the basis of the data of the industrial rearing of pigs.

The applied expressions make it possible to use the well-known energy model of a living organism (Kill et al., 2013; Noblet et al., 2004), when part of the energy entering it (for example, Figure 1 a) is spent on maintaining a viable state (the minimum required amount, i.e. at Ec≤20 MJ), and the excess of this energy begins to be converted into additional products (deposited in the body as a reserve of nutrients and an increase in live weight with the growth of the animal, i.e. at 18 MJ≤Ec≤26 MJ).

If at the beginning of the increase in excess energy the animal receives a comfortable existence, and the amount of increase gradually increases, then after reaching a certain value, an intensive increase in animal weight gain is observed (26 MJ≤Ec≤31 MJ). After the realization of the body's ability to transfer food into the reserves of a living organism, there is a decrease in the efficiency of feed use (Ec≥31 MJ). That is, the proportion of food in transit through the animal increases. These losses worsen not only the efficiency of the feed, but also the ecology of production (De et al., 2018).

The results of the influence of the amount of expended metabolic energy on the specific feed consumption (Figure 1 b) and the duration of rearing (Figure 1 c) are interesting. In both regression models for Ec≤26 MJ indicators have the highest values.

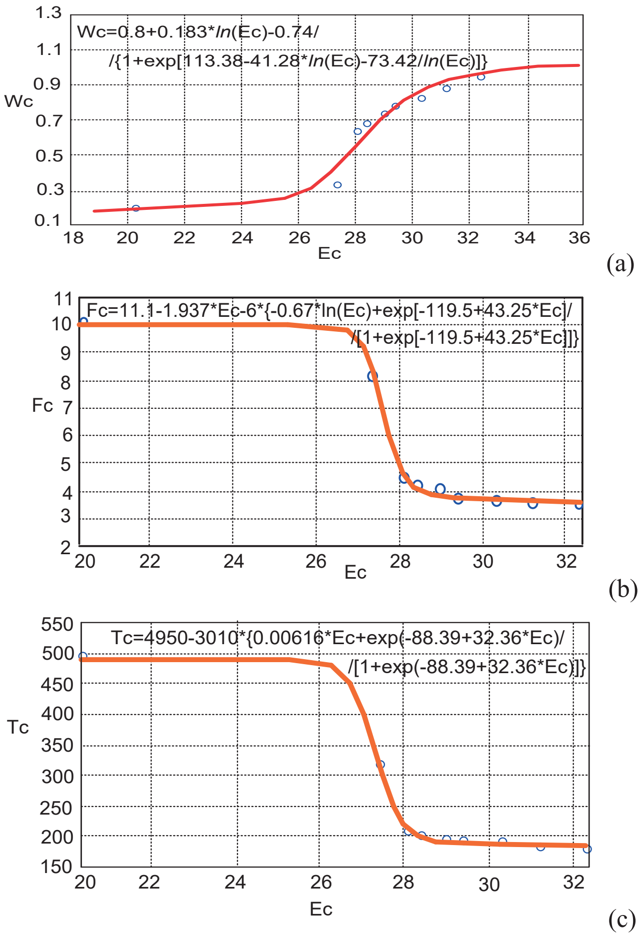

Figure 1. Influence of the average daily consumption of the exchange energy of feed (Ec, MJ) on:
a. - on the average daily gain in live weight (Wc, kg); b. - feed costs per kilogram of live weight gain (Fc, kg);
c. - the duration of rearing the fattening animal (Tc, days)

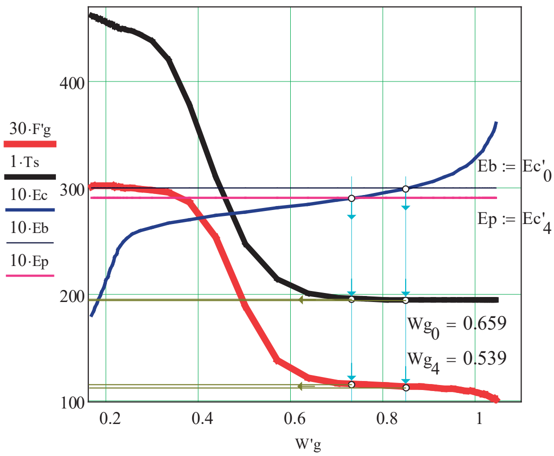

Figure 2. The relationship between the average daily gain in live weight (Wg, kg) and indicators: feed costs per kilogram of weight gain (Fg, kg); the duration of rearing the fattened animal (Ts, days); average daily consumption of the exchange energy of feed (Ec, MJ)

For the interval (26 MJ≤Ec≤31 MJ) is characterized by an intensive improvement in performance. For values of Ec≥At 31 MJ, stabilization of the indicators under consideration is again observed. As a result, a sharp reduction in the growing period stops, and the specific feed consumption decreases slightly.

Interesting information is obtained by changing the abscissa index (Figure 2). With a weight gain of more than 0.6 kg, both the growing period and the specific feed consumption do not improve significantly. At the same time, in the area Wg=0.3-0.9 kg, a linear increase in the consumption of the exchange energy of the feed is observed. This allows us to consider the further use of scaling by the proportionality factor Kw justified. With a further increase in the weight gain of animals, the costs of metabolic energy increase sharply. That is, the limited feeding of animals contributes to the efficient use of the exchange energy of the feed. Feeding ad libitum reduces the energy efficiency of feed. Thus, feeding animals with their consumption of metabolic energy corresponding to this transitional regime (according to Figure 2 - Wg = 0.9-1.0 kg), allows you to reduce the period of growing animals and effectively use the feed.

It should be noted the production conditions for obtaining the initial data of regression models. For the result, the important point is precisely the consumption of the right amount of feed by the animal, and not its issuance to the feeder or accounting for consumption. Since some of the energy can simply be lost. The amount of feed energy stored and taken into account in accounting does not always correspond to the actual energy sent to the livestock department. There is the effect of shrinkage, rotting, natural decline in feed quality, eating by rodents and theft by people. Feed mixtures are prepared from feed components in the workshops. In this case, part of the material is inevitably lost, and during heat treatment, the amount of metabolic energy available to animals increases. When eating food, animals instinctively throw out part of the feed from the feeder,

Losses in specialized feeders that follow the contours of the animal's head can be reduced to 0.3%, and in production - up to 2% (Baxter, 1989). Changes in the dimensions of pigs during the selection process also affect the rational parameters of the feeders (Condotta et al., 2018; Shneider et al., 2021; Neilson et al., 1996). A review (Konovalov et al., 2005) of the technical condition of technological equipment showed that: the loss of feed from dusting when unloading dispensers is about 0.5%, from scattering when falling into the feeder or on the floor - up to 5.2%, when eating - up to 10.3 %; daily fluctuations in the dose of feed on dry matter can be 20-25%, which additionally leads to a decrease in weight gain by 2-4%.

Three areas of the occurrence of losses are considered: 1 - loss of feed (and, accordingly, the exchange energy in it) in the process of eating the given portion by the animal; 2 - loss of exchange energy and feed in the shops of the livestock enterprise in the process of preparing the feed mixture, delivering and distributing it to animals (taking into account the change in exchange energy, the percentage of losses can be negative); 3 - loss of exchange energy and feed in the process of storage of raw feed components. Losses are measured as shares of the amount of feed and its energy according to the company's accounting records.

It should be borne in mind that different breeds of animals are used in different livestock enterprises, with different directions of cultivation and genetic inclinations. In this case, different types of feeding and different balances of nutrients are used (Panin et al., 2017) even if the specific values of exchange energy are equal. Therefore, it is required to create a model capable of predicting the considered indicators of the efficiency of pig production. Based on the fact that the general principal model of the influence of the amount of exchange energy on the efficiency indicators of pig breeding is preserved, we will model the weight gain of animals, taking into account the correction for the results of updated studies (Figure 3). Knowing the weight gain of fattening animals and the amount of metabolic energy consumed by them, as well as the percentage of feed losses, the value of the correction factor Kw is determined (Figure 3) recalculation of the weight gain chart (Figures 4, 5).

At the same time, losses are important. In the above model, the percentage of losses is indicated as notional values to show the logic of the process and the modeling technique. When conducting an updated experiment, the amount of feed given out and the value of weight gain are known (W=0.86 kg, Figure 3). The percentage of losses is conditionally taken as 2% (Flb1=0.02). Taking into account these losses, the amount of feed consumed by the animal was recalculated with the calculated exchange energy (taken as Ec=30 MJ). If these are the results of production work, then its specific percentages of losses are indicated. If these are the results of trial fattening of a group of animals, then the percentages of losses are indicated (for example, Flb2=0.03 and Flb3=0.05) corresponding to the loss conditions of the intended production (Flp2=0.03; Flp3=0.05; Flp1=0.03). When implementing the model, the calculated values are determined.

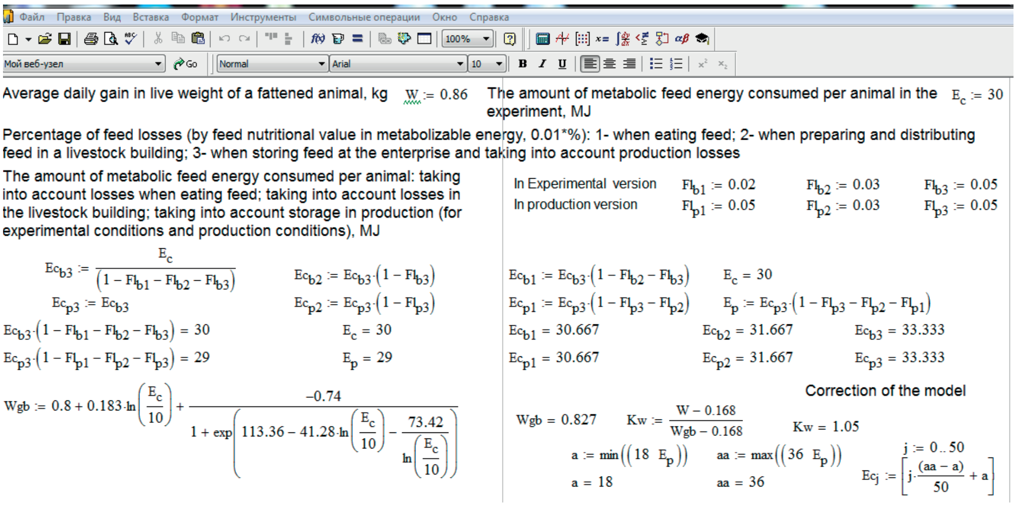

Figure 3. Process modeling (beginning - input of initial data and determination of the correction factor Kw)

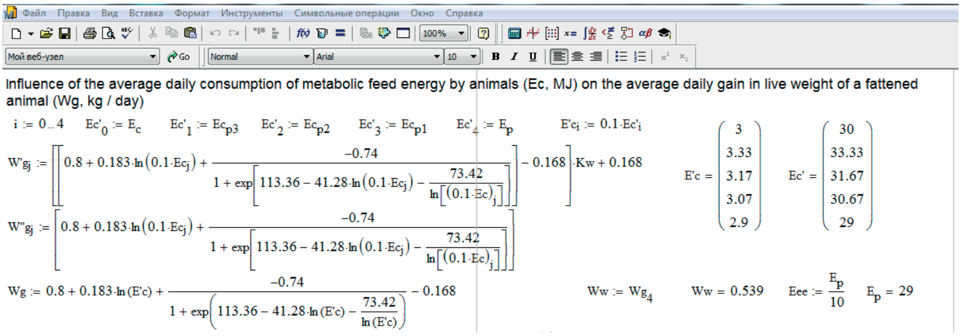

Figure 4. Modeling the process (continuation - calculation of the model to determine the weight gain of animals)

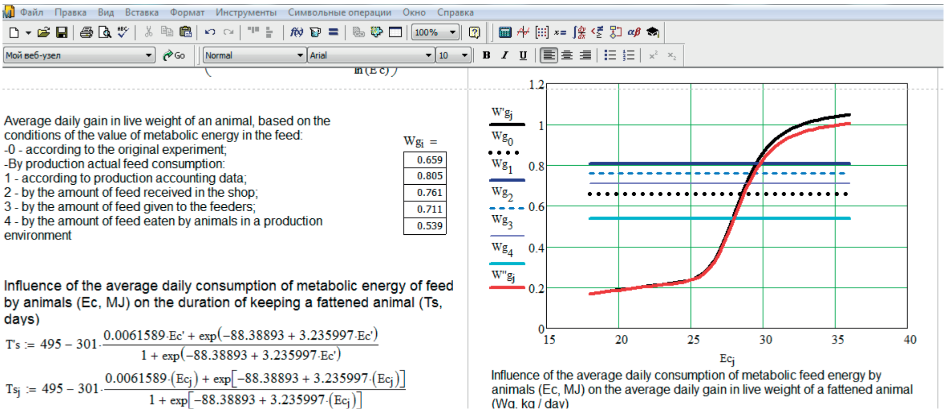

Figure 5. Modeling the process (continued - the graph of animal weight gain and the calculation of the model to determine the duration of rearing)

In Figure 5, the red curve shows the original weight gain model as an analogue of the graph in Figure 1a, and the black curve corresponds to the adjusted calculation model for the updated experiment data. Due to the value of Kw=1.05 (Figure 3), the graph of the calculation model has shifted upwards (Figure 5). Taking into account the percentage of losses, the values of the exchange energy Ec are determined (Figures 4 and 5). Metabolic energy in Figure 4 is given numerically (0 - for the animal in the updated experiment; 1 - according to production records; 2 - according to shop records; 3 - feed given out; 4 - feed consumed), and in the graph of Figure 5, the values are presented in in the form of horizontal lines crossing the weight gain curve of the animal. Due to feed losses, the value of available metabolizable energy decreases, and accordingly the point of intersection with the curve shows a decrease in the expected weight gain. A change in the initial value of the exchange energy of feed based on the results of updated experiments with the same loss values would show a non-linear change in weight gain. The main reference point is the weight gain in terms of the exchange energy of the consumed feed. At the initial value of the exchange energy, the calculated weight gain is Wg = 0.659, and according to the calculation model - 0.539 kg. If we reduce feed losses under production conditions, then we can increase weight gain at the same production costs of feed energy (additional values - 0.805; 0.761; 0.711). In Figure 6, models are implemented for the duration of rearing and specific feed consumption. Based on their values, adjusted graphs were constructed depending on the weight gain of animals, shown in Figure 2. Vertical blue projections on the abscissa (Wg0=0.659 end Wg4=0. 539) the intersection of the thin black horizontal 10·Eb (and the red horizontal 10·Ep) with the blue curve 10·Ec gives indicative values at the points of intersection with the red and black curves (marked with dots in Figure 2) of the specific feed consumption per kilogram of weight gain and duration of cultivation according to the initial and projected options. The interval of the difference between the values of indicators by options (vertically) will show the expected effect of the changes.

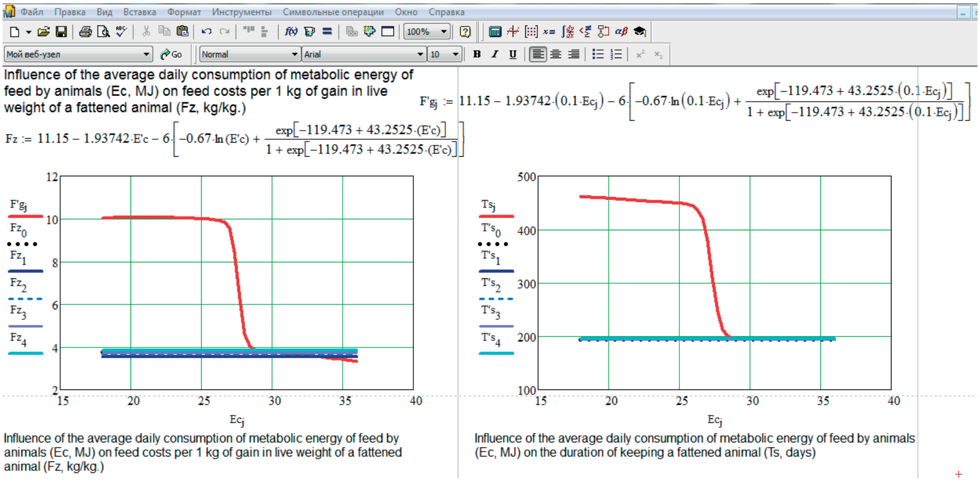

Figure 6. Simulation of the process (end - calculation of the model to determine the specific feed consumption, graphs of the duration of cultivation and specific feed consumption)

CONCLUSIONS

Regression analysis of the known production data on the relationship between the amount of metabolic energy of fattening pigs and the weight gain of pigs, the cost of feed per kilogram of weight gain and the duration of rearing made it possible to obtain adequate functional dependencies of these indicators.

Modeling in the mathematical package MathCAD made it possible to predict the indicated production indicators of the efficiency of raising pigs, taking into account feed losses in the sections of the feed transportation technological chain.

REFERENCES

Angarita, B.K., Han, J., Cantet, R., Wurtz, K.E., Ernst, C.W., & Steibel, J.P. (2021). Estimation of direct and social effects of feeding duration in growing pigs using records from automatic feeding stations. *Journal of animal science*, 99(5). https://doi.org/10.1093/jas/skab042

Baxter, M.R. (1989). Design of new feeder for pigs. *Farm Building Progress,* 96, 19-22.

Bormotov, A., & Gorokhova, A. (2020). Research of the viscosity of unfilled polymers using quality functionals. *IOP Conference Series: Materials Science and Engineering,* 918 (1), 012104. DOI: 10.1088/1757-899X/918/1/012104

Bormotov, A., & Gorokhova, A. (2022). Modeling the Clustering of Dispersed Systems Using Dynamic Models. *Lecture Notes in Civil Engineering*, 180, 61-70. DOI: 10.1007/978-3-030-83917-8_6

Condotta, I.C.F.S., Brown-Brandl, T.M., Stinn, J.P., Rohrer, G.A., Davis, J.D., & Silva-Miranda, K.O. (2018) Dimensions of the Modern Pig. *Transactions of the ASABE*, 61(5):1729-1739 DOI:10.13031/trans.12826

De Quelen, F., Brossard, L., Wilfart, A., Dourmad, J.Y., & Garcia Launay, F. (2021) Eco-Friendly Feed Formulation and On-Farm Feed Production as Ways to Reduce the Environmental Impacts of Pig Production Without Consequences on Animal Performance. front. *Veterinary Sc.*, 06.07.2021 https://doi.org/10.3389/fvets.2021.689012

Ewaoluwagbemiga, E.O., Bee, G., & Kasper, C. (2021) Evaluation of feeding behavior traits to predict efficiency traits in pigs using partial least square regression. *Animal*, 15(10), 100351 https://doi.org/10.1016/j.animal.2021.100351

García-Gudino, J., Blanco Penedo, I., Font-I-furnols, M., Angon, E., & Perea, J.M. (2021). Analysis of the sustainability of fattening systems for iberian traditional pig production through a technical and environmental approach. *Animal,* 11(2),411, p. 1-13https://doi.org/10.3390/ani11020411

He, Y., Tiezzi, F., Howard, J., & Maltecca, C. (2021) Predicting body weight in growing pigs from feeding behavior data using machine learning algorithms. *Computers and Electronics in Agriculture,* 184.106085 https://doi.org/10.1016/ j.compag.2021.106085

Jia, M., Zhang, H., Xu, J., Su, Y., & Zhu, W. (2021). Feeding frequency affects the growth performance, nutrient digestion and absorption of growing pigs with the same daily feed intake. *Livestock Science,* 250. 104558 DOI:10.1016/j.livsci.2021.104558

Kavlak, A.T., Stranden, I., Lidauer, M.H., & Uimari, P. (2021). Estimation of social genetic effects on feeding behavior and production traits in pigs. *Animal,* 15(3), 100168 https://doi.org/10.1016/j.animal.2020.100168

Kil, D.Y., Kim, B.G., & Stein, H.H. (2013). Feed Energy Evaluation for Growing Pigs. *Asian-Australas J Anim Sci.,* 26(9), 1205–1217. doi:10.5713/ajas.2013.r.02

Konovalov, V.V. (2005). *Justification of Technical means of Preparation and Dispensing of Feed in Pig Breeding.* Penza, Russia. ISBN: 5-94338-136-8

Marcos, P., & Covenas, R. (2021) Neuropeptidergic control of feeding: Focus on the galanin family of peptides. *International Journal of Molecular Sciences,* 22(5), 2544, 1-31 doi:10.3390/ijms22052544

Misiura, M.M., Filipe, J.A.N., Brossard, L., & Kyriazakis, I. (2021). Bayesian comparison of models for precision feeding and management in growing-finishing pigs. *Biosystems Engineering,* 211, 205-218.https://doi.org/10.1016/j.biosystemseng.2021.08.027

Monteiro, A.N.T.R., Brossard, L., Gilbert, H., & Dourmad, J.Y. (2021). Environmental Impacts and Their Association With Performance and Excretion Traits in Growing Pigs. *Frontiers in Veterinary Science,* 8, 677857. https://doi.org/10.3389/fvets.2021.677857

Nielsen, B.L., Lawrence, A.B., & Whittemore, C.T. (1996). Feeding behavior of growing pigs using single or multi-space feeders. *Appl. Anim. behavior. sci.,* 47:235-246.

Noblet, J., & Milgen, J. (2004) Energy Value of Pig Feeds: Effect of Pig Body Weight and Energy Evaluation System. *Journal of Animal Science,* 82, E-Suppl (E. Suppl), E229-238 DOI:10.2527/2004.8213_supplE229x

Pomar, C., Andretta, I., & Remus, A. (2021)Feeding Strategies to Reduce Nutrient Losses and Improve the Sustainability of Growing Pigs. *Frontiers in Veterinary Science,* 8, 742220. https://doi.org/10.3389/fvets.2021.742220

Plaksin, I.E., Trifanov, A.V., & Plaksin, S.I. (2021). Theoretical background for a robotic device designed for suckling piglets nursing. *IOP Conference Series: Earth and Environmental Science*, 723(2), 022106. DOI:10.1088/1755-1315/723/2/022106

Razmaite, V., Juska, R., Leikus, R., & Jatkauskienė, V. (2021). Pork quality of two Lithuanian breeds: Effects of breed, gender and feeding regimen. *Animals*, 11(4), 1103. DOI:10.3390/ani11041103

Tronchuk, I.S., Fesina, B.E., & Pochernyaeva, G.M. (1990). *Pig feeding*. Moscow, Russia.