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Original Article

On The Prognosis of Weight Gain in Farm Animals

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Abstract - In this paper, we introduce a model to estimate the increase in the weight of farm animals that depends on several parameters. We introduce an analytical approach for the analysis of the introduced model with account of changes in the above parameters in space and time, as well as taking into account the nonlinearity of the considered process. We consider the possibility of accelerating and decelerating the fattening of farm animals.

Keywords - Fattening of farm animals, Model of fattening, Analytical approach for analysis.

1. Introduction

An analysis of the experience of livestock development shows that in the modern economy, its profitability and competitiveness can be achieved through the use of various technologies, feed, and additives [1-6]. One of the directions of development of the considered technologies may be associated with the use of various stimulating additives. Based on the recent experimental work [1-6], a large amount of experimental experience has been accumulated in the field of cattle breeding. At the same time, it is of interest to forecast the socio-economic effect to take into account the maximum possible number of factors. To do the forecast, it is necessary to formulate an appropriate model. In this paper, we introduce a model to estimate the increase in the weight of farm animals depending on several parameters. We introduce an analytical approach to analyze the introduced model with account changing of parameters of the model in space (inside the animal's body) and time (during the assimilation of food), as well as taking into account the nonlinearity of the considered model. We consider the possibility of accelerating and decelerating the fattening of farm animals.

2. Method of Solution

In this section, we consider a model to estimate and future analysis of the spatio-temporal distribution of concentration of feed in an organism with account of the possibility to take into account changes in conditions of assimilation of the feed. We determined the required spatio-temporal distribution of concentration of feed as a solution of the second law of Fick in the following form

$$\frac{\partial C(x,t)}{\partial t} = \frac{\partial}{\partial x}\left[D(x,T)\frac{\partial C(x,t)}{\partial x}\right] - K(x,T)C(x,t), \quad (1)$$

where $C(x,t)$ is the spatio-temporal distribution of concentration of feed; $D(x, T)$ is the diffusion coefficient of feed (the value of which depends on the condition of the tissues in the body); $K(x, T)$ is the parameter of feed digestibility in the organism of a farm animal; T is the temperature of the organism. The first term on the right side of Equation (1) describes the free transport of feed. The second term on the right side of Equation (1) describes absorption of food by the intestines after preliminary digestion. Initial and boundary conditions for concentration $C(x,t)$ could be written as

$$\left.\frac{\partial C(x,t)}{\partial x}\right|_{x=0} = 0;\ C(L,t)=0;\ C(x,0)=f_C(x). \quad (2)$$

The first boundary condition describes the absence of flow of feed through the mouth to the outside of the animal. The second boundary condition describes the remnants of the animal's feed exiting the body through the intestinal outlet. The initial condition describes the distribution of feed in an animal's organism. This feed distribution can be considered as the feed distribution at the time taken as the reference point, taking into account the previous feedings. We calculate the solution of Equation (1) with conditions (2) by the method of averaging of function corrections [7, 8]. First of all, we transform Equation (1) to the following integral form.

$$C(x,t) = C(x,t) + \frac{1}{L^2}\Big\{\int_0^t\int_0^x D(v,\tau)C(v,\tau)dvd\tau - \int_0^t\int_0^x (x-v)C(v,\tau)\frac{\partial D(v,\tau)}{\partial v}dvd\tau + \int_0^x (x-v)f(v)dv$$

$$-\int_0^t\int_0^x (x-v)K(v,\tau)C(v,\tau)dvd\tau - \int_0^t\int_0^L D(v,\tau)C(v,\tau)dvd\tau + \int_0^t\int_0^L (L-v)C(v,\tau)\frac{\partial D(v,\tau)}{\partial v}dvd\tau$$

$$-\int_0^x (x-v)C(v,t)dv + \int_0^L (L-v)C(v,t)dv\Big\}. \quad (3)$$

In the framework of the method of averaging of function corrections, we replace the required concentration with its not yet known average value α_1) on the right side of Equation (3). The replacement gives a possibility to obtain the first-order approximation of the considered feed in the following form,

$$C_1(x,t) = \alpha_1 + \frac{1}{L^2}\left[\int_0^x (x-v)f(v)dv - \alpha_1\int_0^t\int_0^x (x-v)K(v,\tau)dvd\tau + \alpha_1\frac{L^2-x^2}{2}\right]. \quad (4)$$

Average value α_1 was calculated by the following standard relation [7, 8].

$$\alpha_1 = \frac{1}{L\Theta}\int_0^\Theta\int_0^L C_1(x,t)dxdt. \quad (5)$$

Substitution of relation (4) into relation (5) gives a possibility to obtain the appropriate relation to determine the average value α_1 in the final form,

$$\alpha_1 = \frac{\Theta\int_0^L (L^2-x^2)f(x)dx}{\int_0^\Theta (\Theta-t)\int_0^L (L^2-x^2)K(x,t)dxdt - 2\int_0^\Theta (\Theta-t)\int_0^L x(L-x)K(x,t)dxdt - \frac{2}{3}\Theta L^3}. \quad (6)$$

The second-order approximation of the required concentration of feed in the framework of the method of averaging of function corrections was obtained by using standard replacement of the considered concentration in the right side of equation (3) on the following sum: $C(x,t)\to\alpha_2+C_1(x,t)$ [7, 8]. The replacement gives a possibility to obtain the following relation to determine the required approximation of the considered concentration.

$$C_2(x,t) = \alpha_2 + C_1(x,t) + \frac{1}{L^2}\Big\{\int_0^t\int_0^x D(v,\tau)[\alpha_2 + C_1(v,\tau)]dvd\tau - \int_0^t\int_0^x (x-v)[\alpha_2 + C_1(v,\tau)]\frac{\partial D(v,\tau)}{\partial v}dvd\tau -$$

$$\int_0^t\int_0^x (x-v)\times K(v,\tau)[\alpha_2 + C_1(v,\tau)]dvd\tau + \int_0^L (L-v)[\alpha_2 + C_1(v,t)]dv + \int_0^t\int_0^L (L-v)[\alpha_2 +$$

$$C_1(v,\tau)]\frac{\partial D(v,\tau)}{\partial v}dvd\tau - \int_0^t\int_0^L D(v,\tau)\times[\alpha_2 + C_1(v,\tau)]dvd\tau + \int_0^x (x-v)f(v)dv - \int_0^x (x-v)[\alpha_2 +$$

$$C_1(v,t)]dv\Big\}. \quad (7)$$

Average value α_2 of the second-order approximation of the required concentration of the considered feed was determined by using the following standard relation [7, 8].

$$\alpha_2 = \frac{1}{L\Theta}\int_0^{\Theta}\int_0^L [C_2(x,t) - C_1(x,t)]dxdt. \tag{8}$$

Substitution of the relation (7) into the relation (8) gives a possibility to obtain the following relation to determine the required average value α_2.

$$\alpha_2 = \Big[\frac{1}{2}\int_0^{\Theta}(\Theta - t)\int_0^L (L+x)^2 C_1(x,t)\frac{\partial D(x,t)}{\partial x}dxdt - \int_0^{\Theta}(\Theta - t)\int_0^L (x-v)D(x,t)C_1(x,t)dxdt + 2\int_0^{\Theta}(\Theta - t)\int_0^L x^2\frac{\partial D(x,t)}{\partial x}\times C_1(x,t)dxdt - \frac{1}{2}\int_0^{\Theta}(\Theta - t)\int_0^L (L+x)^2 K(x,t)C_1(x,t)dxdt - 2\int_0^{\Theta}(\Theta - t)\int_0^L x^2 K(x,t)C_1(x,t)dxdt - \frac{1}{2}\int_0^{\Theta}(\Theta - t)\int_0^L (L^2 - x^2)\times C_1(x,t)\frac{\partial D(x,t)}{\partial x}dxdt - L\int_0^{\Theta}\int_0^L (L-x)C_1(x,t)dxdt - \int_0^{\Theta}\int_0^L x(L-x)f(x)dxdt + L\int_0^{\Theta}(\Theta - t)\int_0^L (L-x)D(x,t)C_1(x,t)dxdt + \frac{1}{2}\int_0^{\Theta}(\Theta - t)\int_0^L (L^2 + x^2)D(x,t)C_1(x,t)dxdt + 2\int_0^{\Theta}(\Theta - t)\int_0^L x^2 C_1(x,t)D(x,t)dxdt\Big]\Big[\int_0^{\Theta}(\Theta - t)\int_0^L (x-v)D(x,t)dxdt - \frac{1}{2}\int_0^{\Theta}(\Theta - t)\int_0^L (L+x)^2\frac{\partial D(x,t)}{\partial x}dxdt + 2\int_0^{\Theta}(\Theta - t)\int_0^L x^2 K(x,t)dxdt + 2\int_0^{\Theta}(\Theta - t)\int_0^L x^2\frac{\partial D(x,t)}{\partial x}dxdt + \int_0^{\Theta}(\Theta - t)\int_0^L (L+x)^2\times\frac{1}{2}K(x,t)dxdt + \frac{\Theta^2 L^3}{4}\Big]^{-1} \tag{9}$$

The second term in the Equation (1) describes the mass of digested feed. To determine the value of the mass, we transform Equation (1) to the following integro-differential form.

$$\int_0^x C(v,t)dv = \int_0^t D(x,T)\frac{\partial C(x,\tau)}{\partial x}d\tau - \int_0^t\int_0^x K(v,T)C(v,\tau)dvd\tau + \int_0^x f_C(v)dv. \tag{10}$$

The limit passage $x \to L$ gives a possibility to obtain a relation to determine the value of different masses of feed: initial mass of feed, mass of digested feed, and mass of not digested feed. Mass of not digested feed could be written as:

$$M(t) = \int_0^L f_C(x)dx - \int_0^t\int_0^L K(x,T)C(x,\tau)dxd\tau. \tag{11}$$

Substitution of relation (9) into relation (11) gives a possibility to obtain a relation to determine the mass of not digested feed in the following final form.

$$M_2(t) = \alpha_2\int_0^t\int_0^L K(x,T)dxd\tau + \int_0^t\int_0^L K(x,T)C_1(x,\tau)dxd\tau + \frac{1}{L^2}\int_0^t (t-\tau)\int_0^L (L-x)K(x,T)D(x,\tau)[\alpha_2 + C_1(x,\tau)]dxd\tau + \frac{1}{2L^2}\int_0^t (t-\tau)\int_0^L K(x,T)(L^2 - x^2)[\alpha_2 + C_1(x,\tau)]\frac{\partial D(x,\tau)}{\partial x}dxd\tau - \frac{1}{L}\int_0^t\int_0^L K(x,T)(L-x)[\alpha_2 + C_1(x,\tau)]\frac{\partial D(x,\tau)}{\partial x}dx\times(t-\tau)d\tau - \frac{1}{2L^2}\int_0^t (t-\tau)\int_0^L K(x,T)(L^2 - x^2)f(x)dxd\tau + \frac{1}{L}\int_0^t (t-\tau)\int_0^L (L-x)K(x,T)f(x)dxd\tau + \frac{1}{2L^2}\int_0^t (t-\tau)\times\int_0^L K^2(x,T)(L^2 - x^2)[\alpha_2 + C_1(x,\tau)]dxd\tau - \frac{1}{L}\int_0^t (t-\tau)\int_0^L (L-x)[\alpha_2 + C_1(x,\tau)]K^2(x,T)dxd\tau + \frac{1}{L^2}\int_0^x K(v,T)dvd\tau\int_0^t\int_0^L (L-x)\times[\alpha_2 + C_1(x,\tau)]dx - \frac{1}{L^2}\int_0^t (t-\tau)\int_0^L [\alpha_2 +$$

$$C_1(x,\tau)]D(x,\tau)dx\int_0^L K(x,T)dx\,d\tau+\int_0^t(t-\tau)\int_0^L(L-x)[\alpha_2+C_1(x,\tau)]\frac{\partial D(x,\tau)}{\partial x}dx\times\frac{1}{L^2}\int_0^L K(x,T)dxd\tau-$$
$$\frac{1}{L}\int_0^t\int_0^L(L-x)K(x,T)[\alpha_2+C_1(x,t)]dxd\tau+\frac{1}{2L^2}\int_0^L(L^2-x^2)\int_0^t K(x,T)[\alpha_2+C_1(x,t)]dtdx \quad (12)$$

Mass of digested feed is the other mass of feed. Part of the considered mass of feed is spent on the current needs of the considered organism. Another part of this mass of food is spent on increasing the body weight of the considered organism. Spatio-temporal distribution of concentration of the considered feed was analyzed analytically by using the second-order approximation in the framework of the method of averaging of function corrections. The approximation is usually good enough to make qualitative analysis and to obtain some quantitative results. All obtained results have been checked by comparison with the results of numerical simulations.

3. Discussion

In this paper, we analyzed the increase in the weight of farm animals depending on several parameters. Figures 1 and 2 show typical dependences of the considered growth of the weight of farm animals on the mass of feed m, which was entered into the organism of the considered animal. In Figure 1, an increase in the number of curves corresponds to an increase in the diffusion coefficient of feed in the farm animal organism. In Figure 2, the Figure 2 increasing of number of curves corresponds to an increase in the parameter of feed digestibility in farm animal organisms.

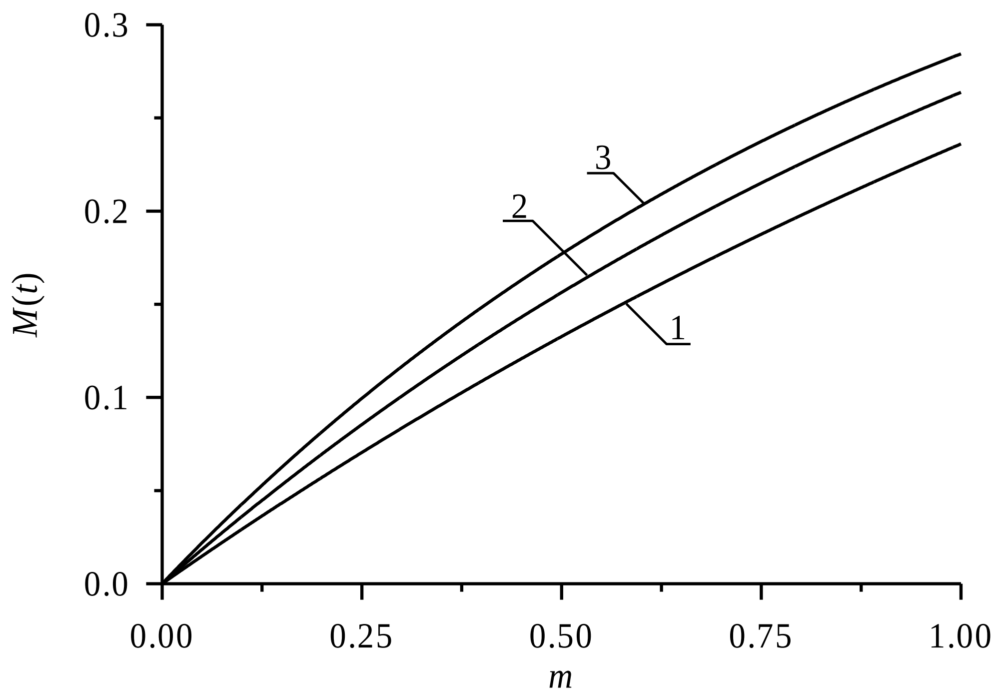

Fig. 1 Typical dependences of the considered growth of the weight of farm animals on the mass of feed m, which was entered into the organism of the considered animal. An increase in the number of curves corresponds to an increase in the diffusion coefficient of feed in the farm animal organism.

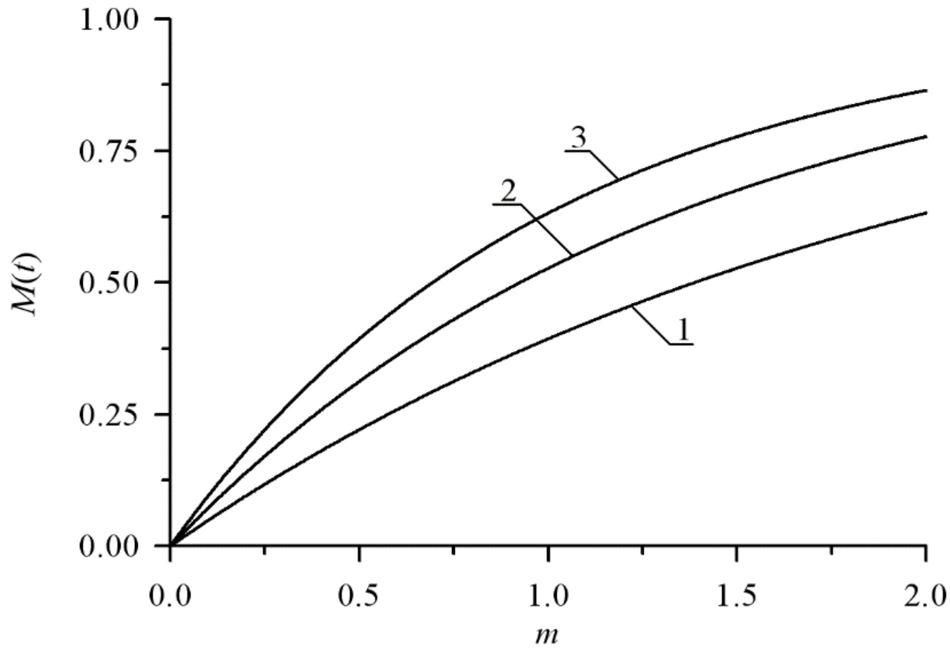

Fig. 2 Typical dependences of the considered growth of the weight of farm animals on the mass of feed *m*, which was entered into the organism of the considered animal. An increase in the number of curves corresponds to an increase in the parameter of feed digestibility in farm animal organisms.

4. Conclusion

We introduced and tested a model to estimate the increase in the weight of farm animals that depends on several native parameters. We introduce an analytical approach for the analysis of the introduced model with account of changing the above parameters in space and time, as well as taking into account the nonlinearity of the considered process. We formulate conditions to accelerate and decelerate the fattening of farm animals.

Data Availability

All appropriate data are available.

Conflicts of Interest

No conflicts of interest.

Funding Statement

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Authors' Contributions

All results of this paper are the results of this author.

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