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RESEARCH ARTICLE

On Model of Weight Gain of Farm Animals

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ABSTRACT

In this paper, we introduce a model to estimate increasing of weight of farm animals depending on several 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 consider the possibility to accelerate and decelerate of the fattening of farm animals.

Key words: Analytical approach for analysis, fattening of farm animals, model of fattening

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. At the same time, it is of interest to forecast the socio-economic effect to take into account the maximum possible number of factors. In this paper, we introduce a model to estimate increasing of 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. We consider the possibility to accelerate and decelerate of the fattening of farm animals.

METHOD OF SOLUTION

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

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

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where $C(x,t)$ is the spatio-temporal distribution of concentration of feed; $D(x,T)$ is the diffusion of 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 organism. Initial and boundary conditions for concentration $C(x,t)$ could be written as:

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

We calculate the solution of equation (1) with conditions (2) by the method of averaging of function corrections.[7-9] First of all, we transform equation (1) to the following integral form:

$$\begin{aligned} C(x,t) = C(x,t) + \frac{1}{L^2}\Bigg\{ &\int_0^t\int_0^x D(v,\tau)\, C(v,\tau)\, d\,v\, d\,\tau - \int_0^t\int_0^x (x-v) C(v,\tau) \frac{\partial D(v,\tau)}{\partial v} d\,v\, d\,\tau \\ &+ \int_0^x (x-v) f(v)\, d\,v - \int_0^t\int_0^x (x-v) K(v,\tau)\, C(v,\tau)\, d\,v\, d\,\tau - \int_0^t\int_0^L D(v,\tau) C(v,\tau)\, d\,v\, d\,\tau \\ &- \int_0^x (x-v)\, C(v,t)\, d\,v + \int_0^L (L-v)\, C(v,t)\, d\,v + \int_0^t\int_0^L (L-v) C(v,\tau) \frac{\partial D(v,\tau)}{\partial v} d\,v\, d\,\tau \Bigg\} \end{aligned} \tag{3}$$

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

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

Average value α_1 was calculated by the following standard relation:[7-9]

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

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:

$$\alpha_1 = \frac{\Theta\int_0^L \left(L^2 - x^2\right) f(x)\, d\,x}{\int_0^\Theta (\Theta - t)\int_0^L \left(L^2 - x^2\right) K(x,t)\, d\,x\, d\,t - 2\int_0^\Theta (\Theta - t)\int_0^L x(L-x) K(x,t)\, d\,x\, d\,t - \frac{2}{3}\Theta L^3} \tag{6}$$

The second-order approximation of the required concentration of feed in the framework of the method of averaging of function corrections was obtained using the standard replacement of the considered concentration in the right side of equation (3) with the following sum: $C(x,t) \rightarrow \alpha_2 + C_1(x,t)$.[7-9] The replacement gives a possibility to obtain the following relation to determine the required approximation of the considered concentration.

$$C_2(x,t)=\alpha_2+C_1(x,t)+\frac{1}{L^2}\left\{\int_0^t\int_0^x D(v,\tau)\left[\alpha_2+C_1(v,\tau)\right]d\,v\,d\,\tau-\int_0^t\int_0^x (x-v)\left[\alpha_2+C_1(v,\tau)\right]\right.$$
$$\times\frac{\partial D(v,\tau)}{\partial v}d\,v\,d\,\tau-\int_0^t\int_0^x (x-v)K(v,\tau)\left[\alpha_2+C_1(v,\tau)\right]d\,v\,d\,\tau+\int_0^L (L-v)\left[\alpha_2+C_1(v,t)\right]d\,v \tag{7}$$
$$-\int_0^t\int_0^L D(v,\tau)\left[\alpha_2+C_1(v,\tau)\right]d\,v\,d\,\tau+\int_0^t\int_0^L (L-v)\left[\alpha_2+C_1(v,\tau)\right]\frac{\partial D(v,\tau)}{\partial v}d\,v\,d\,\tau$$
$$\left.+\int_0^x (x-v)f(v)\,d\,v-\int_0^x (x-v)\left[\alpha_2+C_1(v,t)\right]d\,v\right\}$$

Average value α_2 of the second-order approximation of the required concentration of the considered feed was determined using the following standard relation.[7-9]

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

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.

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

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:

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

The limit passage $x \to L$ gives a possibility to obtain relation gives a possibility to obtain 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:

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

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:

$$\begin{aligned}M_2(t)&=\alpha_2\int_0^t\int_0^L K(x,T)\,d\,x\,d\,\tau+\int_0^t\int_0^L K(x,T)\,C_1(x,\tau)\;d\,x\,d\,\tau+\frac{1}{L^2}\int_0^t\int_0^L(L-x)\,K(x,T)\,D(x,\tau)\times\\
&\times\left[\alpha_2+C_1(x,\tau)\right]d\,x\,(t-\tau)\,d\,\tau+\frac{1}{2L^2}\int_0^t\int_0^L K(x,T)\left(L^2-x^2\right)\left[\alpha_2+C_1(x,\tau)\right]\frac{\partial D(x,\tau)}{\partial x}\,d\,x\\
&\times(t-\tau)\;d\,\tau-\frac{1}{L}\int_0^t(t-\tau)\int_0^L K(x,T)(L-x)\left[\alpha_2+C_1(x,\tau)\right]\frac{\partial D(x,\tau)}{\partial x}\,d\,x\,d\,\tau-\frac{1}{2L^2}\int_0^t(t-\tau)\\
&\times\int_0^L K(x,T)\left(L^2-x^2\right)f(x)\;d\,x\,d\,\tau+\frac{1}{L}\int_0^t(t-\tau)\int_0^L(L-x)\;K(x,T)\,f(x)\;d\,x\,d\,\tau+\frac{1}{2L^2}\int_0^t(t-\tau)\\
&\times\int_0^L K^2(x,T)\left(L^2-x^2\right)\left[\alpha_2+C_1(x,\tau)\right]d\,x\,d\,\tau-\int_0^t(t-\tau)\int_0^L(L-x)\left[\alpha_2+C_1(x,\tau)\right]K^2(x,T)\;d\,x\,d\,\tau\\
&\times\frac{1}{L}+\frac{1}{L^2}\int_0^t\int_0^L(L-x)\left[\alpha_2+C_1(x,\tau)\right]d\,x\int_0^x K(v,T)\,d\,v\,d\,\tau-\int_0^t(t-\tau)\int_0^L\left[\alpha_2+C_1(x,\tau)\right]D\;(x,\tau)\;d\,x\\
&\times\frac{1}{L^2}\int_0^L K(x,T)\,d\,x\;d\,\tau+\frac{1}{L^2}\int_0^t(t-\tau)\int_0^L(L-x)\left[\alpha_2+C_1(x,\tau)\right]\frac{\partial D(x,\tau)}{\partial x}\,d\,x\int_0^L K(x,T)\,d\,x\,d\,\tau\\
&-\frac{1}{L}\int_0^t\int_0^L(L-x)\,K(x,T)\left[\alpha_2+C_1(x,t)\right]\,d\,x\,d\,\tau+\frac{1}{2L^2}\int_0^L\int_0^t K(x,T)\left[\alpha_2+C_1(x,t)\right]d\,t\times\left(L^2-x^2\right)d\,xs\end{aligned} \tag{12}$$

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 using the second-order approximation in the framework of the method of averaging of function corrections. The approximation is usually good enough for qualitative analysis and to obtain some quantitative results. All obtained results have been checked by comparison with the results of numerical simulations.

DISCUSSION

In this paper, we analyzed increasing of weight of farm animals in dependence 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. As shown in Figure 1, increasing of number of curves corresponds to increasing of diffusion coefficient of the feed in the farm animal organism. As shown in Figure 2, increasing of number of curves corresponds to increasing of parameter of feed digestibility in farm animal organisms.

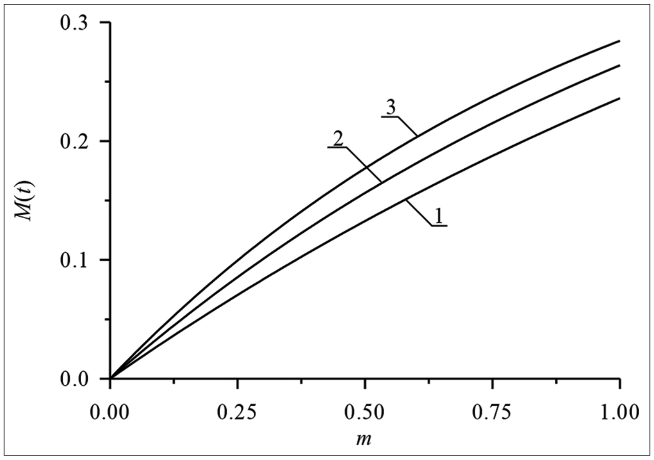

Figure 1: Typical dependences of the considered growth of the weight of farm animals on mass of feed *m*, which was entered into organism of the considered animal. Increasing of number of curve corresponds to increasing of diffusion coefficient of feed in farm animal organism

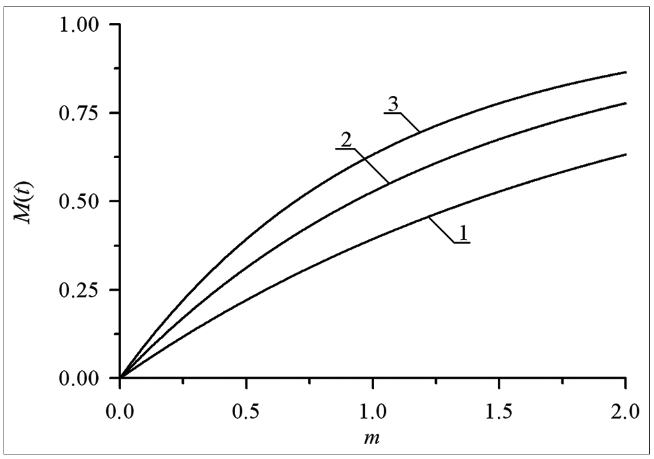

Figure 2: Typical dependences of the considered growth of the weight of farm animals on mass of feed *m*, which was entered into organism of the considered animal. Increasing of number of curve corresponds to increasing of parameter of feed digestibility in farm animal organism

CONCLUSION

We introduced and tested a model to estimate increasing of weight of farm animals depending 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.

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