COMPUTER - ASSISTED SIMULATION OF THE METABOLIC PROCESSES IN PIGS

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Abstract

The paper presents a mathematical model for calculating the rules of energy and protein in growing pigs and fattening. Were used functions and parameters in the literature (Whittemore, 1993; Kyriazakis and Emmans, 1992), including our results. Based on this model is shown a procedure for calculating the feed rations

Key words: mathematical modelling, pig metabolic processes, computer simulation, energy requirement, protein requirement

INTRODUCTION

The method of mathematical modelling of the metabolic processes offers the possibility to assess feed allowances in their evolution, related both to the growth rate and to carcass quality. This paper presents an approach of this issue.

Because for a given weight gain the quality of this gain is included in an interval ($\min\frac{Lr}{Pr} \le \frac{Lr}{Pr} \le \max\frac{Lr}{Pr}$, where Lr = daily retained lipids and Pr = daily retained protein), it results that feed allowance will be expressed as intervals of the form [$norm_{min}$, $norm_{max}$]. We obtain thus an infinity of possible values for the feed allowance.

The choice of one possible value or of another one depends on the used raising technology, on the purpose of growing expressed in economic terms and/or in terms of a human-friendly food. In the present paper, besides the modality of calculating the intervals for the energy and protein allowance we shall also present formulas which, in our opinion, characterise a physiological evolution of the weight gain and of the lipid/protein ratio of the carcass.

MATERIAL AND METHOD

The following parameters should be taken into consideration when calculating the energy and protein requirements:

- body weight (W, g);
- intended final body weight (ΔW, g);
- ratio between the lean gain (protein+water) and the retained protein (α);
- ratio between the daily retained fat and protein ($\frac{Lr}{Pr} = \beta$);
- ratio between the daily gain of ash and protein ($\frac{Ashr}{Pr} = \gamma$);
- biological value of the diet (BV);
- environmental temperature (Ta);

digestible energy per kg DM of diet (MJ/kg DM).

The body weight [kg], function of the age, is calculated with a Gompertz-type equation:

$$G = A \times e^{e^{B\left(t - t^{x}\right)}} \text{ [kg]} \qquad (1)$$

where:

A = body weight at maturity
B = growth coefficient
t = age in days
t^x = inflexion point, i.e. the time in days when maximum gain is achieved

The net weight, *Gn* can be estimated with the formula:

$$Gn = G/1{,}05 \text{ [kg]} \qquad (2)$$

and the net weight gain *ΔGn* is the sum of *Pr (retained protein), Lr (retrained lipids), Cen_r (retained ash)* and *Ar (retained water)*.

The values of *Pr*, were calculated with the following formula:

$$Pr = B \times Pt \times \ln\left(\frac{\hat{Pt}}{Pt}\right) \quad [kg] \qquad (3)$$

where *Pt*, kg is given by the formula:

$$Pt = \hat{Pt} \times e^{e^{B\left(t-t^{x}\right)}} \quad [kg] \qquad (4)$$

Tip	Sex	B	$P\hat{t}$ [Kg]	Pr [Kg]	(Lr/Pr)min
Gospodăresc	M	0,0105	37,5	0,145	0,9
	F	0,0100	35,0	0,120	1,1
	C	0,0095	34,5	0,114	1,2
Comercial	M	0,0115	42,5	0,180	0,7
	F	0,0110	40,0	0,162	0,9
	C	0,0105	37,5	0,145	1,0
Elita	M	0,0125	47,5	0,218	0,5
	F	0,0120	45,0	0,199	0,7
	C	0,0115	42,5	0,180	0,8
Superelita	M	0,0135	52,5	0,261	0,4
	F	0,0130	50,0	0,239	0,5
	C	0,0125	47,5	0,218	0,6

The daily lipid gain *Lr* was calculated from *Lr/Pr* ratio.

$$Lr = Lr/Pr \times Pr \ [kg] \qquad (5)$$

where *Lr/Pr* has been calculated differently for the males, females and castrated pigs, according to their age (Burlacu et al., 1996):

For growing boars:

$$Lr/Pr = e^{-0,935 \ -0,0288t \ +0,000826t^{2} \ -0,00000616t^{3} + 0,000000015t^{4}} \qquad (6)$$

For gilts:

$$Lr/Pr = e^{-2,633 + 0,08t \ -0,00142t^{2} + 0,0000154t^{3} \ -0,0000000793t^{4} + 0,0000000001513t^{5}} \qquad (7)$$

For the castrated pigs:

$$Lr/Pr = e^{-2,074 + 0,06364t \ -0,001317t^{2} + 0,0000168t^{3} \ +0,0000000977t^{4} + 0,0000000000206t^{5}} \qquad (8)$$

The daily retained water and ash (Ar + Cenr) are calculated with the formula:

$$Ar + Cenr = \frac{Ar + Cenr}{Pr} \times Pr \quad [kg] \qquad (9)$$

where $\frac{Ar + Cenr}{Pr}$ has the following values:

For growing boars and castrated pigs:

$$\frac{Ar + Cenr}{Pr} = e^{2,739 - 0,0434t + 0,000421t^{2} - 0,000001325t^{3}} \qquad (10)$$

For gilts**:**

$$\frac{Ar + Cenr}{Pr} = 37{,}423 \times e^{-\frac{t}{10{,}703}} + 4{,}154 \times e^{-\frac{t}{744{,}84}} \quad (11)$$

The net weight *Gn*, ([Kg] at the age *t* + 1) = Gn + (ΔGn at moment *t)*, where initial *t* = 35 days, and initial *Gn* = 9.5 Kg for all sexes and categories.

B) Estimation of *EM* norms

EM = EMm + EPr + ELr + Q' [MJ/day] (12)

For the calculation of:

EMm = requirement of metabolisable energy for maintenance [MJ/day]
EPr = requirement of metabolisable energy for body protein synthesis [MJ/ day]
ELr = requirement of metabolisable energy for body lipids synthesis [MJ/ day]

The following formulas are to be used:

$EMm = 1{,}75 \times Pt^{0{,}75}$ [MJ/ day] (13)

$EPr = 54{,}6 \times Pr$ [MJ/ day] (14)

$ELr = 53{,}3 \times Lr,$ [MJ/ day] (15)

where: Lr (lipid gain in kg.) = 1.1 $Pr^{0.07} \times Pr$

C) Estimation of the norms for available protein and limiting amino acids

PA = Pm + Pr : 0.813 [kg] (16)
where:
Pm (net protein for maintenance)

$Pm = 0{,}04 \text{ x } Pt$, [kg] (17)

P_r = gain of body protein [kg] 0.813 is the output of PA use for Pr

- requirement of lysine = PA x 70, [g] (18)
- requirement of met. + cys.=PA x 40, [g] (19)
- requirement of triptophan = PA x 15, [g] (20)
- requirement of threonine = PA x 45, [g] (21)

THE DIETS CALCULATION

We are often confronted in practice with situations when feeding is limited. In this situation (restricted feeding) we use a different way of calculation; following is the procedure for energy and amino acid requirement calculation:

Input data: Body age: *G* [kg]
Average daily gain: *ΔG* [kg]
Age: *t* [days]

Parameters: B, Pt, Pr, t^* - with the values and significance shown above.

Stage I: Calculation of the requirement for metabolisable energy and protein corresponding to the minimal *Lr/Pr* ratio.

The value of $\frac{Lr}{Pr}$ min ratio was calculated on the basis of the experimental results:

$$\frac{Lr}{Pr}\min = a + \frac{b}{1 + e^{-\frac{t-c}{d}}} \quad (22)$$

where for the castrated pigs we used the values:

a = 0.677; b = 1.95; c = 148; d = 23.63

The amount of retained protein is given in this case by:

$$Pr = \frac{\Delta G}{1{,}05\left(1 + \frac{Lr}{Pr}\min + \frac{Ar + Cenr}{Pr}\right)} \text{ [kg]}$$

where:

ΔG - average daily gain [kg]

The above formulas are to be used for $\frac{Ar + Cenr}{Pr}$ Pt, Pm, PA, EMm, EPr, Lr, ELr, EM, LizD, M+CD, TRID, TREONINAD.

REMARK 1: Obviously, the important measures in determining the requirement of energy and protein, with this system of calculation, are: the metabolisable energy *EM* and the available protein *PA*.

The two stages of calculation presented above show one more fact, maybe striking at first sight, but perfectly justified physiologically: for restricted feeding and weight gains lower than the maximal ones the existence of variable values for *Lr/Pr* ratio.

$$\frac{Lr}{Pr} \in \left[\frac{Lr}{Pr}\min; \frac{Lr}{Pr}\max \right]$$

Involves the existence of norms belonging to intervals:

$$EM \in [EM_{min};\ EM_{max}]$$
$$PA \in [PA_{min}; PA_{max}]$$

In other words, for a fixed daily weight gain, for each value of $\frac{Lr}{Pr}$ there is a distinct norm of energy and protein.

The graphic presentation of Observation 1 is as follows:

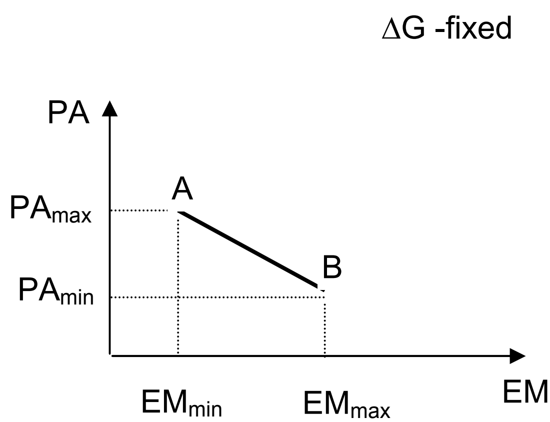

Fig. 1

Any pair *EM, PA* from segment *AB* represent pertinent values allowing achieving the set weight gain.

Obviously, each time the quality indicator given by the *Lr/Pr* ratio will be different.

REMARK 2: It may be readily observed that the protein norms evaluated with the system presented here eliminate the value of the digestible protein. However, diet optimization involves the essential use of an equation with *PBD* (digestible crude protein).

The connection between *PBD* and *PA* is given by the biological value of the diet:

$$VB = \frac{PA}{PBD} \Rightarrow PBD = \frac{PA}{VB}, \qquad 0 < VB < 1$$

As *VB* can not be known beforehand, it results that the norm of *PBD* depends on the nature and structure of the raw diet ingredients; since the value of *PBD* is no longer unique, it can no longer be used traditionally in the "tables of norms" even though diet optimisation is still done at the level of the digestible nutrients.

Stage II. Calculation of the requirement for metabolisable energy and protein, corresponding to the maximal *Lr/Pr* ratio.

We calculate the maximum intake of metabolisable energy:

$$EM_{max} = 44\left(1 - e^{-0,0204G}\right) \quad [MJ]$$

We calculate the maximum amount of retained protein with the formula:

$$Pr_{max} = B \cdot Pt \cdot \ln \frac{\hat{P}t}{Pt}$$

With the formula

$$EPr = 54{,}6 \times Pr \quad \text{[MJ/day]}$$

we compute the energy required to retain the protein corresponding to *Pr* max.

We calculate the energy required to retain the lipids:

$$ELr = EM_{max} - EM_m - EPr - Q' \quad \text{[MJ]}$$

Hence the maximal amount of retained lipids:

$$Lr_{max} = \frac{ELr}{53{,}3} \quad \text{[kg]}$$

Thus, we obtained the maximal ratio retained lipids to retained protein:

$$\frac{Lr}{Pr}max = \frac{Lr_{max}}{Pr_{max}}$$

Further, we use the same procedure as in **stage I** starting with the calculation of *Pr* inclusive.

Figure 2 shows the dependence of *PBD* requirement function of the biological value of the diet.

PA - given

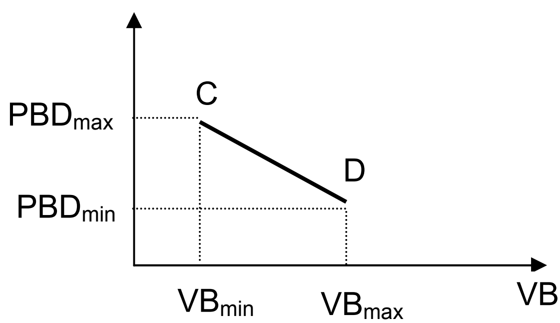

Fig. 2

Figure 3 shows the dependence of *PBD* requirement function of the available protein.

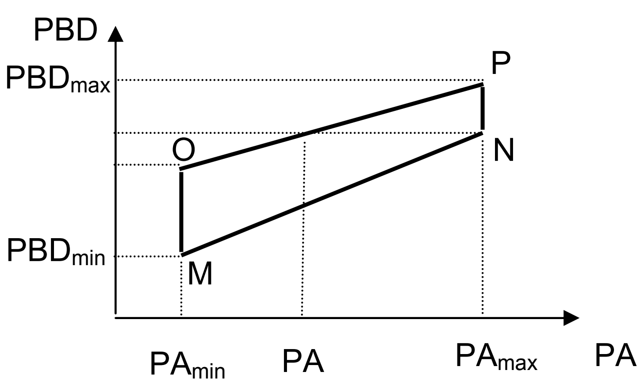

Fig. 3

Figure 4 shows the relation between *EM* and *PBD*.

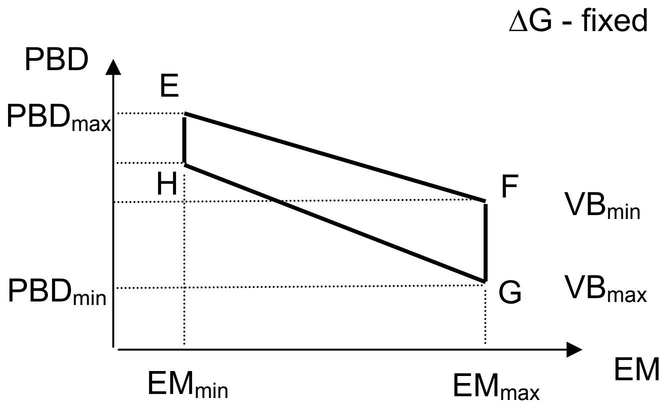

Fig. 4

Any point on *EFGH* trapezium is a norm expressed in *EM, PBD* for the set Δ*G.*

The existence of an area *EFGH* for the requirement of *EM* and *PBD* is due to the two parameters $\frac{Lr}{Pr} \in \left[Lr/Pr\ min, \frac{Lr}{Pr} max \right]$ and VB ∈ [VBmin, VBmax].

REMARK 3: For simplification, the tables may show the average values for *EM* and *PA* (and therefore for the amino acids too).

$$EM_{tabel} = \frac{EM_{max} + EM_{min}}{2}$$

$$PA_{tabel} = \frac{PA_{max} + PA_{min}}{2}$$

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