

ACHIEVEMENT, TESTING AND EVALUATION A MATHEMATICAL MODEL TO OPTIMIZE SWINE NUTRITION

R. BURLACU, C. NIȚU, Ioana RĂDULESCU

University of Agronomic Science and Veterinary Medicine of Bucharest, 59 Marasti, District 1, code 11464, e-mail: Radu.Burlacu@fifim.ro

Corresponding author email: radu.burlacu@fifim.ro

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, Kyriazakis and Emmans), including our results. Based on this model is shown a procedure for calculating the feed rations. 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 of a given weight gain the quality of this gain is included in an interval $(\min \frac{Lr}{Pr} \leq \frac{Lr}{Pr} \leq \max \frac{Lr}{Pr})$, 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.

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

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:

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

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:

$$Gn = G/1,05 \quad [kg] \quad (2)$$

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:

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

where Pt , kg is given by the formula:

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

Table 1. The following parameters

Type	Sex	B	P t [Kg]	Pr [Kg]	(Lr/Pr) min
Familiar	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
Comercia l	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
Elite	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
Supereelit e	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 L_r was calculated from L_r/Pr ratio.

$$L_r = L_r/Pr \times Pr \text{ [kg]} \quad (5)$$

For growing boars:

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

For gilts:

$$L_r/Pr = e^{-2,633 + 0,08t - 0,00142t^2 + 0,0000154t^3 - 0,0000000793t^4 + 0,000000001513t^5} \quad (7)$$

For the castrated pigs:

$$L_r/Pr = e^{-2,074 + 0,06364t - 0,001317t^2 + 0,0000168t^3 + 0,0000000977t^4 + 0,00000000206t^5} \quad (8)$$

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

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

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

For growing boars and castrated pigs:

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

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 $t + 1$) = $Gn + (\Delta Gn$ at moment t), where initial $t = 35$ days, and initial $Gn = 9.5$ Kg for all sexes and categories.

B) Estimation of EM norms

$$EM = EMm + EPr + ELr + Q' \text{ [MJ/day]} \quad (12)$$

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:

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

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

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

where: L_r (lipid gain in kg.) = $1.1 Pr^{0,07} \times Pr$

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

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

$$PA = Pm + Pr : 0.813 \text{ [kg]} \quad (16)$$

where:

Pm (net protein for maintenance)

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

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

- requirement of lysine = $PA \times 70$, [g] (18)

- requirement of met. + cys. = $PA \times 40$, [g] (19)

- requirement of triptophan = $PA \times 15$, [g] (20)

- requirement of threonine = $PA \times 45$, [g] (21)

RESULTS AND DISCUSSIONS

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:

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

where:

$$\Delta G - \text{average daily gain} \quad [\text{kg}]$$

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:

$$\begin{aligned} EM &\in [EM_{\min}; EM_{\max}] \\ PA &\in [PA_{\min}; PA_{\max}] \end{aligned}$$

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:

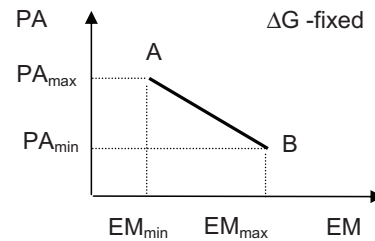


Fig. 1. The graphic presentation of Observation 1

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:

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

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:

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

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

$$Pr_{\max} = B \cdot Pt \cdot \ln \frac{Pt}{Pr}$$

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.

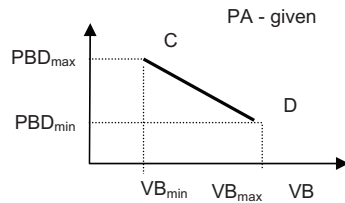


Fig. 2 The dependence of PBD requirement function of the biological value of the diet

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

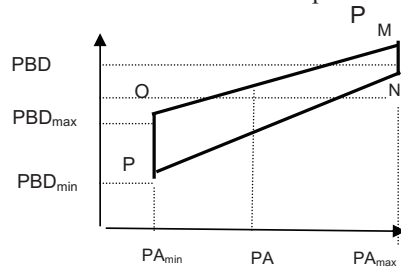


Fig. 3. The dependence of PBD requirement function of the available protein

Figure 4 shows the relation between EM and PBD .

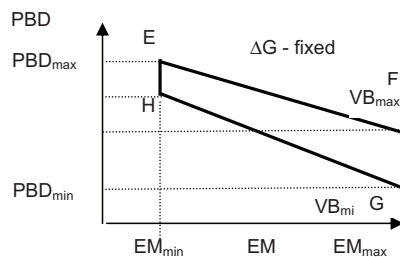


Fig. 4. The relation between EM and PBD

Any point on $EFGH$ trapezium is a norm expressed in EM , PBD for the set ΔG .

The existence of an area $EFGH$ for the requirement of EM and PBD is due to the two

parameters $\frac{Lr}{Pr} \in \left[\frac{Lr}{Pr}_{\min}, \frac{Lr}{Pr}_{\max} \right]$ and $VB \in [VB_{\min}, VB_{\max}]$.

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

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

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

CONCLUSIONS

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 of a given weight gain the quality of this gain is included in an interval

$\left(\min \frac{Lr}{Pr} \leq \frac{Lr}{Pr} \leq \max \frac{Lr}{Pr} \right)$, 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.

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