Research in poultry feeding using mathematical modelling. System for the evaluation of the nutritional value of feed materials and of the feeding norms for poultry

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SUMMARY

The new systems which assess the nutritive value and determine the nutrient requirement triggered changes in the manner of formulation and development of optimized poultry diets. The purpose of this paper is to present a viewpoint on a possible solution for diet optimization. We considered the determination of a possible "common denominator" between the nutritional requirements, mathematical algorithms that can be applied to the stated problem and the economic aspects assimilated as purpose functions in formulating the mathematical models that are used.

Keywords: mathematical modeling, poultry, feeding, metabolic processes, energy requirement, protein requirement weight gain, carcass quality, computer simulation.

On the basis of the research in poultry physiology and feeding, both in Romania and abroad, I developed a system which can be used to evaluate feed materials and the feeding norms with the view to optimise poultry diets using specific software.

1. The nutritive value of feeds is expressed by the corrected metabolisable energy (EM_c), which originates in the measurement of the digestible energy (ED) and of the digestible crude protein (PBD), measured experimentally in experiments of compared digestibility of the feed materials given at two levels of administration versus the basic diet, using first order equations with two unknowns.

EM_c = ED – (EU – Edez – 6.8 (SFB – 0.1) – 1,4 Z)

where:

EU (urine energy) = PD (deaminated protein) x 5.85

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Edez. (deamination energy) = PD x 4.9

SFB (g bacterial fermentable matter) = CBD + SEND – A – Z considering SFB energy content of 17 KJ/g and that 40% of this energy is lost by fermentation:

17 x 0.4 = 6.8 KJ/g SFB

This correction is applied only to the feed materials whose SFB content is larger than 100 g to 1 Kg DM (Oslage, 1985).

Z (g sugar). The 1.4 KJ/g sugar correction is applied only to the feed materials whose SFB content is larger than 80 g per 1 Kg DM feed.

PD (deaminated protein) is measured either directly experimentally, or by difference, taking into account the biological value (VB) of the dietary protein evaluated from its content of digestible amino acids (AAd), which, related to the digestible amino acids content of the broiler meat or of the eggs gives the lowest value:

$$VB = \frac{AAd\ \min, g}{PBD, g} \bullet \frac{X}{100}$$

where X = g content of AA corresponding to 100 g poultry meat or egg protein.

Knowing the VB of the digestible crude protein, we can determine the protein available (PA) to Pr synthesis:

PA = PBD g x Vb

Admitting an 8.83 efficiency of available AA (efAA) utilization, we can calculate the retained protein (Pr).

Pr, g = PA x efAA

Thus, we calculated two experimental nutritive values expressed in E_{mc} and in PA, one for the growing chicks and the other for the layers, due to the different amino acids composition of the broiler meat and of the eggs.

2. <u>The energy and protein norms expressed in EMc and in Pa</u> were calculated as follows:

a). EMc (KJ) = Emm + EPr + Q` - Q"

where Emm, KJ (metabolisable energy for maintenance) = $a \frac{G_n}{1000}$

and: Gn (net weight, g) = A x $e^{\frac{B}{C}\times\left(1-e^{-C\times t}\right)}$ t is the age in days.

<u>Epr, (metabolisable energy for protein synthesis)</u> = 50 x Pr or 50 x Pr egg,

where: Pr, g = D x Pt x $e^{-E\times t}$

and: Pt, g = F x $e^{\frac{D}{E}\left(1-e^{-E\times t}\right)}$

Pt, g = 10.92 x $\frac{Po}{100}$, where Po = egg mass, g

ELr, KJ (<u>metabolisable energy for fat synthesis</u>) = 56 x Lr

where: Lr, g = β x Pr, g

and: β = $\frac{Lr}{\Pr} = \frac{G + H \times t^{I} \times e^{(j \times t - k \times t)} - 23.6 \times D \times Pt \times e^{-E \times t}}{23.6 \times L \times Pt \times e^{-E \times t}}$

Lr, egg, g = 0,9826 Pr egg, g

Q', KJ (requirement of metabolisable energy for thermal regulation) = (Tci – Ta) (31.7215 – 2.042 x 10^{2}G + 6.7 x 10^{-6} – 6.561 x 10^{-10} G^{3}) x G^{5} if Tci>Ta, otherwise = 0

Tci (ºC) = 37.5784 – 2.014 x 10^{-2} G + 8.242 x 10^{-6} G^{2} – 1.231 x 10^{-9} G^{3}

Q", KJ (requirement of metabolisable energy for daily exercise) =

EMm $\left(\frac{140.34 - 0.4034 \times X}{100} - 1\right)$

where X = feeding level (% din ad libitum)

b). PA(g) = Pm + $\frac{\Pr}{0.837}$

where: Pm (g/zi) (requirement of net protein for maintenance) = L x Pt^{M}

Requirement of limiting digestible aminoacids:

- For growing poultry:

Digestible lysine (g)	= 0.060 x PA
Digestible meth. + cys.	= 0.044 x PA
Digestible trypt.	= 0.009 x PA

- For layers:

Digestible lysine (g)	= 0.072 x PA
Digestible meth. + cys.	= 0.064 x PA
Digestible trypt.	= 0.0184 x PA

For the growing poultry we also calculated the maximal amount of ingested dry matter:

g DM max/day = (N + O x t^{P} x $e^{-Q \times t}$) $\times \frac{1}{\sigma}$

or :

$$\text{g DM max/day} = \left[R + S + e^{-T\left(\frac{1}{V}\times\ln\frac{t}{W}\right)^2} \right] \times \frac{1}{\sigma}$$

where: σ = coefficient of chicks genetic breeding, variable from 1.0 to 0.7.

Table 1 shows the significance of the codes noted with letters from A to W.

Table 1. Significance of the codes noted with letters from A to W

Code	Growing poultry						
	Broiler chicks		White- Leghorn pullets	Turkey broilers		Ducklings (Barbarie)	
	M	F	F	M	F	M	F
a	546	518	559	500	480	620	580
b	0.700	0.646	0.646	0.750	0.750	0.750	0.750
A	37.96	37.96	31.80	60.00	60.00	50.00	50.00
B	0.16232	0.15501	0.11020	0.13280	0.12850	0.20260	0.19600
C	0.03282	0.03223	0.02740	0.02480	0.02530	0.04368	0.04792
D	0.17650	0.17000	0.11540	0.13750	0.13860	0.18800	0.18400
E	-0.03453	-0.03449	-0.02790	-0.02380	-0.02640	-0.03380	-0.04150
F	5.99	5.99	5.55	10.80	10.80	8.27	8.27
G	34.60	33.97	-	42.96	42.67	44.62	43.82
H	11.780	14.140	-	10.926	10.926	16.253	11.747
I	1.060	0.940	-	0.727	0.727	1.115	1.133
J	0.00198	0.00536	-0.0586	0.0352	0.0341	0.00392	0.00097
K	0.00017	0.00016	-	0.00020	0.00019	0.00027	0.00030
L	0.038	0.036	1.72	2.4	2.2	3.2	3.0
M	0.744	0.761	0.750	0.750	0.750	0.750	0.750
N	5.686	5.686	5.010	-	8.4	-	-
O	1.904	2.273	1.2512	-	0.0884	-	-
P	1.234	1.194	1.085	-	2.153	-	-
Q	-0.01159	-0.01073	-0.0108	-	-0.0203	-	-
R	-	-	-	29.25	-	23.59	29.86
S	-	-	-	354.2	-	189.3	113.8
T	-	-	-	-0.5	-	-0.5	-0.5
V	-	-	-	1.019	-	0.850	0.750
W	-	-	-	158.9	-	53.0	46.23

3. Poultry diets optimization is done on computer taking into account:

- The nutrient content in corrected digestible energy (Edc, MJ / kg DM), which is the digestible energy of the feed materials minus the energy lost by fermentation (0.0068 (SFB – 0.100) MJ/kg DM) and the digestible energy of each feed material (if SFB > 100 g and Z > 80 g);
- The digestible crude protein content (PBD /kg DM) of each feed material;

- The limiting digestible amino acids content of each feed material (AAdig./kg DM);
- The norms of corrected metabolisable energy (EMc, MJ/day), available protein (PA g/day), net protein for maintenance (Pr, g/day) or retained in the egg (Pr egg, g/day).

Three equations form as follows:

1. Edc,

$$x \bullet X + EDc, y \bullet Y + ...EDc, n \bullet N = EM + 5.85\left(\frac{PA}{VB} - \Pr\right) + 4.9\left(\frac{PA}{VB} - \Pr - Pm\right)$$

$$PBDx \bullet Y + PBDy \bullet Y + ...PBDn \bullet N = PA / VB$$

2. $$\frac{AAdx \bullet Y + AAdy \bullet Y + ... + AAdy \bullet N}{PBDx \bullet X + PBDy \bullet Y + ...PBDn \bullet N} : AAlcp = VB$$

where X,Y .....N = kg DM forages, and AAlcp = limiting amino acid of the meat (egg) in competition with the limiting amino acids of the forages, in kg per 1000 g meat or egg protein.

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APPENDIX

<u>Calculation of the nutritive value of feed materials</u>

ED, KJ/kg DM = EB, KJ/kg DM x %ED

PBD, g/kg DM = PB,g/kg DM x % PBD

EMc = ED – (EU – Edez. – 6.8 (SFB – 0.1) – 1.4Z)

EU (urine energy), KJ = PD (deaminated protein) x 5.85

E dez. (energy for deamination), KJ = PD x 4,9

SFB (fermentescible bacterial matter), g = CBD + SEND – A – Z

where:
6.8 KJ/g SFB = 17 KJ x 0.4
PD, g = PBD, g – Pr, g
Pr, g = PA, g x ef AA

where:
PA, g = PBD, g x VB,
and:

$$VB = \frac{AA\min, g}{PBD, g} : \frac{X}{100}$$

X = content in AA of 100g meat or egg protein.
ef AA = 0.837

Metabolisable energy requirement in poultry

EMc (KJ) = EMm + EPr + ELr + Q' + Q"

where:

EMm , KJ (metabolisable energy for maintenance) = $a\left(\frac{Gn}{1000}\right)^{b}$

and: Gn (net weight, g) = $A + e^{\frac{B}{C}\left(1-e^{-c\times t}\right)}$, t = days

EPr, KJ (metabolisable energy for protein synthesis) = 50 x Pr,g or 50 x Pr egg,g

where: Pr,g = D x Pt x $e^{-E \times t}$

and: Pt,g = 10.92 x $\frac{Po}{100}$ where Po = egg mass, g

ELr,g KJ (metabolisable energy for lipid synthesis) = 56 x Lr, g

where: Lr,g = β x Pr,g

Q', KJ = (metabolisable energy requirement for thermal regulation) =
= (Tci – Ta)(31.7215 – 2.042 x 10^{-2}G + 6.7 x 10^{-6} G^2 – 6.561 x 10^{-10} G^3) x $G^{0.75}$

if: Tci > Ta otherwise = 0

Tci (ºC) = 37.578 – 2.014 x 10^{-2} G + 8.242 x 10^{-6} G^2 –1.231 x 10^{-9} G^3
if : G ≤ 3 kg

Q", KJ (metabolisable energy requirement for daily exercise) = $EMm\left(\frac{140.34-0.4034\times X}{100}-1\right)$
where : X = feeding level (% din ad libitum)

Requirement of accessible protein (PA) and of limiting amino acids

PA,g = Pm + $\frac{\Pr, g}{0.837}$
where: Pm,g (daily requirement of net protein) = L x Pt^M

Requirement of limiting amino acids:

- For growing poultry:

Digestible lysine (g) = 0.060 x PA
Digestible meth. + cys. = 0.044 x PA
Digestible trypt. = 0.009 x PA

- For layers:

Digestible lysine (g) = 0.072 x PA
Digestible meth. + cys. = 0.064 x PA
Digestible trypt. = 0.015 x PA

Maximal amount of dry matter ingested by the growing chicks:
g DM max/day = (N + O x t^P x $e^{-Q\times t}$) x $\frac{1}{\sigma}$
or:
g DM max/day = $\left[R+S+e^{-T\left(\frac{1}{V}\times\ln\frac{t}{W}\right)^2}\right]\times\frac{1}{\sigma}$

where: t = days; σ = coefficient of chicks genetic breeding, varying from 1.0 to 0.7.