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Modeling and Bio-economic analysis of broilers' performance in Benin

F.M. HOUNDONOUGBO[1,2]✉, A. CHWALIBOG[1] et C.A.A.M. CHRYSOSTOME[2]

[1] Department of Basic Animal and Veterinary Sciences, Faculty of Life Sciences, University of Copenhagen, Denmark.
[2] Département de Production Animale, Faculté des Sciences Agronomiques, Université d'Abomey Calavi, Bénin.

✉ Correspondance et tirés à part , e-mail : fho@life.ku.dk ou fredericmh@gmail.com

Abstract

The objective of this paper was to model bio-economic variables in broilers feeding. During 7 weeks, 120 broilers Red Bro were fed with diets containing soybean meals from solvent (Ss) or expeller (Se) processing. At grower phase (d 22 to d 49) the diets were switched for half of broilers in each treatment. The General Linear Model (model I) and Mixed Procedure (model II) were used to analyze data in SAS (2004). In model I no significant effect ($P > 0.05$) of diet was found on the daily feed intake (DFI) and the daily body weight gain (DWG) at both phases, but the starter diet affect significantly the feed conversion ratio (FCR), the feed cost (FC) and the economic feed efficiency (EFE). The model II showed that at starter phase the interaction between diet and age had a significant effect on DFI, DWG, FCR, FC and EFE. At grower phase, there was no interaction effect. The age affected significantly DFI and DWG, while the diet had significant effect on FCR, FC and EFE. The switch of diets resulted in a compensatory growth of broilers fed Se diet previously. At the grower phase the daily feed intake and body weight were fitted by polynomial curve functions with the age as main explanatory variable. (*RASPA,* 7 (S) : 93-98).

Key – Words: Broilers - Economic feed efficiency - Feed cost- Polynomial functions - Soybean meals.

Résumé

Modélisation et analyse bio-économique des performances des poulets de chair au Bénin.

L'objectif de cet article a été de modéliser des variables bio-économiques en alimentation des poulets de chair. Pendant 7 semaines, 120 poulets de souche Red Bro ont été nourris avec des rations alimentaires contenant du tourteau de soja issu du processus solvant (Ss) et de celui mécanique (Se). À la phase de croissance (J 22 à J 49) les rations ont été inversées pour la moitié des poulets de chaque traitement. General Linear Model (modèle I) et Mixed Procedure (modèle II) ont été utilisés pour analyser les données dans SAS. Le modèle I n'a pas montré un effet significatif ($P > 0.05$) de la ration pendant les deux phases d'élevage sur la consommation journalière d'aliment (CJA) et sur le gain moyen quotidien (GMQ) de poids vif, mais l'effet de la ration de démarrage était significatif sur l'indice de consommation (IC), le coût alimentaire (CA) et l'efficacité économique de l'aliment (EEA). Le modèle II a montré qu'au démarrage il y eu un effet significatif de l'interaction entre la ration et l'âge des poulets sur CJA, GMQ, IC, CA, et EEA. L'inversion des rations a engendré une croissance compensatrice chez les poulets ayant reçus la ration Se au démarrage puis Ss plus tard. À la phase de croissance, le poids vif et la CJA des poulets pouvaient être modelés par des fonctions de type polynomial en utilisant l'âge comme variable indépendante.

Mots – Clés : Poulets de chair - Efficacité économique de l'aliment - Coût alimentaire - Fonction polynomiale - Tourteau de soja.

Introduction

Analyses of data in animal feeding require some specific aspects that should be taken into account when studying animal performances. For instance, there is a natural effect of animal age on the growth performance. Thus, the productivity is not similar during starter and grower phase of broilers. Furthermore, when carrying out an experiment, the estimation of some variables like the labor cost is difficult compare to the actual situation in a commercial farm. To evaluate the efficiency of diets for broilers, the feed cost and its combination with the weight gain could be a suitable way to analyze the economic effect of diet [2].

On the other hand, it is relevant in some cases to have mathematical models to fit the daily feed intake, the body weight or other variables according to the age of animals. Such models might allow estimating in similar conditions the value of the variables when the age changes.

The objective of this paper is to evaluate the strengths and the weakness resulting from the use of different statistical models in the analysis of the data recorded in broilers production when testing different diets in tropical conditions. Furthermore, the emphasis has been put on the mathematical expressions of the daily feed intake and the body weight of broilers.

Materials et Methods

1. Feed ingredient and diets

Two soybean meals from solvent (Ss) and expeller (Se) processing technologies where compared during starter and grower phases of boilers. At each phase these two ingredients were used, respectively in two balanced diets (Ss or Se) in which all other ingredients (maize, fish meal, palm oil, salt, oyster shell, lysine, methionine, bi-calcium phosphate and premix of micro minerals) were identical. The starter diet was used from 1 day-old (d 1) to d 21 and the grower diet from d 22 to d 49 of age.

2. Animals and housing

120 broilers of breed Red Brow were used. Three repetitions of 20 broilers were allocated per experimental diet. Broilers were housed in a starter house provided with artificial heating and lighting system. Broilers were transferred into grower pens at the end of week 3. In pen no heating was provided and they were kept under natural lighting conditions. The densities of animal were 12 and 6 broilers/m2 at starter and grower phases, respectively. The broilers were weighted weekly.
In order to study the compensatory growth of broilers, half of them (10 per repetition) fed with a given diet (Ss or Se) at the starter phase were switched to the second diet at the grower phase.

3. Laboratory analyses

Laboratory analyses where performed to estimate chemical composition of soybean meals (Ss, Se) and that of their respective diets; in dry matter (evaporation at 105 oC), ash (sample burnt at 525 oC), crude protein (Kjeldhal method for nitrogen estimation), crude fat (petroleum ether extraction), crude fibre and gross energy (adiabatic calorimetric bomb).

4. Calculations

The equation of CARRE *et al*., (1989) in [6] was used to estimate the content of metabolisable energy in diets Ss and Se:
AMEn (kJ/kg feed) = 0.2184GE – 4.426CP – 26.20CF
AMEn is the apparent metabolisable energy corrected to zero nitrogen retention; GE is the gross energy; CP and CF are respectively crude protein and crude fibre in the diets.
For a given phase, the variable Economic Feed Efficiency (EFE) was calculated as:
EFE (€ WG / € feed) = Revenue from WG /Feed cost
Where WG is the body weight gain.

5. Statistical analyses

Data were analyzed using SAS, version 9.1.2. First, the General Linear Models (GLM) procedure was performed as model I to assess only the effect of the diet. Hence, the following model was used:

- $Y_i = \mu + D_i + \varepsilon_i$
- Y_i = Observation for dependent variables
- μ = Overall mean;
- Di = Fixed effect of diet;
- ε_i = Residual error.

Secondary, the effect of the diet (D), the effect of the age in week (W) and the interaction effect (D*W) between these two explanatory variables were analyzed through the Random Intercept Model in mixed procedure. In the model II, the housing effect was used as a random variable. The model II is often adopted to analyze the data in the cases of repeated measurements as performed in this experiment by collecting data from the same group of animals (experimental unit or repetition) over 7 weeks. The statistical model in that case was:

$Y_{ijk} = \mu + D_i + W_j + D_i{*}W_j + \varepsilon_{ijk}$

In both models I and II the significant effects of the explanatory variable(s) and that of the interaction (in model II) were stated when P < 0.05.
In addition, the mixed procedure was performed to fit at the grower phase the expressions of the daily feed intake curve (Y_{DFI}) and the growth curve (Y_{BW}) according to the diet and the age in week (W). After checking the pattern of the residuals, the logarithm transformation was applied to the original data during the analysis of daily feed intake, whereas no transformation was done for the body weight. Thus, in the expressions of the daily feed intake the exponential function was used to convert the logarithm form to the normal data. The models below were used to fit the polynomial form of the daily feed intake (Y_{DFI}) and of body weight (Y_{BW}), respectively. In the model of Y_{DFI} the effect of the interactions between diet and different exponents of the week were not significant and were removed (P > 0.05). The model of Y_{BW} showed significant interactions between the diet, the first and second exponents of the week (P-value = 0.006 and 0.012, respectively) but not the third (P = 0.58). The models used to fit the expressions of the daily feed intake and of the body weight at the grower phase were:

$\text{Log(DFI)} = \alpha W + \beta W^2 + \gamma W^3 + A(\text{house}) + \hat{A} \quad => \quad Y_{DFI} = e^{[\text{Log (DFI)}]}$
$Y_{BW} = \alpha(\text{diet}) + \beta(W) + \gamma W^2 + \theta W^3 + \lambda(D{*}W) + \eta(D{*}W^2) + A(\text{house}) + \varepsilon$
where ε = Residual error

To take into account the interaction effect, the expressions of body weight were evaluated by combining β and λ to obtain the coefficient of W, γ and η to obtain that of W^2. The coefficient α related to the diet effect was computed in the intercept. The estimated values of all these coefficients were significant (P < 0.05).

Results

1. Composition of soybean meals and diets

The Table I show the chemical composition of meals and diets from laboratory analyses.
The results from laboratory analyses (Table I) showed that solvent meal of soybean (Ss) had 17 % lower gross energy content than expeller meals (Se). On the contrary, solvent soybean meal had 14 % higher content of crude protein than expeller soybean meal. Consequently, these nutritional differences between meals affected the content of metabolisable energy and crude protein in the Ss and Se diets. The differences affected also the cost of gross or metabolisable energy and that of crude protein in the meals and diets. Thus, the protein cost was lower in Ss than Se, while it was the opposite for the gross or metabolisable energy cost.

2. Output from model I: general linear model usingmeans of the phase

The outputs from the GLM procedure for daily feed intake (DFI), daily weight gain (DWG), feed conversion ratio (FCR), feed cost (FC), economic feed efficiency (EFE) are showed in Table II. In the model I, only the effect of diet was focused and it allowed comparing the overall means of both diets at a given phase irrespective of the age. Thus, the within phase variation of variables was not analyzed. The results of Table II showed that the starter diet affected significantly the FCR, FC and EFE, but not the DFI and DWG. Hence, the use of solvent soybean resulted in significantly lower FCR and FC. Consequently EFE was significantly higher in Ss than Se. No significant effect of the diet was found at grower phase.

Table I: Chemical composition of the soybean meals /diets and the costs of protein and energy

	Soybean meals		Starter diets		Grower diets	
	Ss	Se	Ss	Se	Ss	Se
Dry matter (%)	88.8	92.3	91.3	92.0	88.2	88.6
Ash (%)	6.10	5.12	14.3	13.2	7.21	6.50
Crude Protein (%)	47.5	41.8	20.7	18.4	19.3	17.2
Crude Fat (%)	1.08	15.3	4.80	7.57	5.61	7.95
Crude Fibre (%)	7.15	6.16	3.08	2.82	3.09	2.81
Gross energy (MJ/kg of meal or diet)	17.5	20.8	15.8	16.3	15.9	16.6
Metabolisable energy (MJ/kg of diet)	-	-	11.4	12.2	12.8	12.9
Crude protein cost (€ 10^{-4}/g CP)	8.7	9.8	14	16	15	17
Gross energy cost (€ 10^{-4}/MJ GE)	235	198	183	178	184	176
Metabolisable energy Cost (€ 10^{-4}/MJ ME)	-	-	254	237	229	227

Ss: Solvent soybean meal/diet, Se: Expeller soybean meal/diet, ME: Metabolisable energy, GE: Gross energy, CP: Crude protein

3. Outputs from model II: general mixed procedures using means values of the week

Table III demonstrates the daily feed intake, daily weight gain, feed conversion ratio, the feed cost and the economic feed efficiency analyzed through the random intercept model in mixed procedure. The results showed that during the starter phase all the variables in Table III were significantly affected by the interaction between the diet and the age, while no interaction effect was recorded at grower phase. At that phase the significant effects were due to the diet (for DWG, FCR, FC, and EFE) and/or to the age (for DWG and DFI, respectively). The values of the variables in Table III were better in diet Ss than Se at all weeks. These results confirmed that the solvent soybean meal was more economic than the expeller one in broilers feeding.

The expressions of the polynomial curves of the daily feed intake (YDFI) and of the growth (YBW) in both diets during the grower phase were:

$$Y_{DFI}Ss = e\,(7.44 - 2.34W + 0.52W^2 - 0.034W^3)$$
$$Y_{DFI}Se = e\,(7.40 - 2.34W + 0.52W^2 - 0.034Wk^3)$$

$$Y_{BW}Ss = 2138.54 - 1277.45W + 291.18W^2 - 17.3014\,W^3$$
$$Y_{BW}Se = 2717.61 - 1481.85W + 305.32W^2 - 17.3014\,W^3$$

In both models, the mortality rate (2.2 and 2.4% in Ss and Se, respectively) was not significantly affected by the diet. However, in model II the age had significant effect ($P < 0.0001$) on the mortality.

Figures 1 and 2 present the daily feed intake and the growth curves of broilers fed diets Ss and Se during the grower phase. These figures were drown with the fitted values.

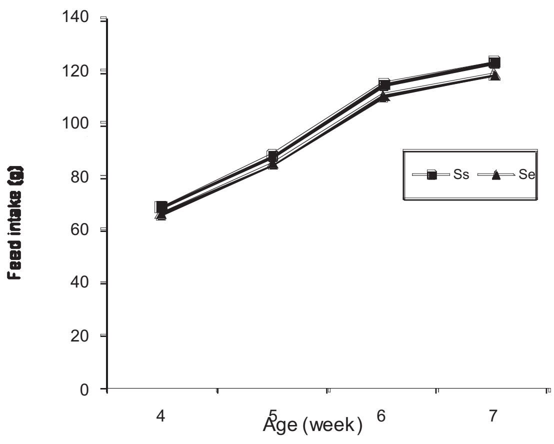


Figure 1: Daily feed intake of broilers.

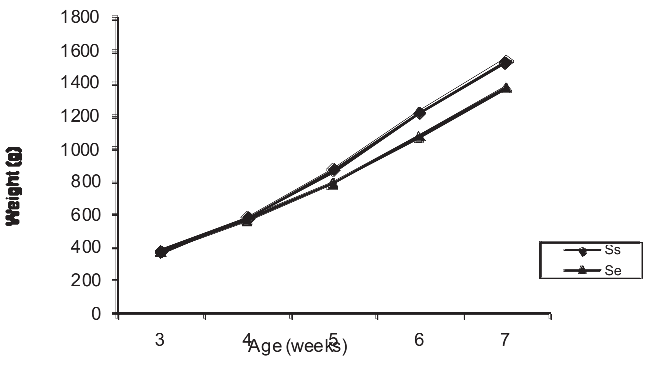


Figure 2: Growth curves of broilers.

Table II: Means values of daily feed intake (DFI), daily weight gain (DWG), feed conversion ratio (FCR), feed cost (FC), economic feed efficiency (EFE) from GLM procedure

	Variables		DFI (g)		DWG (g)		FCR (g feed /g weight gain)		FC (10^{-3} €/kg body weight)		EFE (€ weight gain / € feed)	
	Diets		Ss	Se	Ss	Se	Ss	Se	Ss	Se	Ss	Se
Starter phase	Means		36.8	32.4	17.9	13.2	1.9^{a}	2.5^{b}	563^{a}	729^{b}	2.9^{a}	2.2^{b}
	SE		4.74		0.43		0.01		4		0.05	
	P-value		0.63		0.21		< 0.0001		< 0.0001		<0.0001	
Grower phase	Means		98.5	94.7	41.4	35.8	2.4	2.7	686	773	2.4	2.1
	SE		1.27		0.42		0.02		7		0.02	
	P-value	0.69	0.07	0.08	0.09	0.10						

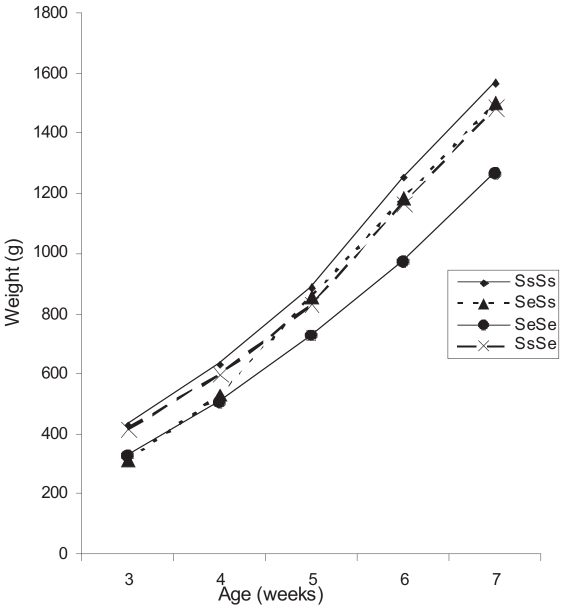
a b Means with unlike superscripts in the same row differ significantly (P-value < 0.05). Ss: Solvent soybean diet, Se: Expeller soybean diet; SE: Standard error

Table III: Weekly variation of daily feed intake (DFI), daily weight gain (DWG), feed conversion ratio (FCR), feed cost (FC), economic feed efficiency (EFE) from mixed procedure

Variables		DFI (g)		DWG (g)		FCR(g feed /g weight gain)		FC (10^{-3} €/kg body weight)		EFE (€ weight gain / € feed)	
Phases		Diets									
	Ages	Ss	Se	Ss	Se	Ss	Se	Ss	Se	Ss	Se
Starter phase	Week 1	3.21^{a}	12.0 1^{a}	8.101^{a}	4.542^{a}	1.631^{a}	2.652^{a}	473 1^{a}	7682^{a}	3.41^{a}	2.12^{a}
	Week2	37.81^{b}	34.02^{b}	19.91^{b}	13.32^{b}	1.901^{b}	2.552a	550 1^{b}	7412^{a}	2.91^{b}	2.22^{a}
	Week3	59.4 1^{c}	51.3 2^{c}	25.91^{c}	21.82^{c}	2.301^{c}	2.351^{b}	6661^{c}	6831^{b}	2.41^{c}	2.41^{b}
	SE	0.64*		0.28*		0.05*		0.015*		0.05*	
	P-value	0.001*		0.002*		<0.0001*		<0.0001*		<0.0001*	
Grower phase	Week4	66.4^{a}	65.6^{a}	29.71^{a}	27.51^{a}	2.241	2.401	652 1	700 1	2.51	2.31
	Week5	86.8^{b}	85.1^{b}	41.7 1^{b}	31.8 2^{a}	2.081	2.602	607 1	785 2	2.61	2.12
	Week6	115.7^{c}	107.3^{c}	49.3 1^{c}	40.6 2^{b}	2.351	2.681	686 1	782 1	2.31	2.11
	Week7	124.9^{d}	120.6^{d}	45.0 1^{bc}	43.21^{b}	2.791	2.871	799 1	819 1	2.01	2.01
	SE	1.86**		1.2**		0.09**		0.026**		0.07**	
		1.9***		1.7***		0.13***		0.037***		0.09***	
	P-value	0.18**		0.006**		0.039**		0.032**		0.02**	
		<0.0001***		<0.0001***		0.06***		0.10***		0.7***	

* Interaction (between diet and age) effect; ** Diet effect; *** Age (in week) effect; 1,2 Means with unlike numbers as superscripts in the same row differ significantly (P-value < 0.05); a b c d Means with unlike letters as superscripts in the same column differ significantly (P-value < 0.05)
Ss: Solvent soybean diet; Se: Expeller soybean diet; SE: Standard error

Figure 3 demonstrates the compensatory growth recorded during the grower phase. The broilers in SsSe were fed diet Ss at starter phase, while they received expeller diet (Se) at grower phase. The broilers in SeSs were fed diet Se at the starter phase and Ss at grower phase. The Figure 3 shows that the switch of the diet for the half of broilers affected the slop of their growth. Thus, the daily weight gain of broilers in SsSe decreased comparatively to that of broilers fed with diet Ss at both phases (SsSs). On the contrary, broilers in SeSs increased their growth rate.



Discussion

1. Bio-economic performance and composotion of soybean's meals and diets

The growth performance (DWG, growth curves) of broilers was better on diet Ss than Se. The efficiency of the diet Ss was confirmed by the compensatory growth that showed the capacity of Red Bro broilers to improve significantly their growth when diet Ss was supplied from grower phase. The difference in growth of broilers affected the FCR, the FC and the EFE. The analyses of meals and diets showed that farmers purchased protein at higher cost when they used expeller soybean meal, whereas the energy cost was more expensive in case they used solvent meal. MADIYA [7] reported that the FC represented about 76 to 83 % of total variable costs, while according to the WORLD POULTRY SCIENCE ASSOCIATION [11], feed accounts for 60 to 70 % of the total production cost. Thus, the FC affects significantly the benefit of farmers. The decrease of the FC and the increase of EFE by using Ss might result therefore in an increase of the benefit, the revenue from broilers being irrespective of the type of diet used. These results suggest that farmers could improve their benefits by using solvent soybean meal instead of expeller one since both are sold at the same price in the market. In the case of significant difference between the prices of both meals, some evaluation should be done to find the adapted price at which the expeller meal might be sold to allow similar FC and EFE in both diets. Such practice might allow limiting the situation of an inadequate balance between feed price and feed efficiency reported by CISSE *et al.* [1] when testing seven commercial feeds in Senegal. The daily feed intake and the daily weight gain recorded at start phase (in Table II) were lower than 21.7 g reported by ODUNSI *et al.* [8]. At d 49 the average body weight of broilers on diet Ss (1531 g) and Se (1374 g) were also lower than 1696 g recorded at d 42 by DONGMO *et al.* [2] in Cameroon for Ross boilers. However, the feed cost on diet Ss (0.563 €/ kg body weight) was lower than 0.643 €/kg body weight stated by DONGMO *et al.* [2].

2. Model I versus model II

The results summarized in Table II and III gave two types of information. In the case of GLM procedure (model I), the weekly pattern of variables could not be appreciated. In contrast, some significant differences can be pointed out at a specific age when the mixed procedure (model II) was performed. For instance, at the starter phase the DFI was significantly affected by the interaction between diet and the age at week 2 and 3, while no difference was found in model I at the same phase. Similar difference between both models is related to the DWG indicating that the diets affected the growth according to the age of broilers. In the present experiment, the differences between diets in DWG were higher from week 2 to 3 and from week 5 to 6 of age than before and after these ages. Regarding the FCR, the model II showed a significant difference due to the diet effect in week 5; while in model I no difference was found at grower phase. At both phases, the model I showed a significant effect of diets on the FC and EFE, while the model II precised that both variables were significantly affected by the diets from week 1 to 2 and at week 5. Models I and II are therefore two complementary approaches of data analysis. Each of them can be used to analyze bio-economic variables in broiler production according to the details focused. For example, HELLWING *et al.* [4] run the mixed procedure (Model II) to analyse data from broilers feeding experiment, while the model I was used by CISSE *et al.* [1], ERUVBETINE *et al.* [3], JORGENSEN *et al.* [5], ODUNSI *et al.* [8] and OLIVER *et al.* [9].

In the present experiment, the data were collected over 7 weeks from the same animals in each pen (repetition) as in the case of repeated measurements for which the model II is often use because of the random effect of the pen and the repetition effect of the successive weeks.

The modelling of the mathematic expressions of DFI and of the body weight (Figure 1 and 2 respectively) confirmed the non-significant effect of the interaction between diet and age on DFI and the opposite on the body weight. Thus, the parallelism of both curves of daily feed intake (Figure 1) was the consequence of the non-interaction effect, while no parallelism was noticed between the growth curves (Figure 2).

Conclusion

This study showed that the solvent soybean meal was biologically and economically more efficient in broiler feeding than expeller soybean meal. The mixed procedure allowed to precise the age at which the effects of diets were significant. Thus, the mixed procedure is an appropriate model to analyse data from repeated measurements and to evaluate the effect of the explanatory variable (diet) over the weeks on the same group of animals. However, when the objective is to have an overview of the differences between diets irrespective of the age, the GLM procedure may be used.

Finally, the curves of boilers' daily feed intake and body weight have a polynomial form. When modelling the daily feed intake and growth curve it is important to test the significance of the coefficients defining the effect of the explanatory variable (the age in week in this case) before formulating the final expression. The modelling can be done for a given growth period of broilers.

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