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Nutritional and economic values of by-products used in poultry diets in Benin: the case of soybean, cotton and palm kernel meals

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Abstract

The aim of this study was to compare the effects of two soybean meals (S1, S2) and two palm meals (P1, P2) from solvent and expeller processing, and two cotton meals (C1, C2) both from solvent processing on the bio-economic performances of broilers. 360 broilers Red Bro were fed six diets containing these meals. At starter phase (d 1 to 21 of age) only the diets S1 (solvent) and S2 (expeller) were used, while at grower phase (d 22 to 49 of age) the six diets were tested. Then, a balance experiment was carried out to evaluate the metabolism of nitrogen and energy.

Results showed similar feed intake in all diets at each phase. The body weight was significantly lower in S2 at d 21 (419 g in S1 vs 320 g in S2) and at d 49 (1531 g in S1 vs 1374 g in S2). At d 49, the highest average body weight (1543 g in C1) was significantly different from the lowest weight (1374 g in S2). However, the daily body weight gains (WG) were not affected by diets. The mortality rates were null at grower phase and similar at starter phase (2.4% in S1 vs 2.1% in S2). The feed conversion ratio was significantly lower in S1 than S2 at starter phase (1.9 vs 2.5), and similar later. The processing of soybean significantly affected the feed cost (FC) and the economic feed efficiency (EFE) during the starter phase. FC was 0.563 vs 0.729 € / kg WG, and EFE was 2.9 vs 2.2 € WG / € feed, respectively in S1 and S2. At grower phase, the lowest FC (0.633 € / kg WG in C1) was significantly different from the highest (0.773 € / kg WG in S2). On the contrary, no significant effect of the processing technology was noticed on the FC and the EFE with palm meals and cotton meals diets. The metabolizability of energy was affected by the diet, while it was the contrary for nitrogen. Computed per kg of metabolic body size ($kg^{0.75}$), the daily intake of nitrogen was significantly affected by the processing technology of all three types of meals. On the contrary, only the processing technology of cotton meals had significant effect on the intake of ME.

It can be concluded that in Benin the processing of soybean meal had significant effects on bio-economic performances of broilers at starter phase, and on their body weight at grower phase.

Keywords: balance experiment, Benin, broilers, by-product, economic feed efficiency, processing technology

Introduction

Efficiency of poultry feed is one of the most important determinant of the benefit in poultry production. For that reason, ingredients should be selected on the basis of their availability, price, and quality (National Research Council, 1994). Unfortunately in Benin, the composition of feedstuffs is less known. According to Pond et al (1995), feed intake of broiler depends on the composition of the diet, whereas ingredients and especially, by-products vary in chemical composition according to their processing. Smith (1996) defined the oil seed meal (or cake) as the residue remaining after the greater part of the oil has been removed from the seed. The processing of meals varies according to the technology used. In Benin, expeller screw press (expeller or mechanic processing) and solvent extraction (solvent processing) are used to extract the oil. According to Smith (1996), meal from expeller processing has an oil content of 5 to 6%, while those from solvent process contain 1 to 2%. Thus, Pond et al (1995) reported a great variation of the energy content of meals depending on processing methods. The composition of meals produced in Benin might therefore vary according to the processing technology used.

Larbier and Leclercq (1994) stated that, appropriate processing treatment is necessary to improve the nutritional value (digestion, metabolism) of some raw materials (legume seeds) by destroying anti-nutritional factors resulting at the same time, in a decreasing availability of amino acids and heat labile vitamins. According to them, heat treatments are the most common processing and the three variables that influence the nutritional value being the temperature, the duration of treatment and the moisture content of the raw material treated.
The objective of this work was to investigate the relationship between the processing technology, and the nutritional value of meals used in poultry diets in Benin, and how that could affect broilers' performance and economic variables.

Material and method

Ingredients and diets

At the starter phase (d 1 to 21 of age), two diets were compared in a growth performance experiment. The first contained soybean meal from solvent processing (S1) and the second, soybean meal from expeller processing (S2). At the grower phase (d 22 to 49 of age) and during the balance experiment, six dietary treatments were used (Table 1).

Table 1. Types of meals and experimental diets

Phases	**Starter phase**		**Grower phase**					
Types of meals	soybean solvent	soybean expeller	soybean solvent	soybean expeller	Cotton solvent	Cotton solvent	Palm solvent	Palm expeller
Diets	S1*	S2	S1	S2	C1*	C2	P1*	P2

** Meals for diets S1, C1, and P1 were from the same factory using solvent processing*

Diets were formulated in the solver of Microsoft Excel® (Thomson and Nolan 2001) using the six types of meals from soybean (two), cotton seed (two) and palm kernel (two). The chemical compositions of feedstuffs used were from Institut National de la Recherche Agronomique (1989). Soybean and palm meals from solvent process of oil extraction were respectively compared to the corresponding expeller meals, while both cotton meals were from two factories producing such meals by solvent processing in Benin. However, during the formulation of the diets the same chemical compositions were considered independently to the processing technology; that because of lack of information. In the case of palm meals, hull of palm seeds are removed before oil extraction process. In each couple of diets in comparison, apart from the difference in the type of meal, all others ingredients included in diets were the same.

The table 2 presents the ingredients and the chemical composition of experimental diets as calculated in Excel®.

Table 2. Ingredients, prices and chemical composition of diets formulated in Excel®

Ingredients / Nutrients	**Starter diets**	**Grower diets**		
	S1 , S2	**S1 , S2**	**C1 , C2**	**P1 , P2**
Ingredients, %				
Maize	60	61	60.9	56.4
Soybean meal	28	28	20	26
Cotton meal [1]	-	-	10	-
Palm kernel meal	-	-	-	8
Fish meal	8	5.9	4	4
Palm oil	1	2	2	2.5
Salt (NaCl)	0.31	0.31	0.31	0.31
Oyster shell	1.50	1.50	1.50	1.50
Lysine	0.10	0.10	0.10	0.10
Methionine	0.40	0.40	0.40	0.40
Bi-calcium phosphate	0.44	0.54	0.54	0.54
Premix[2]	0.25	0.25	0.25	0.25
Prices, € / kg diet	0.290	0.287	0.265	0.286
Chemical compositions				
ME[3] , MJ/kg dry matter	12.6	12.9	12.7	12.5
Crude Protein, %	21.5	20.6	20.4	19.8
Crude fat, %	4.6	5.4	5.1	5.5
Crude fibre, %	3.4	3.4	4.0	4.3
Lysine, %	1.4	1.3	1.1	1.2
Methionine, %	0.73	0.70	0.68	0.67
Methionine + Cystine, %	0.91	0.86	0.82	0.86
Calcium, %	1.2	1.1	1.0	1.0
Total Phosphorus, %	0.68	0.64	0.63	0.61
Phosphorus available, %	0.36	0.32	0.27	0.27

[1] *Ferrous sulphate (FeSO4) were added at the rate of 3 g per kg of cotton meal*

[2] *Premix contained per kg: Vitamins: A 4000000 UI; D3 800000 UI; E 2000 mg; K 800 mg; B1 600 mg; B2 2000 mg; niacin 3600 mg; B6 1200 mg; B12 4 mg; choline chloride 80000 mg*
Minerals: Cu 8000 mg; Mn 64000 mg; Zn 40 000 mg; Fe 32000 mg; Se 160 mg.

[3] *Metabolisable energy*

To keep high level of protein in diets and to limit the negative effect of gossypol in cotton meal and of high crude fibre in palm meal, the rates of these two ingredients were lower than that of soybean meal in diets (Table 2). The market prices of meals were independent from the processing technology. In consequence, prices of diets in comparison two by two were the same (Table 2).

Feeding

Diets were assigned to repetitions (pen) by random. From first day of experiment, chickens in 3 repetitions were fed the same diet. At the beginning of grower phase, the starter diet was progressively substituted by the grower diet at the respective daily rate of 33, 67 and 100%. Birds were fed *ad libitum* and had free access to drinking water. Feed delivered and feed residue, were recorded daily per pen.

Animals and housing

396 broilers chickens of breed Red Bro were used during the growth experiment. They were day-old chickens of both sexes purchased from a hatchery in Benin. At their arrival, they were divided in 6 repetitions of 66 chicks each. In the repetitions the average weight per chicken was between 42.1 ± 0.25 g and 42.8 ± 0.13 g. The design of experiment is summarized in Table 3.

Table 3. Experimental design

Phases		**Starter phase**		**Grower phase**					
Diets		**S1**	**S2**	**S1**	**S2**	**C1**	**C2**	**P1**	**P2**
Animals per treatment		198	198	60	60	60	60	60	60
Repetitions per treatment		3	3	3	3	3	3	3	3
Body weight at start, g	Means	42.3	42.2	372	372	372	372	372	372
	SE	0.05		0.13					

During the first 3 weeks, chickens were kept on deep litter in a starter room provided with heating and lighting. The heating was stopped at the end of week 2. In the room, the average temperatures measured during the whole starter phase were between 27.0 and 31.5°C, while the relative humidity varied from 68.0 to 82.1%.

At day 22 of age (d 22), chickens from the same treatment were weighted and then divided into 18 repetitions each with 20 birds. The average weights per treatment were similar (Table 3). Chickens were moved during night time from the starter room to pens under natural light for the grower phase. During 4 weeks, chickens were kept in 18 pens until d 49 of age. In pens, the average temperature and relative humidity varied respectively from 24.3 to 31.3°C, and from 73.4 to 89.4%. The densities of animal on litter were respectively 12 birds/m^2 and 6 birds/m^2 at starter and grower phases. During the whole growth experiment, birds were weighted weekly.

Balance experiment

At the end of the growth experiment (d 49), 4 males and 4 females (8 chickens) were sampled from each treatment on the basis of their body weight for a balance experiment. Thus, the initial body weights were similar at the start of balance experiment. The average weight of overall 48 chickens used were respectively 1681 ± 62 g and 1836 ± 106 g at the start and at the end of the experiment. Chickens were placed in individual cage on Friday and 4 days of dropping collection started from Monday. Daily feed and water supplied and their residues were collected. At 8 am, residues of feed and water were removed and droppings were collected individually and weighted. Then, dropping from the 8 chickens in the same treatment were mixed and a daily sample (300g) was frozen immediately for laboratory analysis. During balance experiment, the average temperatures and relative humidity varied respectively from 24.5 to 34.0°C, and from 68.0 to 91.2%.

Laboratory analyses

The meals, the diets and the droppings were analyzed at the Faculty of Life Sciences, University of Copenhagen in Denmark. Wet samples of dropping were used for nitrogen and dry matter analyses, while freeze dried samples were used for other analyses. Dry matter (DM) was determined by evaporation of water at 105ºC. Ash was obtained after burning the material at 525ºC. Nitrogen (N) content was estimated by the technique of Kjeldahl. Then, the percentage of crude protein (CP) was calculated as N x 6.25. The method of petroleum ether extraction after HCl hydrolysis was used to determine fat content. Gross energy (GE) was measured in an adiabatic bomb calorimeter (IKA® calorimeter system, IKA® GmbH & Co. KG, Staufen, Germany). Crude fibre (CF) was determined using the Fibertec FiberCap 2021/2023 system (FOSS Tecator AB, SE-263 21 Hoganas Sweden).

Calculations

The content of metabolisable energy in the starter diets was estimated by the equation of Carré et al (1989) in Larbier and Leclercq (1994):
AME_n (kcal/kg feed) = 0.913GE – 18.5CP – 109.5CF

Using the results of balance experiment the metabolisable energy (ME) in the grower diets was estimated by the following equation:
AME (MJ) = GE – DpE

In these equations, AME_n is apparent metabolisable energy corrected to zero nitrogen retention;
GE is the gross energy in feed intake;
DpE is energy in dropping;
CP and CF are respectively crude protein and crude fibre.

For a given phase, the economic feed efficiency (EFE) was calculated as following:
EFE (€ WG / € feed) = Revenue from WG / Feed cost

Where, WG is the body weight gain during the phase.
Total water intake = water drunk + water in feed intake.

Statistical analyses

Data were analyzed using GLM procedure in SAS (2004). Mean values were presented in tables with the pooled standard error. The significant effects were stated when $P < 0.05$. The effect of pen (repetition) and the interaction between diet and pen were not significant ($P > 0.05$). Hence, analyses were performed according to the following model:
$Y_i = \mu + D_i + \varepsilon_i$
Y_i = Observation for dependent variables
μ = Overall mean;
D_i = Fixed effect of diet;
ε_i = Residual error

Results

Composition of meals and diets

The chemical composition of the meals and the diets from the laboratory analyses and calculations are presented in Table 4 and 5 respectively. The meals S2 and P2 from expeller processing contained more fat and consequently higher gross energy (GE) than respectively the meals S1 and P1 from solvent processing (Table 4).

Table 4. Chemical composition of the soybean, cotton and palm kernel meals; cost of crude protein (CP) and gross energy (GE)

	S1*	**S2**	**C1*[a]**	**C2[b]**	**P1***	**P2**
Dry matter, %	88.8	92.3	87.5	88.5	88.5	89.7
Total ash, %	6.10	5.12	6.75	6.75	4.46	3.47
Crude Protein, %	47.5	41.8	40.8	38.1	16.7	16.9
Crude fat, %	1.08	15.3	3.97	7.46	3.40	15.0
Crude Fibre, %	7.15	6.16	10.8	11.3	22.0	11.5
GE, MJ[c]/kg of meal	17.5	20.8	17.8	18.4	17.6	19.5
CP Cost, € 10^{-4}/g CP	8.7	9.8	3.0	3.2	8.2	8.6
GE Cost, € 10^{-4}/MJ GE	235	198	69	66	82	74

** Meals from the same factory using solvent process*

[a,b] *Cotton meals from different factories using solvent process*

[c] *MJ= Mega Joule*

However, the content of crude protein (CP) was higher in S1 than S2, while it was similar in both palm meals. The difference between cotton meals in CP (1%) was low as well as that in GE (0.6 MJ/kg) although the difference in crude fat. Comparatively to solvent meals, the cost of CP was higher in speller meals while it was the opposite for the cost of GE. Cost of protein and energy in both cotton meals from solvent process were close. These results showed that in Benin cotton meals provided more cheap GE and CP than soybean and palm kernel meals. The content of crude fibre was low in soybean meals and particularly high in solvent palm kernel meal (P1).

The differences in chemical composition between meals affected the composition of the diets. Thus, a positive relationship was found between meals and diets regarding the chemical composition and in the costs of CP and ME (Table 5).

Table 5. Chemical composition of diets; Cost of crude protein (CP), gross energy (GE) and metabolisable energy (ME)

Nutrients	**Starter diets**		**Grower diets**					
	S1	**S2**	**S1**	**S2**	**C1**	**C2**	**P1**	**P2**
Dry matter, %	91.3	92.0	88.2	88.6	88.1	88.3	87.8	87.4
Total ash, %	14.3	13.2	7.21	6.50	6.16	7.14	6.95	6.59
Crude Protein, %	20.7	18.4	19.3	17.2	21.2	19.3	21.5	19.7
Crude fat, %	4.80	7.57	5.61	7.95	4.79	5.58	5.56	6.46
Crude fibre, %	3.08	2.82	3.09	2.81	3.62	4.16	5.13	4.21
ME, MJ/kg diet	11.4	12.2	12.8	12.9	13	12.9	12.6	12.9
ME/GE, %	72	75	80	79	78	78	76	77
ME/CP, MJ 10^{-3}/g	55	66	66	75	61	67	59	65
CP Cost, € 10^{-4}/g CP	14	16	15	17	13	14	13	15
GE Cost, € 10^{-4}/MJ GE	183	178	184	176	160	159	174	172
ME Cost, € 10^{-4}/MJ ME	254	237	229	227	204	206	227	222

The use of soybean meals resulted in a higher difference in ME cost at starter phase than at grower phase (17 versus 2 € 10 $^{-4}$/MJ ME); the difference being similar for CP cost (2 € 10^{-4}/g CP) at both phases. In general, diet with cotton meals had low ME cost, while the lowest CP cost was in diet C1 and P1.

Feed intake and feed efficiency

The table 6 presents the daily feed intake (DFI) and the feed conversion ratio (FCR). DFI was similar in all diets at starter and grower phases. However, FCR was significantly higher in S2 than S1 ($P < 0.001$) at starter phase, while it was similar at grower phase.

Table 6. Daily feed intake (DFI) and feed conversion ratio (FCR)

	Phases	**Diets**						**SE**
		S1	**S2**	**C1**	**C2**	**P1**	**P2**	
DFI, g	Starter	36.8	32.4	-	-	-	-	4.74
	Grower	98.5	94.7	97.4	100	99.6	96.3	1.27
FCR, g feed / g WG[1]	Starter	1.9^{a}	2.5^{b}	-	-	-	-	0.01
	Grower	2.4	2.7	2.3	2.5	2.7	2.4	0.02

$^{a\,b}$ Means with unlike superscripts in the same row differ significantly (P < 0.05)

[1] Body weight gain

Growth and mortality

During the both phases, no significant effect of diet was recorded ($P > 0.05$) on the daily body weight gains (Table 7).

Table 7. Daily body weight gain (WG) and final body weight (FBW) at 49 days-old

	Phases	**Diets**						**SE**
		S1	**S2**	**C1**	**C2**	**P1**	**P2**	
WG, g	Starter	17.9	13.2	-	-	-	-	0.43
	Grower	41.4	35.8	41.8	40.6	37.6	39.7	0.42
FBW, g	Starter	419^{a}	320^{b}	-	-	-	-	0.28
	Grower	1531^{a}	1374^{b}	1543^{a}	1509^{a}	1425^{bc}	1484^{ac}	1.97

$^{a\,b}$ Means with unlike superscripts in the same row differ significantly (P < 0.05)

However, the final body weights (FBW) at the end of starter and grower phases were significantly affected by the type of soybean meal ($P < 0.001$ in both phases). From week 2 of age until the end of the experiment, the live weight of broilers fed with solvent soybean (S1) became higher than that of broilers fed with S2 (Figure 1).

At d 49 the FBW of the broilers fed expeller soybean meal (S2) was the lowest (about 90% of FBW of broilers fed diet S1). No significant difference ($P > 0.05$) was found according to the processing technology in the growth of the broilers fed cotton and palm meals diets (Table 7, Figure 2 and 3). The FBW (Table 7) showed that the growth performances of broilers fed both cotton meals diets, and expeller palm meal diet (P2) were similar to that recorded in broilers fed solvent soybean diet (S1).

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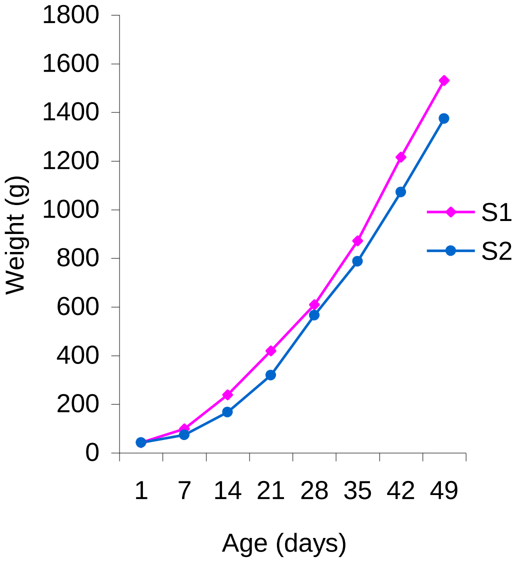
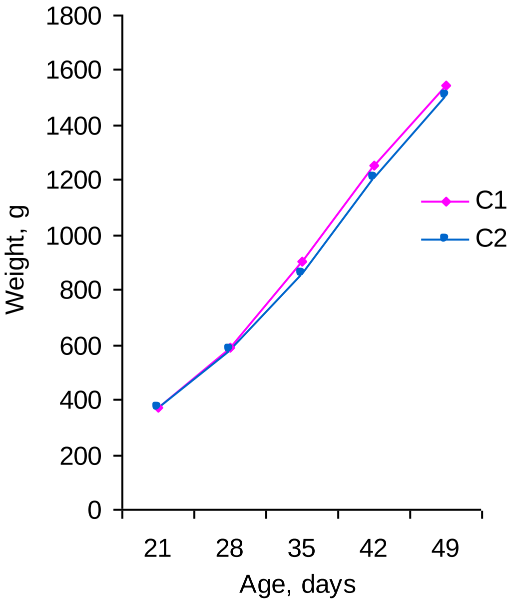


Figure 1. Growth curves of broilers fed with soybean meal diets



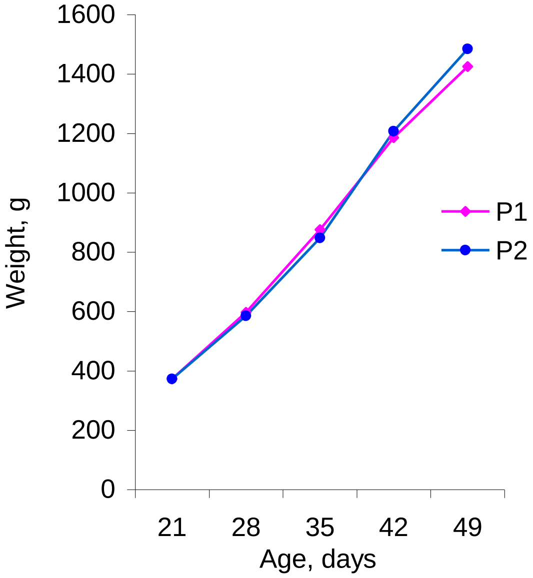


Figure 2. Growth curves of broilers fed with cotton meal diets.

Figure 3. Growth curves of broilers fed with palm meal diets

Economics of feeding

The feed cost (FC), and the economic feed efficiency (EFE) which is the revenue got from the body weight gain by investing a unit of money in feed cost, are shown in Table 8.

Table 8. Feed cost (FC) and Economic feed efficiency (EFE)

	Phases	Diets						SE
		S1	S2	C1	C2	P1	P2	
FC, €/kg WG[1]	Starter	0.563^{a}	0.729^{b}	-	-	-	-	0.004
	Grower	0.686^{abc}	0.773^{b}	0.633^{c}	0.669^{ac}	0.762^{ab}	0.698^{abc}	0.007
EFE, € WG/€ feed	Starter	2.90^{a}	2.20^{b}	-	-	-	-	0.05
	Grower	2.36^{abc}	2.11^{b}	2.61^{c}	2.45^{ac}	2.19^{ab}	2.35^{abc}	0.02

[a b c] Means with unlike superscripts in the same row differ significantly (P < 0.05)

[1] Body weight gain

At the starter phase, the FC and the EFE in diet S2 were respectively higher and lower ($P < 0.001$) than in diet S1. However, at the grower phase, the processing technology did not affect significantly both variables ($P > 0.05$), while the effect of diet was significant. Comparing overall six diets used at grower phases, FC was significantly lower in C1 than in S2 and P1, while it was the opposite for EFE. The lowest FC (in C1) represented about 82% of the highest one (in S2). Also at starter phase, FC in S1 was 77% of that in S2. Independently to the soybean meal, FC and EFE were better during the starter phase than the grower phase, indicating a better economic productivity at the earlier growth phase of broilers Red Bro.

Balance experiment

The results of balance experiment are presented in Table 9 and 10.

Table 9. Daily intakes of water, nutrients, gross energy (GE) and metabolisable energy (ME); body weight and daily body weight gain of broilers during the balance experiment

	Grower Diets						
	S_1	S_2	C_1	C_2	P_1	P_2	SE
Water drunk, ml, g	265	312	294	275	322	252	1.53
Total water intake, ml, g	280	328	309	289	338	266	1.54
Feed intake, g DM[1]	115^{a}	122^{a}	117^{a}	104^{b}	109^{ab}	102^{b}	0.214
Organic matter intake, g	107^{ab}	112^{b}	109^{ab}	95^{c}	100^{ac}	94^{c}	0.198
Fat intake, g	7.31^{a}	10.9^{b}	6.28^{c}	6.56^{c}	6.89^{ac}	7.54^{a}	0.014
Nitrogen intake, g	4.02^{ab}	3.79^{a}	4.44^{b}	3.62^{a}	4.21^{b}	3.68^{a}	0.008
Nitrogen retention, g	2.22^{ac}	2.06^{ac}	2.61^{b}	2.00^{c}	2.34^{ab}	2.06^{ac}	0.007
Crude fibre intake, g	3.66^{a}	4.24^{b}	4.75^{c}	4.89^{c}	6.35^{d}	4.91^{c}	0.010
NFE[2] intake, g	70.4^{a}	72.8^{a}	69.7^{a}	61.3^{b}	60.6^{b}	58.9^{b}	0.125
Carbohydrate intake, g	74.0^{a}	77.1^{a}	74.5^{a}	66.2^{b}	67.0^{b}	63.8^{b}	0.135
GE intake, MJ	2.08^{ab}	2.25^{a}	2.17^{a}	1.96^{b}	2.04^{ab}	1.95^{ab}	0.004
ME intake, MJ	1.67^{ab}	1.77^{b}	1.70^{b}	1.52^{c}	1.56^{ac}	1.51^{c}	0.003
Initial body weight gain, g	1665^{a}	1723^{b}	1726^{b}	1675^{ab}	1645^{a}	1650^{a}	1.16
Final body weight, g	1821^{a}	1964^{b}	1860^{a}	1800^{a}	1794^{a}	1775^{a}	1.88
Daily body weight gain, g	39.1^{a}	60.1^{b}	33.4^{a}	31.3^{a}	37.2^{a}	31.3^{a}	0.301

[1] Dry matter

[2] Nitrogen free extract

[a b c d] Means with unlike superscripts in the same row differ significantly (P < 0.05)

Table 10. Daily nitrogen intake (NI), nitrogen retention (NR); daily intakes of gross energy (GE) and energy metabolisable energy (ME) per metabolic body size ($kg^{0.75}$) of broilers

	Grower Diets						
	S1	**S2**	**C1**	**C2**	**P1**	**P2**	**SE**
NI, g / $kg^{0.75}$*	2.64^{ac}	2.39^{b}	2.86^{c}	2.39^{b}	2.80^{c}	2.46^{ab}	0.005
NR, g / $kg^{0.75}$	1.45^{acd}	1.30^{ac}	1.68^{b}	1.32^{c}	1.56^{bd}	1.38^{acd}	0.004
NR / NI	0.54	0.54	0.59	0.55	0.56	0.56	0.001
GE intake, MJ/$kg^{0.75}$	1.37	1.42	1.40	1.29	1.36	1.30	0.002
ME intake, MJ/$kg^{0.75}$	1.10^{a}	1.12^{a}	1.10^{a}	1.00^{b}	1.04^{ab}	1.00^{b}	0.001
ME / GE	0.80^{a}	0.79^{b}	0.78^{c}	0.77^{d}	0.76^{e}	0.77^{d}	0.000

* *(Body weight in kg)* $^{0.75}$ *is the metabolic body seize*

$^{a\,b\,c\,d}$ *Means with unlike superscripts in the same row differ significantly ($P < 0.05$)*

The daily intake of water, nutrients and energy; the body weight and the weight gain were computed in the correspondent unit ml, g or MJ (Table 9), while for metabolism purpose nitrogen and energy were also computed in Table 10 per kg of metabolic body seize ($kg^{0.75}$). The results showed that the intakes of water (Table 9) and of gross energy (Table 10) were not significantly affected by the diet. However, significant effects of the diet were recorded on the intakes of feed, nutrients and metabolisable energy (ME) per day (Table 9) or per $kg^{0.75}$ (Table 10). When the feed intakes were similar (as in S1, S2, C1, P1), the use of expeller soybean meal (S2) resulted in a significantly high fat intake (Table 9). The daily nitrogen intake (NI in $kg^{0.75}$) was significantly affected by the processing technologies of all meals (Table 10). However, when NI was computed in g the effect of the processing technology was not significant (Table 9). The retained nitrogen represented 54 to 59% (56% on average) of the nitrogen intake and that ratio was not affected by diet ($P > 0.05$). The daily intakes of carbohydrate and nitrogen free extract (NFE) depended significantly on the processing technology of cotton meals, while the intake of crude fibre varied significantly according to soybean meals and palm meals processing technology (Table 9). The pattern of significant differences was similar for the intakes of carbohydrate and NFE. The intake of ME (Table 9 and 10) was significantly affected by the processing technology of cotton meal but not by that of soybean and palm kernel meals. However, the metabolisability of the energy (ME/GE) was significantly different ($P < 0.001$). The ratio ME/GE was between 76 and 80% (78% on average). The body weight gain of broilers fed expeller soybean diet was particularly high, while these broilers had the lowest growth performance during the whole growth experiment.

It can be concluded that, when the intakes of energy and nutrients were computed per $kg^{0.75}$ (Table 10), the daily NI was more affected by the processing technology of all types of meals than the intakes of energy and other nutrients.

Discussion

Composition of meals and diets

The high level of fat in meals S2 and P2 compare to S1 and P1 showed that the expeller processing is less efficient in oil extraction than the solvent processing. Similar results were reported by McDonald et al (2002), Smith (1996), Labier and Leclercq (1994). Moreover, the solvent processing seemed to be more efficient in the extraction of oil from soybean than from cotton seed and palm kernel because, although the meals were processed in the same factory, the fat content in respectively P1 and C1 was 3 and about 4 times higher than that in S1.

Due to the difference in processing technology farmers purchased gross energy and crude protein (CP) at high cost when they use respectively solvent meals and expeller meals. The market prices of meals were not therefore adapted to their chemical composition and particularly to the CP content, the bio-economic performances being significantly better with solvent soybean meal than expeller soybean meals. The high level of crude fibre (CF) in meal P1 showed that the raw material used in industry for solvent extraction might be affected by some agronomic factors or might contain more wastes (husk and hull) than that used in expeller processing. O'Mara et al (1999) reported that the nutrient content of palm kernel meal depended on the oil extraction process, the species of the palm nut and the amount of shell in the meal. The rate of CF in P1 (22%) was in the range 21 - 23% reported by Sundu et al (2006). CF being almost indigestible by broilers (Spesfeed 2006; Francesch et al 2002, Siri et al 1993), the use of P1 in diet for broilers without the use of additive (enzyme for example) improving the digestion of CF might be limited or avoided.

The cotton meals were profitable for providing both energy and crude protein in poultry diet in Benin. However, due to the probable effect of gossypol and the risk of aflatoxicosis, the used of cotton meals should be relatively low compare to soybean meal. McDonald et al (2002) and Labier and Leclercq (1994) stated respectively that a treatment of cotton meals with 1 - 4 and 1 - 2 part of ferrous sulphate to 1 part of gossypol can reduce its negative effects.

The differences between meals (Table 4) according to the processing technologies resulted in some variations in the composition of the diets (Table 5). Furthermore, the results of analyses (Table 5) showed some differences between the chemical compositions of the diets in ME, CP, fat, CF and the calculated values (Table 2). Thus, by using the chemical composition of feedstuffs from Institut National de la Recherche Agronomique (1989) without taking into account the processing technology of meals, a surplus or a deficit in ME, CP and other nutrients occurred in the formulated diets. These results confirmed the necessity to make a table of the chemical composition of feedstuffs used in each country by taking into account among other criteria the processing technology of their production.

Feed intake and feed efficiency

The result showed that the differences between the feedstuffs in the diets did not affect the daily feed intake (DFI) of broilers at both phases (Table 6), while these differences had significant effect on the feed conversion ratio (FCR) at starter phase. These results indicated that the efficiency of the diet depends on the age of broilers (Red Bro); starter broilers being more sensitive to the type of soybean meal than growers. The starter phase seemed to be therefore the most sensitive phase in broilers feeding. Two assumptions could be discussed to explain that result.

Firstly, the chemical analysis of diets (Table 5) showed that the difference between diets S1 and S2 in ME was higher at starter phase than at grower phase (respectively 0.8 versus 0.1 MJ/kg diet). In fact, the level of ME in diet is known to affect the feed intake of birds (Perry et al 2003; McDonald et al 2002; Smith 1996; Pond et al 1995; Labier and Leclercq 1994); but in this experiment the feed intakes were similar due maybe to the low difference in ME between diets at each phase. A cumulative effect of the energetic difference combined with the effects of nutrients on the body weight gain could explain the difference of FCR recorded between S1 and S2 at starter phase and not at grower phase.

Secondly, within factors affecting voluntary feed intake of birds, McDonald et al (2002), Smith (1996) and Pond et al (1995) reported that, in the short-term regulation, overall control of feed intake is influenced by the hypothalamus, while for the two first authors the long-term regulation is controlled by fat deposit. Thus, it seemed that, the activity of hypothalamus on the feed intake was not affected by the composition of the diets at both phases. Also, one can assume that the fatness of broilers might be similar irrespective of the diets, although no analysis of carcass was performed to estimate the deposition of the fat in the body.

The daily feed intakes in this experiment were lower than 108 - 123 g recorded by Yo et al (1997) with broilers (of breed Ross) in Ivory Coast. The FCR were higher than 2.1 (Yo et al 1997) and than 1.9 (Fasuyi and Aletor 2005), but were close to 2.4 reported in Nigeria by Odunsi et al (1999). The high FCR (2.7) found in diets S2 and P1 might be due respectively to the low content of crude protein and the high content of crude fibre in the corresponding meals and diets.

Growth and mortality

The difference between diets in energy and nutrients content might affect the growth performance of broilers. Thus, the final body weights (FBW) at the end of each phase were significantly different, although the daily body weight gains (WG) were similar. These results showed a cumulative effect of the diets on the growth of broilers at both phases. The cotton diets and the expeller diet P2 were as efficient as the solvent soybean diet (S1). The FBW were similar in both cotton diets suggesting that the efficiency of diets C1 and C2 was similar. Thus the raw material (cotton seeds) and the efficiency of the solvent processing technologies used in both industries for oil extraction in Benin were almost similar, although the light difference in fat content between meals C1 and C2. The soybean meals were heated during and after the expeller processing. However, the low performances recorded in S2 could be due to a high content of antitrysique factor that reduced the availability of amino acids (McNaughton 1981). Also, the opposite assumption should not be excluded as an extra heating might destroy the amino acids (Larbier and Leclercq 1994).

In general, the average body weights of broilers at d 49 of age were between 1374 ± 16.3 g (in S2) and 1543 ± 61.8 g (in C1). These FBW were lower than 1696 g reported at d 42 of age in Cameroon (Dongmo et al 2005), but were close to 1514 g reported in Côte d'Ivoire (Yo et al 1998) at d 42 of age. The differences between these references and the results of this experiment might be due to the breed effect, because the broilers Red Bro have a lower growth performance than the broilers Ross used by those authors. The reduction of the difference of live weight between S1 and S2 at d 28 (figure 2) is due to the mixing of chickens from both treatments at the end of starter phase (d 21).

The mortality rates (2.2 to 2.4%) recorded were lower than 3.3 to 6.7% reported by Eruvbetine et al (2003) in broilers Ross. No mortality of broilers occurred during the grower phase confirming that when the cotton meal was used at 10% in the diet with the addition of 3 g of ferrous sulphate per kg of cotton meal, no effect of gossypol was found on the mortality.

Economics of feeding

The feed intake was similar in all diet. Thus, the significant effects of diet on the feed cost (FC) and the economic feed efficiency (EFE) at both phases resulted from the differences in growth performances (Table 7) combined with the differences of diets prices (Table 2).

When comparing diets two by two, there was no significant effect of the processing technology of meals on FC and EFE at the grower phase. Although that, the use of a kind of meal instead of another might be less benefit at large scale of production. For example, per kg of live weight produced by using S2 instead of S1, farmers might expend respectively at starter and grower phases, 0.17 and 0.087 € more in feeding resulting in a loss of 0.7 and 0.3 € of revenue (EFE). Thus, at starter and grower phases about respectively 10 and 5% of the revenue might be expended as additional feed cost because of such practice.

As stated previously, the use of cotton meals in diet of broilers allowed the best FC and EFE, and consequently the highest benefit, other costs being similar in all dietary treatments. The feed cost found in C1 (0.663 € / kg WG) was almost the same as 0.643 € / kg WG reported by Dongmo et al (2005) in Cameroon with broilers Ross.

Balance experiment

Nitrogen intake (g/kg$^{0.75}$) was the most affected nutrient by the processing technology of all meals. Thus, at similar intake of ME, broilers fed solvent meals of soybean and palm kernel consumed and retained more nitrogen (crude protein) than those fed expeller meals. That result could explain why during balance experiment the daily body weight gain (WG) of broilers in P1 was lightly higher than that of broilers in P2, the initial body weight being similar. Thus, in short time the diet P1 was lightly more efficient than P2, while both diets had quite similar efficiency during the growth experiment. The significantly high weight gain (WG) in diet S2 might be due to a compensatory growth of broilers. That assumption is supported by the fact that, the broilers sampled at d 49 in diet S2 for balance experiment had the best body weight gain (the growth being the lowest in S2). Thus, they might have similar genetic potentials of growth, the sexual dimorphism effect being avoided in the experimental design. Apart from the specifically high WG in S2, the WG recorded in other diets during the balance experiment (31.3 to 39.1 g) were almost the same as those form the growth experiment at grower phase (35.8 to 41.4 g). Thus, up to two months-old (d 59), the broilers Red Bro continue to grow at quite uniform pattern (Figures 1 to 3).

According to McDonald et al (2002), the general relationship between food intake and energy requirement suggests that, as with energy, intake should vary not directly with live weight but with metabolic live weight ($W^{0.75}$). The results of this balance experiment showed that the broilers consumed similar amounts of gross energy per kg$^{0.75}$, while the ME intakes were significantly different. Consequently, the metabolizability of energy measured by the ratio ME/GE was significantly affected by the processing technology of meals. However, the ratio NR/NI neither was affected by diet, nor by the processing technology when comparing diet two by two. Similar result was reported by Hellwing et al (2005) on the metabolizability of nitrogen. It seemed that broilers have a better regulation in nitrogen (crude protein) metabolism than energy metabolism. Such a difference in regulation could be linked to the multiple sources of nutrients providing energy (carbohydrate, fat, crude protein, etc.), while nitrogen is a single nutrient. Thus, a variation in the pattern of the sources of energy might affect metabolism. In this experiment, such a variation was basically due the difference in fat content of meals, expeller meals being more concentrated in fat than solvent meals. The similarity of ME intake in soybean diets and palm diets irrespective of the level of fat in the diet suggested that the behaviour of broilers regarding energy intake depended more on the total energy content than the sources of energy. That result confirms why the feed intake of broilers is often reported to be regulated by the energy content simply and less by its sources. For example, McDonald et al (2002) and Smith (1990) reported that the major dietary factor which affects food intake is the concentration of energy in the diet, an increase of dietary energy results in a decrease in food intake; while Institut National de la Recherche Agronomique (1989) stated that the feed intake of birds is less dependent on crude protein content than energy content.

Conclusion

- This experiment showed that in Benin, the processing of soybean meal mainly had significant effects on bio-economic performances of broilers. That situation resulted from a disparity in feed efficiency due to the significant effect of the processing technology on the daily intake of nitrogen (g/kg$^{0.75}$), and on the metabolizability of energy, while prices of meals were similar, so irrespective of their nutritional quality.

- Thus, at large scale of production the benefit of farmers might be low when they used expeller meal instead of solvent meal of soybean. It is therefore necessary to have a table of the composition of the local meals in nutrients and energy in the aim to define their market prices accordingly.

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