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Is the nutritional value of grains in broiler chickens' diets affected by environmental factors of soybean (*Glycine max*) growing and the variety of maize (*Zea maize*) in Benin?

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Abstract

A six-week experiment was carried out in Benin to evaluate under tropical conditions the variation in nutritional value of soybean and maize grains due to, respectively, environmental factors and the plant variety. Two soybean grains of the same variety (Jupiter) but grown in two agro-ecological zones and two varieties of white maize grains (Local and DMR-ESRW) produced in the same environmental conditions were compared. These grains were used in four balanced diets for unsexed broiler chickens (Red Bro) from 8 to 49 days of age.

Per kg of dry matter (DM), a difference of about 0.396 MJ of metabolisable energy and 27 g of crude protein content were found between varieties of maize. Crude protein content was identical in both soybean grains, while a difference of 16 g/kg DM was found between them in crude fibre content. In spite of these differences in chemical components, there was no significant effect ($P > 0.05$) of the grains' origin or variety on the growth performance of chickens. The daily feed intake, the daily weight gain, the feed conversion ratio and the final body weight of chickens at 28 and 49 days of age were similar between diets. In addition, the partial substitution of maize by soybean grains to supply mainly the dietary energy did not show an adverse effect of the diet on these variables. However, the variety of maize affected significantly the feed cost and the economic feed efficiency at starter phase.

It can be concluded that under the particular conditions of this experiment, the environmental factors did not change significantly the nutritional value of soybean grains in chickens' diets. The grains of local variety of white maize were suitable at all ages, whereas the grains of DMR-ESRW were more economic in grower than starter broiler chickens feeding.

Keywords: *Benin, Broilers, Environmental factors, Plant variety, Maize, Soybean*

Introduction

Maize and soybean are the most cops used as ingredients in poultry diets in Benin. One variety of soybean (Jupiter) and many varieties of maize are cultivated. Local varieties constitute the most part of maize production. However, there are many improved varieties of maize within which the most adopted by farmers is DRM-ESRW. In the Southern of Benin there is a subequatorial climate (two dry and two wet seasons), whereas the Northern is characterized by a Sudanese climate (a dry and a wet seasons). The fertility of soils is not similar everywhere and the use of fertilizer is seldom.

It is often reported that crops' composition varies according to several factors. The chemical composition of maize can vary substantially from batch to batch resulting in considerable variation in its energy value for poultry (Cowieson 2005). According to Barbour et al (2008), corn grain imported by feed mills is higher in moisture by 27% and lower by 10.6, 17.6, and 15.4% in protein, fat, and fibre, respectively, than that of premium corn reported by National Research Council (1994). Feil et al (2005) found that the mineral content of tropical grains of maize was not affected by the water regime, while there were significant differences in the content of nitrogen and minerals (P, K, Mg, Ca, Mn, Zn and Cu) between varieties. An increase of protein and lysine content with an increasing level of soil nitrogen was reported in two varieties of maize, and chickens fed opaque-2 corn grew significantly faster than those fed normal corn (Cromwell et al 1983). Keeney (1970) reported similar among of amino acid composition in protein of four maize grain varieties; but he specified that an increase of the protein content of maize grain by fertilizer treatment appeared to adversely affect the essential amino acid balance. McDonald et al (2002) reported a nutritional superiority of Opaque-2 compared to normal maize for rat, pig and young chicken fed methionine supplemented-diets, while Floury-2 variety having increased contents of both methionine and lysine and had been shown to be superior to Opaque-2 in chickens' feeding. Regarding soybean, investigations on the effects of the environmental factors on the nutritional value of its grains in animal feeding are seldom. However, significant variation of total carbohydrate, oil and protein according to the variety and the environment was found in soybean grains by Wilcox and Shibles (2001). Earlier, Kuiken and Lyman (1948) studying meals from twenty strains, reported that since soybean culture is limited to Corn Belt states (in USA), variations which result from environmental conditions probably have little effect on the protein content and composition of commercial soybean meals.

The purpose of this study was to evaluate in feeding of broiler chickens, the eventual variation in nutritional value of soybean grains caused by environmental factors and that of maize grains linked the effects of plant variety in the tropical conditions of Benin.

Material and method

Ingredients and diets

Two varieties of white maize grains and two soybean grains of the same variety (Jupiter), but produced in two different agro-ecological zones (Northern and Southern) were compared. Both varieties of white maize were produced in similar soil. The yield of the local variety of maize (ML) named "gbogboé" is between 1 and 2.5 tons/ha, while the variety DMR-ESRW of maize (MI) is an improved population which yields 3.5 to 5 tons/ha (FAO 2008). The grains of these crops were used in the corresponding diets (Table 1). Soybean grains were toasted before the processing of diets to destroy the trypsin inhibitor which reduces the digestion of amino acids.

Table 1. Origins of soybean, varieties of maize and the corresponding diets

Ingredients	Soybean Southern	Soybean Northern	Maize Local*	Maize Improved**
Diets	SS	SN	ML	MI

** The local variety is named "gbogboé"*

***The improved variety is named DMR-ESRW*

Diets were formulated to meet the requirements of National Research Council (1994) by using the chemical compositions of feedstuffs reported by Institut National de la Recherche Agronomique (1989). The solver of Microsoft Excel (Thomson and Nolan 2001) was used for diet formulation. The Table 2 shows the composition of diets. The market prices of grains for feed were irrespective of the variety and the agro-ecological zone of production. During the experimental period (May-June, 2008) the prices of soybean and maize grains were 396 and 374 €/ton respectively. Due to the similarity between these prices added to the high energy content in soybean grains, their used in SS and SN diets decreased the level of maize by 10 and 9% in starter and grower diets respectively compared to the corresponding ML and MI diets. However, adjustments in the main protein and mineral sources were necessary (Table 2). As consequence, feed prices were lower in SS and SN diets than in ML and MI diets.

Table 2. Ingredients, prices and chemical composition of diets as formulated

Ingredients / Nutrients	Starter diets*		Grower diets*	
	SN , SS	ML , MI	SN , SS	ML , MI
Ingredients (% of diets as fed)				
Maize grain	50	60	54	63
Soybean grain	22	-	20	-
Soybean meal	-	27	-	25
Cotton meal [1]	10	-	7	-
Fish meal	7	7	6	6
Wheat bran	8	3	9.9	3
Oyster shell	1.65	1.75	1.65	1.65
Salt (NaCl)	0.20	0.30	0.30	0.20
Lysine	0.10	0.10	0.10	0.10
Methionine	0.30	0.30	0.30	0.30
Bi-calcium phosphate	0.50	0.30	0.50	0.50
Premix[2]	0.25	0.25	0.25	0.25
Prices (€/ton of diet)	352	357	345	351
Chemical compositions (Per kg dry matter)				
ME[3] (MJ)	12.6	12.1	12.8	12.2
Crude Protein (g)	214	209	195	199
Crude fat (g)	71.0	36.3	64.5	35.8
Crude fibre (g)	44.9	35.7	46.0	34.7
Lysine (g)	14.6	13.1	12.9	12.6
Methionine (g)	6.4	6.3	6.0	6.1
Methionine + Cystine (g)	9.4	8.1	8.8	7.8
Calcium (g)	12.1	12.1	11.4	11.6
Total Phosphorus (g)	7.6	6.6	6.3	6.6
Phosphorus available (g)	3.9	3.2	3.4	3.3

**Diets containing: Northern soybean (SN), Southern soybean (SS), local maize (LM), improved maize (MI)*
[1]*Ferrous sulphate ($FeSO_4$) 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]*Metabolizable energy*

Animals and housing

Initially, 250 chickens one-day-old (mixed sexes) of breed Red Bro were purchased in a hatchery in Benin. At their arrival the average weight per chicken was 33.5 ± 3.4 g. Chickens were kept on deep litter in a starter room and were fed the same diet during a week (d 1 to 7). At seven-day-old, 240 chickens were splited in twelve randomized replications of 20 chickens each. The replications (experimental unit) were divided in three blocks. Hence, per block there was one replication per dietary treatment. Thus, a completed randomized block was used. The replications were maintained during the six weeks of experiment. At the start of the experiment the average body weights (g/chicken) were similar between diets ($P > 0.05$). The experimental design is summarized in Table 3.

Table 3. Experimental design

Diets*		SS	SN	ML	MI
Replication per block**		1	1	1	1
Replications per diet		3	3	3	3
Chickens in replications per diet		60	60	60	60
Body weight at start (g)	Means	75.1	75.1	75.1	75.3
	SE	0.09			

**Diets containing: Northern soybean (SN), Southern soybean (SS), local maize (LM), improved maize (MI)*

***There were 3 blocks of 4 replications each*

During the first 3 weeks of experiment (d 8 to 28), chickens were in a starter room provided with heating and lighting. The heating was stopped after a week. The temperatures recorded in the room were between 27 and 34^{o}C, while the relative humidity varied from 64 to 83%. The density of chickens on litter was 15 chickens/m^2 at the starter phase.

At 29 days of age (d 29), chickens were moved from the starter room to pens under natural light for the grower phase. During the following 3 weeks, chickens were kept in 12 pens (replications) until d 49. In pens, the temperatures were between 26 and 32^{o}C, while the relative humidity varied from 77 to 91%. On average, there were 6 chickens/m^2 at the grower phase. During the experiment the body weight of chickens was recorded weekly.

Feeding

Each diet was given to chickens in 3 random replications. Starter and grower diets were used to feed chickens from d 8 to 28 and from d 29 to 49 respectively. At the beginning of the grower phase, the starter diet was progressively substituted by the grower diet at the respective daily rates of 33, 67 and 100%. Chickens were fed *ad libitum*. They had also free access to drinking water. Daily, the quantity of feed gave and the residues of feed were recorded per replication.

Analytical procedures

Soybean and maize grains were analyzed in the laboratory of the Faculty of Life Sciences, University of Copenhagen in Denmark. Dry matter (DM) was determined by evaporation of water at 105 ºC. Ash was got by burning the material at 525 ºC. Nitrogen (N) content was estimated by Kjeldahl technique. Then, crude protein (CP in %) was calculated as N x 6.25. The method of petroleum ether extraction after hydrochloric acid (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). First the sample were defatted using acetone, then sulphruric acid, 1.25 % and sodium hydroxide, 1.25 % were used to isolate the crude fibre.

Calculations

Larbier and Leclercq (1994) reported 74.6 and 84.2% as the part of maize grains' gross energy (GE) that is metabolizable by young and adult chicken respectively. Thus, the content of metabolisable energy (ME) in grains of maize was estimated assuming that on average about 80% of GE was metabolisable by broiler chickens: ME = 0.8GE.

The economic feed efficiency (EFE) was calculated by the following formula:
EFE (€ WG / € feed) = Revenue from WG/Feed cost (Houndonougbo et al 2008a)
Where, WG is the body weight gain and feed cost is the amount invested in feeding.

Statistical analyses

The general linear model (GLM) was used to analyze data in SAS Institute Inc. (2004). Mean values are shown in tables with the pooled standard error. Significant effect of diets is stated when P-value (P) is less than 0.05. The effect of replications and of the interaction between diets and replications were not significant (P > 0.05). Hence, the following model was used:

$$Y_i = \mu + G_i + \varepsilon_i$$

Where, Y_i is the observation for dependent variables, μ is the general mean, G_i is the fixed effect of soybean or maize grains and ε_i is the residual error.

Results

Composition of soybean and maize grains

The chemical composition of soybean and maize grains are presented in Table 4. The soybean grains from the Southern (SS) had about 1.5 MJ/kg DM of gross energy (GE) content more than grains from the Northern (SN). Both SS and SN grains had the same content of crude protein (CP). However, a difference of 16.1 g of crude fibre/kg DM was found between them; the content of crude fibre being higher in SS than in SN grains. Regarding maize grains, the main difference was found in crude protein. Per kilogramme of DM, the local variety of maize (ML) had 26.9 g of CP and 0.4 MJ of metabolizable energy more than the improved variety (MI). As the price of the grains for feed was irrespective of the origin and the variety, the cost of CP from MI grains was 1.3 time that from ML grains. However, the cost of ME was nearly the same in both maize grains. The difference of GE cost was low (11 €/10^4 MJ) between soybean grains (Table 4).

Table 4. Chemical composition of soybean and maize grains (per kg of dry matter); cost of crude protein (CP), gross (GE) and metabolizable (ME) energy in grains

	Soybean grain*		Maize grain*	
	SS	SN	ML	MI
Dry matter (g)	930	880	900	900
Total ash (g)	55.9	54.5	14.4	14.4
Crude Protein (g)	449	449	118	91.1
Crude fat (g)	196	198	47.6	47.8
Crude fibre (g)	83.4	67.3	19.0	21.1
GE (MJ)	22.5	21.0	19.0	18.5
ME ((MJ)			15.2	14.8
CP cost (€ 10^{-4}/g CP)	8.5	8.5	32	42
GE cost (€ 10^{-4}/MJ GE)	170	181		
ME cost (€ 10^{-4}/MJ ME)			250	257

**Grains evaluated: Northern soybean (SN), Southern soybean (SS) local maize (LM), improved maize (MI)*

Feed intake and feed efficiency

The daily feed intake (DFI) and the feed conversion ratio (FCR) of broiler chickens are shown in Table 5. Neither the agro-ecological zone of soybean growing, nor the variety of white maize had significant effect on these variables at both phases. However, DFI of chickens fed with SS diet became higher than that of chickens fed with SN diet from the fifth week of age until the end of the experiment (Figure 1). The difference of DFI between ML and MI diet was more remarkable during week 4 and 6 of age. The pattern of DFI in all four diets showed an inflexion in the first week of the grower phase (d 29 to 35).

Table 5. Daily feed intake (DFI) and feed conversion ratio (FCR) of broilers

		Diets*				SE	P-value
	Phases	SS	SN	ML	MI		
DFI (g)	Starter	61.7	63.0	59.6	62.1	7.49	0.99
	Grower	109	105	106	104	7.21	0.96
	Overall	85.5	83.8	82.9	83.2	7.39	0.99
FCR (g feed / g WG[1])	Starter	2.36	2.17	2.20	2.47	0.09	0.10
	Grower	2.29	2.52	2.33	2.25	0.10	0.28
	Overall	2.32	2.34	2.26	2.36	0.07	0.81

**Diets containing: Northern soybean (SN), Southern soybean (SS), local maize (LM), improved maize (MI)*

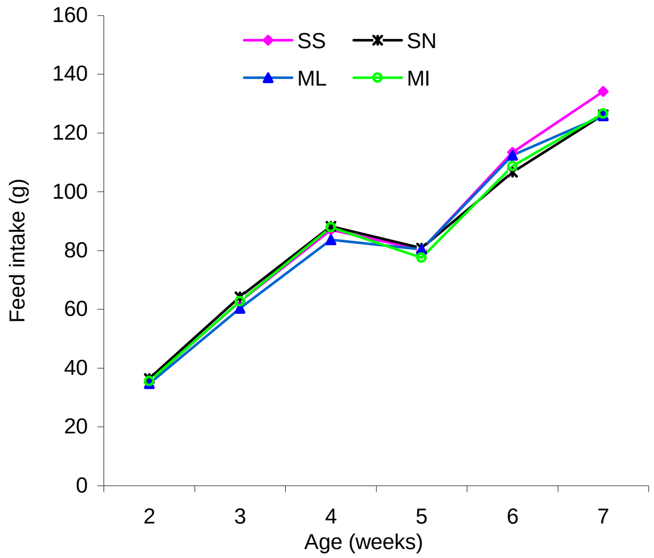

Figure 1. Daily feed Intake of chickens fed diets containing soybeans from Northern (SN) and Southern (SS) and varieties of local (ML) and improve (MI) maize

Growth and mortality

The agro-ecological zone of soybean growing and the variety of maize had no significant effect on the daily weight gain and the final body weight (FBW) of chickens at the end of starter and grower phases (Table 6). Thus, the growth curves of chickens were similar (Figures 2 and 3). At seven-week-old (d 49), chickens fed SN diet had about 96% of the body weight of those fed SS diet, whereas that ratio was 98% between respectively the weight of chickens fed MI and ML diets. Carcass quality was not investigated. Mortality rates were similar at starter phase (0.8 to 1.1%) and there was no mortality at grower phase.

Table 6. Daily body weight gain (WG) and final body weight (FBW) of broilers

	Phases	Diets*				SE	P-value
		SS	SN	ML	MI		
WG (g)	Starter	26.0	29.1	26.4	24.8	2.88	0.76
	Grower	48.0	41.7	46.3	46.6	3.02	0.50
	Overall	37.0	35.4	36.4	35.7	3.11	0.98
FBW (g)	Starter	621	685	630	596	23.7	0.13
	Grower	1628	1562	1603	1575	16.8	0.09

**Diets containing: Northern soybean (SN), Southern soybean (SS), local maize (LM), improved maize (MI)*

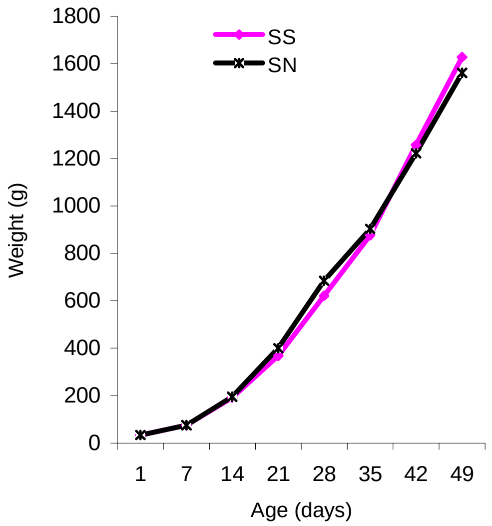

Figure 2. Growth curves of chickens fed diets containing soybeans from Northern (SN) and Southern (SS)

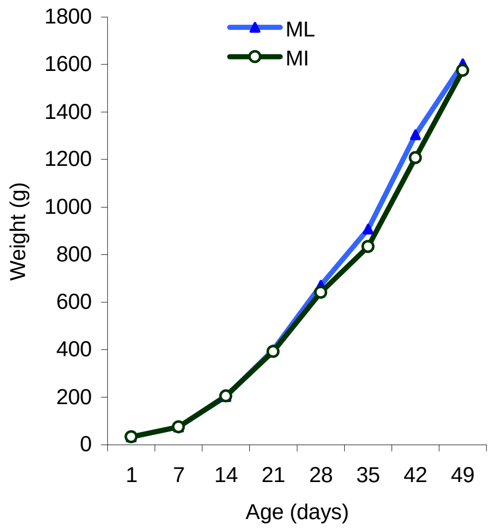

Figure 3. Growth curves of chickens fed diets containing local (ML) and improved (MI) maize

Economics of feeding

At the starter phase, the feed cost (FC) was significantly higher in diet containing MI maize (Table 7). Hence, the economic feed efficiency (EFE) was significantly lower in MI diet at this phase. Compared to ML diet, the MI diet increased FC by about 12% and reduced EFE by 12% at the starter phase. However, no significant effect of soybean and maize grains on FC and EFE was found at grower phase or when data of both phases were pooled into an overall mean. The lowest overall FC and the highest overall EFE were found in SS diet. The overall FC was lower by 7.7% and EFE was higher by 8.3% when FC and EFE recorded in MI diet were compared to the values from SS diet. Thus, the partial substitution (9 to 10%) of maize by soybean improved the economic results. In this experiment, FC and EFE were not better at the starter phase compared to the grower phase as expected.

Table 7. Feed cost (FC) and economic feed efficiency (EFE) of broilers

	Phases	Diets*				SE	P-value
		SS	SN	ML	MI		
FC (€ / kg WG[1])	Starter	0.849[a]	0.779[a]	0.846[a]	0.950[b]	0.036	0.02
	Grower	0.808	0.890	0.877	0.846	0.038	0.45
	Overall	0.829	0.835	0.861	0.898	0.027	0.26
EFE (€ WG / € feed)	Starter	1.91 [a]	2.06 [a]	1.94 [a]	1.71 [b]	0.08	0.02
	Grower	2.01	1.81	1.89	1.90	0.08	0.38
	Overall	1.96	1.93	1.92	1.81	0.06	0.25

**Diets containing: Northern soybean (SN), Southern soybean (SS), local maize (LM), improved maize (MI)*
[a b] Means with unlike superscripts in the same row differ significantly ($P < 0.05$)
[1]Body weight gain

Discussion

Composition of grains, intake and efficiency of diets

The nutritional value of maize for poultry depends on the content of starch, oil, protein and anti-nutritional factors primarily phytase, enzyme inhibitors and resistant starches (Cowieson 2005). The energy content being quite similar between maize grains, ML and MI diets were therefore iso-energetic. This might explain the similar daily feed intake (DFI) in these diets as chickens regulate their intake according to mainly the energy content of the diet (McDonald et al 2002, Pond et al 1995). Regarding the intake of SS and SN diets it seems that the higher crude fibre content in SS reduced its metabolizability. Thus, no effect of the gross energy difference between soybeans was noticed on DFI. Crude protein (CP) contents of both maize varieties were different. However, they were between 90 to 140 g/kg DM (McDonald et al 2002). Similar feed conversion ratio was noticed were between ML and MI diets despite the CP difference between maize. This could be linked to the lower contribution of maize in the total dietary CP. In starter and grower ML and MI diets, maize supplied respectively 26 and 29% of the total CP, whereas soybean meal supplied 55 and 54%. However, these maize's contributions in dietary CP were higher than 20% (Cowieson 2005). The results suggested that in soybean-maize based diet, a partial substitution of the sources of energy (maize grain by soybean grain) allowed to keep feeding behaviour of chickens and the efficiency of feed. Houndonougbo et al (2008b) reported such a feeding behaviour when comparing six qualities of meals. However, these authors specified the variation of the metabolizability of dietary energy according to the source of energy. In case of significant increase of maize price (basic human food in many African countries), the approach of ingredients substitution evaluated in this study can be adopted to reduce feed cost in broilers farms. However, the bio-economic optimum rate of substitution of maize should be investigated carefully by category of poultry and according to the production system because the oil in soybean grain has a laxative effect and may cause soft body fat (McDonald et al 2002). Such a feeding strategy could therefore affect poultry's metabolism and fatness which constitutes a high risk in layers mainly, and consequently the quality of the products (meat carcass, eggs, edible visceral organs, etc.).

The overall DFI in all four diets were close to 83 g (Yo et al 1998), but higher than to 79.7 g reported in Benin with broilers Ross 308 (Houndonougbo et al 2008a). Also, the overall FCR were similar to 2.29 (Obun et al 2008), but higher than 1.95 (Houndonougbo et al 2008a). The inflexion of DFI in the fifth week of age might be the consequence of the switch of diet and housing. The management of feed and the housing are therefore crucial in broilers keeping. Fortunately, that change in feed intake did not affect significantly chickens' growth curves.

Growth performance and economics of feeding

The growth performance was evaluated by the daily weight gain and the final body weight. These variables were similar between diets. This was confirmed by the similar pattern of growth curves. However, economically some differences were noticed. Thus, at starter phase, feed cost (FC) and economic feed efficiency (EFE) in MI diet were, respectively, significantly higher and lower than those found in other three diets. These results showed the importance of bio-economic analyses in poultry feeding. They confirmed in certain extent why nutritional recommendations for poultry must be defined on the basis of economic results (Leclercq and Beaumont 2000). The differences in FC and EFE can be linked to the identical feed price between, respectively, soybean diets and maize diets, combined with a cumulative effect of the lower nutritional value of DMR-ESRW maize for young chickens which could be due to the lower content of protein and probably a lower metabolizability of nutrients in that maize. The effect of DMR-ESRW on feed efficiency in young chickens could be therefore higher if the experiment started at d 1 instead of d 8. Grains of DMR-ESRW may contain high content of many components which reduce nutrients and energy metabolizability. The components could be the water insoluble starch by amylase (Carré 2004), the starch resistance (Brown 1996) or anti-nutritional factors such as amylase inhibitor, phytin, trypsin inhibitor and lectins (Cowieson 2005; Eekhout and De Paepe 1994). Fat and protein are found on the surface of starch granules and may act as physical barriers to the digestion of starch as well as a high amylose content which is associated with reduced digestibility (Svihus et al 2005). However, in the present investigation, the content of fat and protein were lower in MI than ML grains. A negative relationship between hardness of grains and starch digestibility was demonstrated by Carré et al (2007) in wheat. Hence, the low nutritional value of DMR-ESRW grains in young chickens feeding could also be due to a probable hardness of these grains. Further research is therefore needed to evaluate an eventual increase of the metabolizability of DMR-ESRW grains by young chickens. This could be done by using exogenous enzymes such as xylanase, amylase, protease and phytase. Such a practice was stated as an effective strategy to improve the body weight gain, FCR and flock uniformity of broiler chickens (Cowieson 2005).

The overall WG recorded in all dietary treatments were higher than 30.3 g reported in Nigeria by Obun et al (2008), whereas the final body weights at d 49 were close to 1696 g (Dongmo et al 2005). In this experiment, FC were higher than the maximum values 0.729 and 0.773 €/kg WG found by Houndonougbo et al (2008b) at starter and grower phases respectively using the same breed of chickens during a study carried out in the prior year. Comparing 0.773 €/kg WG with 0.890 €/kg WG recorded in SN diet (at grower phase), one can infer an inflation rate of 15% per annum on FC, whereas in the same period the price of chickens' live weight increased by only 5%. Apart from the lower EFE in MI diet at starter phase, the overall bio-economic results of this experiment demonstrated that in broilers feeding the nutritional value of soybean and maize grains did not depend on the environmental factors and the variety respectively. Hence, there is no need of price differentiation between these grains according to, respectively, the origin and the variety. Smith (1996) stated that the development of poultry industry has been possible in the last forty years only because for most of that period there has been a surplus of grains in Western countries. The DMR-ESRW maize having high yield, farmers can be advised and motivated for its production to supply at least the market of feeds. Thus, price of maize could decrease allowing a reduction of feed cost in Benin and other West African countries (Nigeria, Ivory Coast, Burkina Faso, Mali, Togo, Ghana and Senegal) reported by FAO (2008) as production areas of DMR-ESRW. However, further research should be done on the storage ability/conditions because according to Lawal et al (2004) the majority of farmers (68%) interviewed in Nigeria adopted DMR-ESRW maize and about 83% of them stated the storage problem as a constraint associated with its use. Considering the variables FCR, FC and EFE, the age of starter chickens (d 8 *versus* d 1 as usual) affected negatively the superiority of feed efficiency reported at starter phase compared to grower phase independently of diet quality (Houndonougbo et al 2008a).

Conclusion

This experiment demonstrated that in Benin the nutritional value of soybean grains for broilers feeding did not depend on the agro-ecological zone of production. Also, apart from the lower nutritional value of the grains of DMR-ESRW maize for starter chickens compared to growers, this improved variety was suitable for broilers feeding. The use of DMR-ESRW maize could become economic if the increase of its production results in a decrease of the market price of maize grains. However, further investigations on the metabolisability of DMR-ESRW grains should be done to determine the causal factors responsible of the lower performance of young chickens, and how to avoid these factors. The optimal age of chickens from which the negative effect of DMR-ESRW grains is negligible could be also focused.

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