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Effect of grasshopper meal on laying hens' performance and eggs quality characteristics

NOURI BRAH[1], SALISSOU ISSA[2] and FRÉDÉRIC M HOUNDONOUGBO[3]

National Institute for Agricultural Research of Niger, BP 429 Niamey, Niger
and
University of Abomey Calavi, Republic of Bénin, BP 03 BP 256 Cotonou, Bénin

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ABSTRACT

The purpose of this study was to investigate the potential effects of gradually substituting fish meal by grasshopper meal in laying hens diets. Laying performance and egg quality were evaluated during 4 months on 140 laying hens ISA Brown of 20–week age with an average initial body weight of 1,386±10 g at the beginning of the experiment. Layers were fed 5 diets in which fish meal was gradually replaced by grasshopper meal. The hens were randomly allotted into 20 pens with 4 pens (repetitions)/feed and 7 hens/pen. The fish meal (FM) was replaced by the grasshopper meal (GM) in the proportion of 0, 25, 50, 75 and 100% to obtain G0 (Control), G25 (25% GM + 75% FM), G50 (50% GM + 50% FM), G75 (75% GM+ 25% FM) and G100 (100% GM+ 0% FM). During the 4 months experiment lasted, laying rate, daily feed intake, feed efficacy and efficiency, eggs weight and shape index, albumen height and egg shell thickness were statistically insignificant (P>0.05) for all birds. In addition, diets containing grasshopper meal (G25, G50, G75 and G100) improved egg yolk colour and Haugh unit compared to the control diet (G0). Therefore, Niger poultry farmers could replace fishmeal by grasshopper meal in the diets of laying hens.

Key words: Egg quality, Fish meal, Grasshopper meal, Hens, Laying performance

The development of poultry production was very fast during last 2 decades in the developing countries, especially in Sub-Saharan Africa (Téguia *et al.* 2002). The availability of grain and protein for the formulation of poultry feeds is a major constraint for this development (Daghir *et al.* 2008). In addition, poultry feed represents over 70% of variable cost of meat and egg production (Oladokun and Johnson 2012). Maize (corn) is the most commonly energy source used in poultry diet, while the main protein sources are fishmeal and legume meal. Almost all developing countries import these ingredients, and poultry feed industries in Africa and Asia depends on imports, which are a draining their foreign exchange reserves (Ravindran 2013). Indeed, maize and protein comprise up to 80% farm-made diet (Teguia and Beynen 2005). But alternative raw material can be used to reduce poultry feed cost (Houndonougbo *et al.* 2012), without compromising laying hen performance (Farrell 2005).

Present adress: [1]PhD Scholar (brahnouri@yahoo.fr), National Institut of Agricultural Research of Niger (INRAN), Maradi, Niger. [2]Scientific Director and Head-Animal Nutrition (salissouissa@yahoo.fr). [3]Associate Professor (fredericmh @gmail.com), School of Animal Science and Technology, Faculty of Agronomic Sciences.

In Niger, sorghum or millet is used to replace corn in poultry feeds (Issa *et al*. 2015, 2016). However, fish meal supply is a main constraint in poultry feeding (FAO 2009). Insects can be used as a replacement for fish meal and fish oil in animal diets (Van Huis 2012). Locust and grasshopper have a great potential as a more affordable source of protein (Kenis *et al.* 2014). Grasshopper which is known to have a high capacity for damaging crops, thus causing big economic losses could be used as feed ingredient (Hassan *et al.* 2009) especially in Niger. Its amino acids composition is an advantage for poultry feed, especially the content in lysine, methionine and cysteine (Wang *et al.* 2005). In addition, grasshopper contains significant amount of several carotenoids. These carotenoids are sources of vitamin A, and may play important roles in yolk coloration, immune response, and reproduction in insectivores (Finke 2015). Grasshopper and locust were used in broiler diets (Hassan *et al.* 2009, Adeyemo *et al.* 2008). Their utilisation in layer hen's diets in Niger would contribute to reduce feed cost and improve egg quality. Thus, the objective of this study was to evaluate the effect of fish meal substitution by grasshopper meal in laying hens diets.

MATERIALS AND METHODS

Ingredients and experimental diets: Yellow corn, wheat bran, peanut meal, fish meal, grasshopper meal, bone meal, salt, premix and peanut oil were used in the diets formulation (Table 1). Grasshopper is a commercial product in Niger. The species used in the present study (*Ornithacris cavroisi*) is the main commercial species. All of the ingredients were purchased at the local market. Grasshopper and fish were ground separately to obtain the meal.

The control diet was corn-based with fish meal and peanut meal as the primary protein supplements. The diet was formulated to 0.66 for Lysine, 0.30 for Methionine and 2,833 Mcal/kg for ME (NRC 1994). The fish meal (FM) was replaced by the grasshopper meal (GM) on a wt/wt basis with treatments in the proportion of 0, 25, 50, 75 and 100% to obtain G0 (control: 0% GM + 100% FM), G25 (25% GM + 75% FM), G50 (50% GM + 50% FM), G75 (75% GM + 25% FM) and G100 (100% GM + 0% FM) (Table 1).

Experimental birds, management and design: ISA Brown laying hens (140), 20 week-old with an initial body weight of 1,386±10 g were randomly allotted into 20 pens. There were 7 pullets/pen, and 4 pens/treatment having groundnut hulls as beddings in a naturally-ventilated house with humidity at 24.6±0.4%, wind speed at 1.6±0.4 m/sec, and temperature at 28±2°C in the morning, 38±3°C at midday and 29±3°C in the afternoon.

The hens were vaccinated against common diseases including Newcastle and Gumboro diseases. They were prevented against coccidiosis, and anti-stress was giving during vaccination.

Chemical analysis: Samples of yellow corn, wheat bran, peanut meal, fish meal and grasshopper meal were taken and analysed for chemical analysis at Laboratory of food and Animal Nutritions, National Institute of Agricultural Research of Niger in Niamey, Niger. Analysis for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and ashes was performed according to the standard method of (AOAC 1995).

Data collection: The feed and water were offered *ad lib*. Feed offered and refusals per pen were recorded daily. The feed intake was determined by the difference of feed offered and refusals divided by the number of hens. Egg production was collected daily. Laying rate (as percentage) by month was determined as per NRC (1994).

$$\text{Laying rate} = \frac{\text{Number of eggs collected per month}}{\text{Number of hens present in that month}} \times 100$$

Feed conversion ratio (FCR) was calculated using two methods viz. FCR 1 (gram feed/egg) and FCR 2 (gram feed/gram egg). The feeding cost (FC) was determined by FCFA feed/egg. Feed economic efficiency (EFE) was obtained by FCFA egg/FCFA feed. The egg quality was determined twice per month. Egg weight was collected daily with an accurate scale. Eight eggs per treatment were used to determine the egg shape index, egg yolk colour, albumen height, egg shell thickness and Haugh unit. Egg length (L) and grand diameter (GD) were measured with coulisse's leg ruler to determine the shape index (SI) (SI = GD/L).

Three persons were used to determine the egg yolk colour by comparing with a Roche fan colour which consists of 1 to 15 strips ranging from pale to orange yellow colour. Albumen height was measured with tripod micrometre and egg shell thickness with micrometre ruler. Haugh unit (HU) was calculated from the egg weight (W) and albumen height (H) as suggested by Haugh (1937):

$$HU = 100 \log (H + 7.57 – 1.7 W^{0.37})$$

Statistical analysis: Data were analysed with R software (R 2016) by ANOVA using general linear models (GLM) procedures. The statistic model used was

$$Y_{ij} = \mu + R_i + \varepsilon_{ij}$$

where, Y_{ij}, dependent variable observed; μ, general mean; R_i, fixed effect of replacement rate of fish meal with grasshopper meal; $[_{ij}$, residual error.

Variable's means are presented in tables with standard error (SE) and probability (P-value) among means comparison. Significant differences among treatments were assessed by least significance difference. Fish meal substitution with the grasshopper meal was significant if P-value < 0.05.

Table 1. Diet's composition used in a layer's experiment

Ingredient (%)	G0*	G25*	G50*	G75*	G100*
Yellow corn	69,00	69,00	69,00	69,00	69,00
Wheat bran	8,00	8,00	8,00	8,00	8,00
Peanuts cake	6,00	6,00	6,00	6,00	6,00
Fish meal (55.87% CP)	8,00	6,00	4,00	2,00	0,00
Grasshopper meal (47.73% CP)	0,00	2,00	4,00	6,00	8,00
Bones meal	8,00	8,00	8,00	8,00	8,00
Salt	0,30	0,30	0,30	0,30	0,30
Vit/Min prémix[1]	0,20	0,20	0,20	0,20	0,20
Peanuts oil[2]	0,50	0,50	0,50	0,50	0,50
Total	100	100	100	100	100
Calculated nutritional composition					
ME (Kcal/kg DM)[3]	2833	2832	2830	2829	2827
Crude fibre (%)	4,27	4,51	4,75	4,99	5,23
Crude protein (%)	16,78	16,60	16,42	16,24	16,06
Lysine (%)	0,66	0,66	0,65	0,64	0,64
Methionine (%)	0,30	0,30	0,29	0,29	0,28
Calcium (%)	2,33	2,34	2,35	2,36	2,37
NPP (%)[4]	1,19	1,19	1,19	1,19	1,19
Ca/NPP	1,96	1,97	1,97	1,98	1,99

*Feeds where the fish meal was substituted by the grasshopper meal in the proportion of 0% (G0), 25% (G25), 50% (G50), 75% (G75) and 100% (G100). [1]Premix contents per kg : vitamins A, 4000,000 UI; vitamin D3, 800,000 UI; vitamin E, 2,000 mg; vitamin K, 800 mg; vitamin B_1, 600 mg; vitamin B_2, 2,000 mg; niacin, 3,600 mg; vitamin B_6, 1,200 mg; vitamin B_{12}, 4 mg; choline chloral, 80,000 mg. Minerals: Cu, 8,000 mg; Mn, 64,000 mg; Zn, 40,000 mg; Fe, 32,000 mg; Se, 160 mg; [2]Non refined peanut oil; [3]Metabolisable energy in kcal/kg of dry matter; [4]Non pythic phosphorus.

RESULTS AND DISCUSSION

Chemical composition: Results of the chemical analysis are presented in Table 2, where dry matter (DM) and crude protein (CP) content were 1.94% and 8.14% higher in fish meal than in grasshopper meal respectively. But, ether extract (EE), crude fibre (CF) and ashes were 1.17%, 9.23% and 4.06% higher in grasshopper meal than in fish meal respectively.

Table 2. Chemical composition of fish meal and grasshopper meal used in laying hen feeds

Ingredient	DM* (%)	CP* (%)	EE* (%)	CF* (%)	Ash (%)
Fish meal	95.02	55.87	10.52	2.66	5.07
Grasshopper meal	93.08	47.73	12.23	11.89	9.13

*DM, Dry matter; CP, crude protein; EE, ether extract; CF, crude fibre.

Chemical composition of grasshopper meal varied among studies. It may be due to the difference of grasshopper species, source, processing method (Makkar *et al*. 2014), sex, stage of maturity and environmental factors (Paul *et al.* 2016). Dry matter of grasshopper in the present study was higher than results of grasshopper meal chemical evaluation from Ojewola and Udon (2005), but lesser than those obtained by Elegba (2015). Crude protein content of grasshopper meal was inferior and superior to findings of Wang *et al.* (2005) and Adedutan (2005) respectively. The ether extract rate of grasshopper in the present study was higher than reported by Ojewola and Udon (2005) but similar results were obtained by Adeyemo *et al.* (2008). Crude fibre content of grasshopper overlapped works reported by Makkar *et al.* (2014) and Elegba (2015) whereas ash content was similar to findings from Wang *et al*. (2005) and Adeyemo *et al*. (2008). The lower CP and higher CF content in grasshopper meal than fish meal affected the feed formulation, where CP decreased and CF increased with increasing level of GM in diets.

Laying rate: The weekly laying rate of the hens fed with the control and experimental diets is depicted in Fig.1. The hens fed G0 and G100 had the highest laying rate during the starting phase while G25 and G50 had the best up to the laying peak. The gradual substitution of fish meal by grasshopper meal had no significant impact (P>0.05) on hens' monthly laying rate during all months of the study (Table 3).

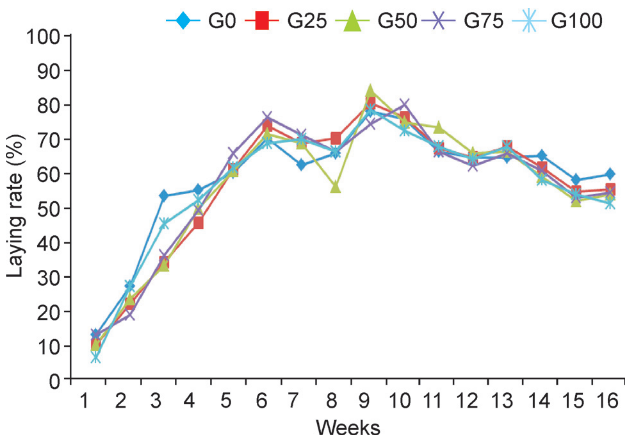

Fig. 1. Effect of grasshopper meal on hen laying rate (%).

Replacement of fish meal by grasshopper meal did not affect laying rate in the present study. Protein content in fish meal and in grasshopper meal was comparable to support laying rate. In fact, the main feed parameters that influence laying rate are the variation of metabolisable energy, crude protein, lysine (Novak *et al*. 2006), methionine (Safaa *et al*. 2008), tryptophan (Peganova and Eder 2003) and crude fibre (Kalmendal and Bessei 2012). However, the variation from 2,880 to 2,790 Kcal/Kg in metabolisable energy in *ad. libitum* regime (Murugesan and Persia 2013), 1% of crude protein (Novak *et al*. 2006), 0.5% of methionine (Safa *et al*. 2008), 0.9% of tryptophan (Peganova and Eder 2003) and from 3.4 to 5.5% of crude fibre (Kalmendal and Bessei 2012) in diet don't significantly affect egg production. Feeds formulated were in this interval of variation. Gernat (2001) reported the same tendency where, replaced soybean with shrimp meal did not significantly influenced laying production. However, Agunbiade *et al.* (2007) reported that replacing fish meal with maggot meal in cassava – based layer's diets significantly affected egg production. The laying rate in the present study was lower than reported by Gernat (2001) with shrimp meal, Agunbiade *et al.* (2007) with maggot meal, and Issa *et al.* (2016) with maize, sorghum and millet. These differences with our study may be due to insect species, experimental methodology and environmental conditions (38°C at midday during the present study). Furthermore, Daghir *et al*. (2008) reported that from 27°C, temperature negatively influenced the egg production.

Feed intake: The daily feed intake from month 1 to 4 is presented in Table 4. Feed intake was not significantly affected (P>0.05) by the substitution of fish meal by

Table 3. Effect of replacement of fish meal by grasshopper meal on hen's laying rate (%)

Laying month	G0	G25	G50	G75	G100	SE	P-value
1	36.95	27.47	28.57	28.57	32.56	6.09	0.213
2	64.29	68.12	63.63	69.44	66.14	4.68	0.386
3	70.79	71.81	74.11	70.28	70.28	2.75	0.291
4	61.45	59.24	57.27	57.88	57.14	2.20	0.073
Overall	58.31	56.69	55.91	56.56	56.46	2.33	0.668

Table 4. Daily feed intake (g/d) per month of ISA Brown laying hens in gradual replacement of fish meal by grasshopper meal in their diet

Laying month	G0	G25	G50	G75	G100	SE	P-value
1	87.30	87.59	89.30	88.75	86.81	4.01	0.895
2	91.40	98.04	93.26	91.25	89.84	5.81	0.350
3	90.41	97.08	89.45	89.72	86.98	5.63	0.181
4	90.90	85.56	83.19	82.16	88.38	7.66	0.492
Overall	90.00	92.07	88.80	87.97	88.00	4.81	0.729

Table 5. Effect of gradual replacement of fish meal with grasshopper meal on efficacy and efficiency of hen's egg production

Parameter	C0	C25	C50	C75	C100	ES	P-value
FCR1[1] (g feed/egg)	174.6	198.6	189.7	188.0	187.2	12.8	0.182
FCR2 (kg feed/kg egg)	3.07	3.50	3.37	3.34	3.30	0.25	0.225
FC[2] (FCFA feed/egg)	43.5	48.5	45.3	44.5	42.8	3.06	0.129
EFE[3] (FCFA[4] egg/FCFA feed)	2.01	1.94	2.07	2.09	2.13	0.09	0.077

[1]FCR, Feed conversion ration; [2]FC, feeding cost; [3]EFE, economic feed efficiency; [4]FCFA, Republic of Niger currency; 1•=655.957 FCA at 2016-10-22.

grasshopper meal in the laying hens' diets.

Poultry feed intake is controlled by the physiological and nutritional factors. The physiological factors were attributed to the hypothalamic region which control appetite and feed preference (Bouvarel *et al*. 2010). Feed characteristics such us colour, texture, taste and smell have a much influence of this physiological regulation (Ferket and Gernat 2006). The nutritional factors that influence feed intake are the chemical composition quality (Richards 2003) either in deficient or in great excess relative to the bird's requirement (Ferket and Gernat 2006). Dietary energy, protein and amino acids content have the most predicate effect on feed intake (Ferket and Gernat 2006, Richards 2003). The non-significant difference of feed intake among all the treatments showed the palatability of grasshopper meal in laying hens' diet. The diets content in CP, lysine and methionine was in agreement with recommendation of the National Research Council (NRC 1994). This confirmed plenty the potential of grasshopper meal as source of protein especially lysine and methionine content (Wang *et al.* 2005). In addition, the crude fibre content of the experimental diets agreed with work of Mateos *et al.* (2012). Also, the absence of significant difference of feed intake in this study may be associated to the similar level of CP, lysine, methionine and CF in the different diets as supported by Ferket and Gernat (2006) who stipulated that imbalance of these nutrients can modify feed intake in chicks. The non-difference of feed intake in the present was in agreement with Agunbiade *et al.* (2007) wherein fish meal was replaced by maggot meal. However, Gernat (2001) reported that the increase of shrimp meal in laying hens' diet significantly increased the feed intake. This could be due to higher level of chitin found in shrimp meal (Khempaka *et al.* 2006a) compared to the level of chitin found in the grasshopper meal (Wang *et al.* 2005).

Feed efficacy and efficiency: The impact of replacing fish meal by grasshopper meal in laying hens' diets on their efficacy and efficiency is presented in Table 5. The feed conversion ratio (FCR 1 and FCR2), feeding cost (FC) and the economic feed efficiency (EFE) were not significantly affected (P>0.05) when fish meal was replaced by grasshopper meal in laying hens' diet. During the four laying months, the average feed intake was 187.64 g (FCR1) and 3.32 kg (FCR 2) to produce one egg and one kilogram of egg respectively. The feeding cost to produce one egg was 44.90 FCFA (FC), whereas the investment of 1 FCA in the feed would generate 2.05 FCFA (EFE).

In spite of the highest price of grasshopper meal which coincided to the study period, feed conversion ratio, feeding cost and economic feed efficiency were not affected by increasing level of grasshopper meal in laying hens' diet. Economically, the grasshopper meal can be used even alone in laying hens' diet. Therefore, grasshopper meal appeared as an efficient source of protein in laying hens' diet. Agunbiade *et al.* (2007) reported that maggot meal as fish meal substitution did not affect the FCR. On the contrary, use of shrimp meal for soybean meal replacement (Gernat 2001) and black soldier fly larvae (Al-Qazzaz *et al.* 2016) for fish meal replacement in laying hen diets statistically influenced FCR.

Egg quality: The effect of gradual substitution of fish meal with grasshopper meal in laying hens' diet on eggs quality is presented in Table 6. The substitution did not significantly affect (P>0.05) the egg weight, egg shape index, albumen height and egg shell thickness. However, replacing fish meal with grasshopper meal significantly improved egg yolk colour (P<0.01) and Haugh unit (P< 0.05). In fact, the control diet had the lowest egg yolk colour compared to the experimental diets containing various proportions of grasshopper meal.

Table 6. Effect of gradual replacement of fish meal with grasshopper meal in laying hen diet on eggs quality

Parameter	G0	G25	G50	G75	G100	ES	P-value
Egg weight (g)	57.5	57.1	56.7	57.0	56.7	1.20	0.876
Egg yolk colour	8.39[b]	9.08[a]	9.14[a]	9.15[a]	9.00[a]	0.25	0.003
Egg shape index	77.3	77.9	78.0	77.6	77.1	1.29	0.851
Haugh Unity (HU)	84.8[b]	90.2[a]	88.1[ab]	87.0[ab]	89.3[ab]	2.23	0.031
Albumen height (mm)	7.26	8.15	7.75	7.61	7.98	0.40	0.055
Egg shell thickness (mm)	0.41	0.42	0.44	0.45	0.44	0.05	0.675

[a,b,c]Means with the different superscripts along the same row are significantly different ($P < 5\%$).

The use of grasshopper meal enhances the commercial quality of egg by improving the egg yolk colour, due to the carotenoids found in the grasshopper meal (Finke 2015). Carotenoids represent a fraction of yolk, and give it its colour (Rainer et *al*. 2007). However, carotenoid cannot be synthetized by the hen, it's dependent on the diet supply (Yoshinori 2008). Haugh unit was influenced with higher albumen height observed in this study.

Gernat (2001) also observed, that shrimp meal improved yolk pigmentation contrary to Agunbiade *et al.* (2007) who reported that maggot meal did not affect egg yolk colour. These differences could be due to the presence of astaxantin found in shrimp meal (Khempaka *et al*. 2006b) which may play the same role as the carotenoids in grasshopper meal (Finke 2015).

Calcium is important for egg shell formation (Yoshinori 2008) and egg shell thickness was significantly influenced by the calcium quantity in diet (Safaa *et al*. 2008). Egg shell thickness in this study did not significantly differ among treatments instead of the high mineral content of the grasshopper meal compared to the fish meal. The presence of chitin in the grasshopper meal (Wang *et al.* 2005) may influence the absorption of some of those minerals (Ca and P) (Gernat 2001).

Grasshopper meal can replace fish meal in laying hen's diet up to 100% without affecting feed intake, egg production, feed efficacy and efficiency and egg quality. Furthermore, the use of grasshopper meal in laying hens' diet can improve the commercial quality. Thus, poultry farmers could completely replace fishmeal by grasshopper meal in the laying hen's diet.

In the perspective of using grasshopper meal in poultry diet, it is important to develop a technology of producing grasshopper meal and evaluate the effect of grasshopper species consumed or not by human on their meals quality.

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