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Full Length Research Paper

Effect of supplements based on fishmeal or cottonseed cake and management system on the performance and economic efficiency of exotic hens in Burkina Faso

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A trial was carried out on-station to evaluate the effect of replacing a low protein fishmeal diet by a high protein diet containing cottonseed cake and cereal bran on the performance of semi-scavenging and confined exotic layers in comparison with full-scavenging birds. One hundred and twenty laying hens at 28 weeks of age were randomly distributed to four feeding/management regimes; (1) CCB, confined and given *ad libitum* a mixed diet (CB) containing cracked maize, cottonseed cake, cereal bran and a vitamin-mineral premix, oyster shells being provided separately; (2) SCB, scavenging in the daytime (08.00 to 16.00 h), with the CB diet available between 16.00 and 08.00 h; (3) SFM, managed as in SCB, but with fishmeal replacing cottonseed cake and cereal bran (diet FM); (4) SO, scavenging only with no supplement provided. Daily dry matter intakes for CCB, SCB and SFM were 95.5%, 60.5% and 48.5% of the expected intakes, respectively ($P < 0.05$). No significant difference was found in energy, calcium and phosphorus intakes between SFM and SCB, but crude protein and essential amino acid intakes were lower in SFM than in SCB ($P < 0.05$). Hen -day and hen-housed production were the highest in CCB and the lowest in SO ($P < 0.05$), while no significant differences were found between the two semi-scavenging treatments. Feed conversion ratio and feed cost / kg eggs were the lowest in CCB and the highest in SFM ($P < 0.05$). Egg weight and shell thickness were higher in SCB compared to SFM. Yolk colour was darkest in SO and palest in CCB. It is concluded that fishmeal can be replaced advantageously by cottonseed cake and a mixture of wheat and maize bran in diets for confined and semi-scavenging exotic layers.

Key words: Burkina Faso, egg production, exotic hens, fishmeal, cottonseed cake, semi-scavenging.

INTRODUCTION

Poultry farming in Burkina Faso plays an important role in the daily life of the rural farmers, who raise village chickens for several purposes (Kondombo et al., 2003). Local poultry are appreciated for their superior taste, justifying the existence of marketing systems to provide the cities with poultry products from the rural areas (Ouedraogo, 2002). However, chicken eggs, unlike guinea fowl eggs, are not part of the established trade in poultry products, since all eggs are required for hatching to maintain the flock (FAO, 2004). Therefore it is neces-sary to develop improved feeding and management sys-tems using improved layer breeds reared in semi-intensive condi-tions to meet the increasing demand for eggs of the u-rban population, and in addition to increase the in-comes of women and young people in the rural areas. Improve-ment of smallholder chicken production in rural areas should take into account improved feeding, with diets for-mulated using locally available feedstuffs to reduce feed costs.

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Burkina Faso is the first cotton producer in Sub-Saharan Africa, and the annual production was estimated to be approximately 750,000 tons (Mission Economique, 2006). Cottonseed cake is locally produced by oil factories, and has become a very useful source of supplementary protein for cattle and poultry in the country. Fishmeal is in limited supply in most developing countries, and in particular in Burkina Faso, where it is imported from neighbouring countries. Because of their relative high costs, fishmeal and decorticated cottonseed cake are generally not given to chickens in rural areas in Burkina Faso, but are included as standard ingredients in com-mercial poultry feeds. The cotton varieties grown in Burkina Faso are glandless, and therefore low in free gossypol, which is important, as it is well known that high levels of gossypol can result in an olive-green discoloration of the yolk in storage (Göhl, 1999) and can also induce symptoms of poisoning, such as anaemia, diarrhoea and eventual paralysis (Smith, 2001). Despite the importance and the wide distribution of poultry among smallholder farms, little information is available in Burkina Faso on the effects of improved nutrition, and in general poultry production improvement and research have not been included in agricultural research and development pro-grams in the country. Formerly, dietary adjustments to meet requirements were aimed at maximizing production performance, without special concern for nutrient over-supply, especially protein and amino acids (Schutte and De Jong, 1999). Protein ingredients are the major cost in poultry feeds in developing countries (Zou and Wu, 2005), and therefore, it is of considerable importance to evaluate the effects on performance and the economics of replacing expensive imported protein supplements such as fishmeal by cheaper local ingredients such as cottonseed meal and cereal brans.

The overall objective of this study was to examine the effect of semi-scavenging and replacing a low protein fishmeal based diet with a high protein diet containing a mixture of cottonseed cake and local brans, as the main source of protein, on nutrient intake, egg production parameters and economical efficiency of exotic laying hens.

MATERIALS AND METHODS

Site description

The experiment was carried out during a period of 6 months (from early September to late February, 2006) at the INAGOR research centre, situated 35 km south of Ouagadougou in Burkina Faso. This part of the country is included in the Soudano-Sahelian zone, which lies between the 900 and 600 mm isohyets. The study period included two months of the hot-rainy season and four months of the dry-cool season. Average minimum and maximum temperatures of 15. 8 and 40.0^{o}C, and minimum and maximum relative humidities of 16 and 86% were recorded during the experimental period. The poultry yard had an area of around 1000 m^{2} and the dominant vegetation was V*itellaria paradoxa* and *Eucalyptus alba* trees, and various species of grass.

Experimental birds

A total of 120 exotic hens (Isa Brown) at 28 weeks of age (already in lay for about 4 weeks) were purchased from a commercial producer. The birds were randomly allocated to 4 dietary treatments, with 3 replications (pens) for each treatment (10 hens / replication). Mean initial live weight was equalized among pens.

Feed ingredients

The main feed ingredients were locally available feedstuffs (maize, wheat and maize bran and cottonseed cake) and imported fishmeal. Cracked maize, cottonseed cake and bran were purchased in a local market, while fishmeal was bought from a poultry feed company in Ouagadougou. It was manufactured from small marine fish, and had a very low content of crude protein (CP, 39.1% of dry matter [DM]) and high ash content (35.0% of DM) compared to standard values. The cracked maize used was a local variety of white maize. The cottonseed cake was decorticated expeller, which is locally available in Burkina Faso after oil extraction in the factories. The bran used was a mixture of by-products from small-scale wheat and maize processing mills. The chemical composition and the cost of the feed ingredients are given in Table 1. Diets were formulated to meet the requirements for energy and the ideal amino acid profile for layers, using a least-cost computer program (Table 2). The chemical composition and the amino acid profile of the diets and of the Ideal Protein for layers are shown in Table 3 and 4. The essential amino acid balance of the diets FM and CB was similar to that of the Ideal Protein for layers.

Experimental treatments

Birds in treatment CCB were confined and given *ad libitum* a mixed diet (CB) containing cracked maize, cottonseed cake, cereal brans and a vitamin-mineral premix, and with oyster shells provided separately. Hens in treatment SCB were allowed to scavenge in the daytime (08.00 – 16.00 h), with diet CB available between 16.00 and 08.00 h. Management of the hens in treatment SFM was the same as in SCB, but with fishmeal replacing cottonseed cake and cereal bran (diet FM). In treatment SO birds scavenged in the daytime (08.00 – 16.00 h), with no supplement provided. Water was available *ad libitum* outside all pens in the daytime and in the pens at night. Ground oyster shell was provided *ad libitum* in separate feeders to all treatment groups except SO to allow the hens to meet their calcium requirement for egg production.

Bird management

All the birds were vaccinated against common chicken diseases in Burkina Faso according to the period of the year: Newcastle disease and fowl pox. The birds were treated against internal and external parasites. The birds on all treatments except CCB were allowed to scavenge from 08.00 to 16. 00 h and were confined at night. The pens were 2.0 m x 1.5 m and sawdust was provided as litter. Two nesting boxes were provided for each pen. The birds were identified by painting the legs with different colours.

Data collection and analytical procedures

Feed ingredients and diets were analysed for chemical composition using standard AOAC methods (AOAC, 1985). Calcium (Ca) was determined using a spectrophotometric method (FAO, 1980) and phosphorus (P) by continuous flow analysis (Hornchurch Essex) . Metabolisable energy (ME) contents of the diets were calculated by

Table1. Chemical composition and cost of the feed ingredients.

Item	Cracked maize	Local brans	Fish meal	Cottonseed cake
Dry matter (DM), %	92.7	94.1	96.5	94.6
% of DM				
Organic matter (OM)	98.6	94.9	65.0	92.0
Crude protein (CP)	8.34	17.1	39.1	46.3
Crude fibre (CF)	3.8	9.8	1.45	10.6
Ether extract (EE)	4.4	4.35	16.3	6.87
Nitrogen-free extract (NFE)	82.1	63.6	8.15	28.3
Ash	1.4	5.1	35.0	7.95
Calcium (Ca)	0.03	0.08	7.36	0.14
Phosphorus (P)	0.98	0.99	3.39	1.3
Lysine	0.21	0.55	1.10	1.57
Methionine	0.17	0.25	0.72	0.78
Threonine	0.3	0.69	1.68	1.92
ME (MJ/kg), calculated	15.9	13.0	13.8	12.8
Cost (USD/kg)	0.23	0.11	0.60	0.15

Table 2. Ingredient composition of the experimental diets (%, as fed)

Ingredient	Diet*	
	FM	CB
Cracked maize	84.0	43.5
Wheat and maize bran	-	35.5
Cottonseed cake	-	20.0
Fishmeal	15.0	-
Dicalcium phosphate	0.25	0.25
Vitamin – mineral premix **	0.25	0.25
NaCl	0.5	0.5
Oyster shell (*ad libitum* in separate feeder)	+	+

***FM: protein supplied by fishmeal. CB: protein supplied by cottonseed cake and a mixture of wheat and maize bran** **
Contained the following per 1,000 g premix: Vitamins: A 4,000,000 IU; D_3 800,000 IU; E 6,000 mg; K_3 800 mg; B_1 600 mg; B_2 1,600 mg B_3 3,600 mg; B_6 800 mg; B_{12} 10 mg; nicotinic acid 10,000 mg; folic acid 300 mg; choline chloride 200,000 mg; antioxidant 4,000 mg; iron 24,000 mg; copper 2,400 mg; manganese 24,000 mg; zinc 20,000 mg; iodine 200 mg; selenium 80 mg. Minerals: Dicalcium phosphate (Ca 24%; P 17.5%)

Table 3. Chemical composition of the experimental diets (%, DM basis).

Item	Diet*	
	FM	**CB**
Dry matter (DM)	92.8	93.2
Organic matter (OM)	90.4	94.9
Crude protein (CP)	13.9	19.3
Crude fibre (CF)	2.15	6.97
Ether extract (EE)	5.38	4.8
Nitrogen-free extract (NFE)	69.8	63.8
Neutral Detergent Fiber (NDF)	8.63	21.5
Acid Detergent Fiber (ADF)	3.01	9.4
Ash	9.60	5.04
Calcium (Ca)	1.72	0.2
Phosphorus (P)	0.93	0.75
Lysine	0.48	0.71
Methionine	0.25	0.31
Cystine	0.23	0.4
Threonine	0.44	0.63
ME (MJ / kg), calculated	15.3	14.2
Cost (USD / 100kg)	29.8	19.2

* See footnotes, Table 2

an indirect method, using the following equation (INRA, 1987):True ME (MJ / kg dry matter) = (3951 + 54.4EE – 88.7CF - 40.8Ash) * 0.004184.

Amino acids were analysed by standard methods (Analycen, Lidköping, Sweden). Data collection started two weeks after the hens were introduced to the experimental diets in mid- August. Feed intake, mortality and egg production were recorded daily for each replicate treatment (pen). Nutrient intakes, feed conversion ratio, and mean weight gain were calculated. Hen-day production and hen-housed production were calculated according to Smith (2001):

Hen-day production = (production of all eggs produced by the flock / product of the number of days and the number of birds alive on each of these days) * 100

Hen-housed production = (Total number of eggs produced / product of the total number of hens housed and the number of days that the birds were actually in lay) * 100.

Five representative eggs from each pen were collected twice each week for determination of shell thickness, egg width, egg length, albumen width, albumen height, yolk width and yolk height, using a micrometer. Also yolk colour was determined using

Table 4. Amino acid profile of the experimental diets* compared to the Ideal Protein concept for layers (% of total lysine)

Amino acid	Diet FM	Diet CB	Ideal Protein**
Lysine,% of N*6.25	3.45	3.67	3.80
Lysine	100	100	100
Methionine	53	43	45
Methionine + cystine	100	100	84
Threonine	92	89	64

*Analysed **Schutte and Jong (1999).

Table 5. Effect of diet on daily dry matter and nutrient intakes of confined and semi-scavenging exotic hens Treatment[1]

Intake (g/day)	Treatment					
	CCB	SCB	SFM	SO	SEM	P-value
DMI	103[a]	66.7[b]	52.9[c]	-	3.02	0.00
Oyster shell	10.6[a]	7.14[b]	5.59[b]	-	0.51	0.00
CP	19.9[a]	12.9[b]	7.35[c]	-	0.18	0.00
Ash	5.21[a]	3.36[b]	5.13[a]	-	0.30	0.00
CF	7.21[a]	4.65[b]	1.14[c]	-	0.10	0.00
NDF	22.3[a]	14.4[b]	4.61[c]	-	0.48	0.00
ADF	9.76[a]	6.30[b]	1.59[c]	-	0.15	0.00
NFE	62.6[c]	75.8[b]	83.5[a]	-	1.10	0.00
Calcium	0.21[b]	0.13[b]	0.93[a]	-	0.03	0.00
Phosphorus	0.8[a]	0.53[b]	0.49[b]	-	0.01	0.00
Ca intake from oyster shell	4.02[a]	2.70[b]	2.12[b]	-	0.30	0.00
Total Ca intake	4.23[a]	2.83[b]	3.05[b]	-	0.40	0.00
Methionine	0.32[a]	0.20[b]	0.13[c]	-	0.007	0.00
Lysine	0.74[a]	0.47[b]	0.25[c]	-	0.01	0.00
Cystine	0.41[a]	0.26[b]	0.12[c]	-	0.008	0.00
Threonine	0.64[a]	0.42[b]	0.23[c]	-	0.009	0.00
ME (MJ)/day	1.46[a]	0.94[b]	0.80[b]	-	0.04	0.00

[1]CCB:Birds confined and given diet CB, composed by mixing cracked maize, cottonseed cake and bran with a vitamin-mineral premix *ad libitum*, and with oyster shells given separately; SCB: Birds scavenging in the daytime (from 08.00 to 16.00h) and given free access to diet CB from 16.00 to 08.00h ; SFM: management as for SCB, but given diet FM (consisting of fishmeal and cracked maize mixed with a vitamin-mineral premix) and with oyster shells provided separately; SO: scavenging only without any supplement. [a,b,c,d] Means with different superscript letters in the same row are significantly different at $P < 0.05$

Roche Fan, with values from 1 to 15 corresponding to pale yellow to deep orange, respectively.

Egg shape index was determined according to Reddy et al. (1979):
Egg shape index = (width of egg / length of egg)* 100
The Haugh unit (Haugh, 1937) score was calculated according to Doyon et al. (1986)
$HU = 100 \log (H-1.7w^{0.37} + 7.6)$ where:
HU = Haugh unit
H = observed height of the albumen in mm
W = weight of egg (g)

Statistical analysis

The data were subjected to analysis of variance techniques according to the GLM procedure of MINITAB Software (2000), version 14. The Tukey test was done for pairwise comparisons between treatment means. The experimental units for feed intake and egg production parameters were the pen means and for live weight changes and egg quality parameters were the individual values within pen.

Statistical model was $Y_{ij} = \mu + \alpha_i + e_{ij}$, where: Y_{ij} = output (eggs produced, egg weight), μ = overall mean, α_i = I^{th} treatment, e_{ij} =

Table 6. Effect of diet on egg production traits, feed conversion and feed cost of confined and semi-scavenging exotic hens.

Item	Treatment[1]					
	CCB	SCB	SFM	SO	SEM	P-value
Number of birds	30	30	30	30	-	-
Initial weight (g)	1520	1567	1563	1590	24.6	0.317
Final weight (g)	1686^{a}	1625^{ab}	1483^{b}	1475^{b}	34.3	0.003
*Total eggs produced	3142	1509	1125	121	-	-
**Eggs/pen	1047^{a}	503^{b}	375^{b}	40^{c}	72	0.00
Hen-day production (%)	72.4^{a}	29.0^{b}	20.8^{b}	2.30^{c}	1.90	0.00
Hen-housed production (%)	58.3^{a}	27.9^{b}	20.8^{b}	2.24^{c}	4.63	0.00
Mortality (%)	20.0	3.33	0	3.33	11.4	0.43
FCR (kg DM/kg eggs	2.92^{b}	4.90^{a}	5.11^{a}	-	0.14	0.00
Feed cost/30 eggs (USD)	1.03^{c}	1.8^{b}	2.7^{a}	-	0.11	0.00
Feed cost/kg eggs	0.6^{c}	1.0^{b}	1.6^{a}	-	0.1	0.00
Sale price/kg eggs	2.6^{b}	2.5^{c}	2.6^{b}	2.8^{a}	0.04	0.00
Gross margin***	2.0	1.5	1.0	2.8		

[a, b, c, d] means with different superscript letters in the same row are significantly different at P < 0.05
[1]see footnote 1 Table 5. SO, scavenging only, without supplementation *eggs produced by 30 hens in 6 months ** eggs produced per pen (10 hens) in 6 months *** Sale price minus feed cost per kg eggs

random error term.

Economic analysis

Market prices of the feed ingredients and the mean sale price of eggs were used to compare the economic efficiency of the feeding and management regimes.

RESULTS

Effect of feeding and management regime on feed and nutrient intakes

Dry matter (DM), nutrient and oyster shell intakes are shown in Table 5. Higher daily DM and nutrient intakes were observed in the confined treatment (103 g DM) compared to the semi-scavenging groups (52.9 and 66.7 g DM, respectively, for SFM and SCB) ($P < 0.05$). In the semi-scavenging treatments, daily DM and nutrient intakes were higher in SCB compared to SFM, the differences being significant for DM CP and amino acid intakes. However, intakes of ash, calcium and NFE were higher in SFM than in SCB ($P < 0.05$).

Effect of feeding and management regime on final body weight, egg production traits, feed conversion ratio and feed cost

Egg production parameters, feed conversion ratio, feed cost and final weights are given in Table 6. Final body weight was lower than initial body weight in SFM and SO, but was higher in SCB and CCB. The mean final body weight of the confined hens (CCB) was higher than in SFM and SO ($P < 0.05$), but differences among the semi-scavenging treatments were not significant. Mean total egg production per pen, and hen- day and hen-housed percent were higher in CCB (1047, 72.4 and 58.3%, respectively) than in SCB (503, 29.0 and 27.9%, respecttively) and SFM (375, 20.8 and 20.8%, respect-tively) ($P < 0.05$), and were the lowest in SO (40, 2.30 and 2.24%, respectively) ($P < 0.05$).

Higher mortality was found in the confined treatment (CCB) (20%) compared to the scavenging only (3.33%) and semi-scavenging groups (3.33 and 0% for SCB and SFM, respectively).

Feed conversion ratio (FCR) was significantly lower for the confined treatment (CCB: 2.92 kg feed DM / kg eggs) compared to the corresponding semi-scavenging treatment (SCB: 4.90 kg feed DM / kg eggs). No significant difference was found between the semi-scavenging birds for FCR (5.11 and 4.90 kg feed DM / kg eggs for SFM and SCB, respectively).Feed cost / kg eggs produced was the lowest for the con-fined birds (0.60 USD / kg eggs), followed by the SCB group (1.0 USD / kg eggs) and SFM (1.6 USD / kg eggs) ($P < 0.05$). Gross margins of sale price over feed costs per kg eggs were 2.0, 1.5 and 1.0 USD for treatments CCB, SCB and SFM, respectively.

Effect of feeding regime on egg quality characteristics

Egg quality characteristics are shown in Table 7. No sig-

Table 7. Effect of diet on egg quality characteristics of confined and semi-scavenging exotic hens

Items	Treatment[1]					
	CCB	SCB	SFM	SO	SEM	P-value
Egg weight (g)	61.4^a	60.8^a	56.1^b	54.5^b	0.30	0.001
Egg length (mm)	57.9^a	57.0^a	57.0^a	55.2^b	0.29	0.001
Egg width (mm)	43.3^a	43.2^a	42.6^a	41.6^b	0.14	0.000
Albumen height (mm)	7.60	7.73	7.87	7.83	0.19	0.1
Yolk height (mm)	15.7^a	15.6^a	15.6^a	14.6^b	0.11	0.005
Albumen width (mm)	72.1	70.5	66.4	68.2	1.4	0.09
Yolk width (mm)	40.3	39.6	39.5	40.1	0.15	0.151
Yolk colour	1.59^d	3.37^c	4.32^b	5.75^a	0.13	0.00
Shell weight (g)	8.08^a	7.41^b	7.21^b	6.67^b	0.1	0.00
Shell thickness (mm)	0.43^a	0.43^a	0.39^b	0.41^{ab}	0.006	0.00
Shape index	76.1	75.8	74.7	75.9	0.34	0.06
Haugh unit	83.9	85.1	87.3	88.7	1.85	0.1

[1]See footnote 1 Table 5. SO, scavenging only, without supplementation. [a, b, c, d] Means with different superscript letters in the same row are significantly different at P < 0.05

nificant difference (P > 0.05) was noted in mean egg weight and shell thickness between the confined birds (CCB: 61.4 g and 0.43 mm) and the corresponding semi-scavenging treatment (SCB: 60.8 g and 0.43 mm) . In the semi-scavenging groups, these parameters were significantly higher (P < 0.05) for SCB compared to SFM (56.1 g and 0.39 mm). The SO hens laid the smallest eggs with a significantly deeper yolk colour (54.5 g and 5.75 respectively) and yolk colour was significantly paler in the confined treatment (CSB: 1.59) compared to the corresponding scavenging (SCB: 3.37) birds. No significant difference was recorded for egg shape index and Haugh Unit score among treatments.

DISCUSSION

Nutritive values of the feed ingredients and diet formulation

The most common variety of cotton cultivated in Burkina Faso is gossypol-free (a glandless variety) and the seeds are used in human nutrition and for livestock (Schwartz, 1993; INERA, 1995). This explains why it was possible to use a higher (20%) inclusion level of cottonseed, compared to the maximum of 10% recommended by Smith (2001) and Göhl (1999). Fishmeal that is available in Burkina Faso comes from different neighbouring countries, in particular Senegal and Ivory coast, and the nutritive value varies considerably depending on the type of fish used and the manufacture. It should also be mentioned that to increase profits, sand and sawdust and other materials are often added to fishmeal in some developing countries. This practice, in addition to inadequate storage conditions, can explain the low nutritive value and low intake of the fishmeal diet used in the present study. Commercial bran in Burkina Faso is either imported (wheat bran) or a by-product from local cereal processing (wheat, maize, sorghum and milo).

The metabolizable energy (ME) level of the experimental diets is in agreement with the requirement for laying hens in hot climates (INRA, 1987; Smith, 2001). Requirement for ME and an amino acid ratio close to the Ideal Protein for layers were introduced as main constraints in the diet formulation. The purpose was to formulate a low-cost diet which would meet at least the energy requirement and ideal amino acid profile of layers, assuming that feed intake is not significantly affected by dietary crude protein level, as mentioned by Bunchasak et al. (2005), and that the major dietary factor that affects feed intake is energy concentration (Smith, 2001) . However, although the essential amino acid balance of the FM diet was comparable with the Ideal Protein for layers, the lysine content of 0.48% of diet DM was well below the recommended concentration of 0.80% for layers (Smith, 2001).

Effect of feeding regime on feed and nutrient intake

The birds in the CCB treatment met around 85% of their daily DM and nutrient requirements according to NRC (1994) data for exotic brown egg layers. The difference can be explained by the fact that laying hens reduce their feed intakes at ambient temperatures above 32°C (Smith, 2001), a temperature that was regularly attained in the present study. The lower DM intake by the SFM birds compared to SCB birds can probably be attributed to palatability problems in relation to the poor quality of the fishmeal, that is development of rancidity (personal observation), and possibly also due to the low crude protein content of the FM diet, although there is some controversy concerning the relationship between the crude protein level in diet and feed intake by laying hens (Penz and Jensen, 1991; Keshavarz and Jackson, 1992; Hum-phrey and Klasing, 2004; Bunchasak et al., 2005). In the semi-scavenging groups, supplementary feed DM intake accounted for only 44.0 and 55.0% of the expected daily DM intake for layers, respectively, for SFM and SCB, which implies that they would have needed to get more than 56 and 45%, respectively, of their requirements from scavenging (Farrell, 2000). However, the extremely poor egg production performance of the scavenging only hens indicates that the scavenging feed resource base was extremely limited, and Farell (2000) also showed that birds need additional energy for scavenging. The lower egg production performance of the SCB birds compared to those in confinement (CCB) in the present study confirms the poor quantity and / or quality of the available scavenging feed in the research station. It should also be mentioned that improved breeds are not considered to be particularly efficient at scavenging and may need a long period of learning. It was observed during the study that the scavenging hens generally stayed in the shade of the poultry house during the hottest part of the day, which would also have reduced the feed intake from scavenging. However, the research station environment does not reflect real scavenging conditions and egg production performance would probably have been better in the scavenging groups if household leftovers and other kitchen waste were provided, and if access to fields with growing crops had been possible, as is usually the case for village poultry. A previous study related to the quantity and nutritional value of the crop contents in village chickens in Burkina Faso (Pousga et al., 2005) showed that scavenging crossbred pullets were getting only 37 g DM per day from scavenging in real village conditions. Assuming that this value is 30% of the expected 122 g daily feed DM intake for brown egg layers, as reported by NRC (1994), this implies that in village scavenging conditions, the SFM and SCB hens would get 74 and 85%, respectively, of their daily DM requirement from both scavenging and the supplementary feed, thus increasing theoretical egg production performance. Calcium intake was 76 and 70% of the requirement of 4 g per day for layers (Smith, 2001), respectively for SFM and SCB, implying that scavenging layers need an extra calcium source.

Effect of feeding regime on egg production traits, mortality, feed conversion and feed cost

Egg production data confirm that the glandless, low gossypol cottonseed cake produced in Burkina Faso is of good quality and can be included at higher levels in layer diets than the recommended maximum of 10% (Göhl, 1999; Smith, 2001) . In addition, no symptoms of gossypol toxicity were seen during the study and no olive green colour was seen in the yolks with storage. The lower egg production of the SFM compared to the SCB hens was a result of the lower feed and crude protein intake. In addition the lysine concentration in the FM diet was only about 60 % of the recommended requirement (Smith, 2001). Egg production performance in the semi-scavenging treatments confirms that the layers did not meet their nutrient requirements from the supplements and scavenging resource base, also confirmed by the poor egg production performance of the SO birds. However, the results in this study are in contrast with other studies on scavenging birds. For example, Minh et al. (2004) did not find any significant difference in egg production between semi-scavenging and confined layers, and Acamovic et al. (2005) reported considerably higher laying performance in semi-scavenging hens compared to our study. This can be due to differences in the scavenging feed resource base, that varies according to climate, agro-ecological zone and season, as has been shown in a number of studies, for example Dessie (1996) and Pousga et al. (2005). The intake of the cottonseed/bran diet was around 35% lower for the semi-scavenging hens compared to those in confinement, indicating that the time available in the late afternoon and early morning was insufficient for the SCB hens to consume sufficient supplementary feed to compensate for their low intakes from scavenging.

The higher mortality than expected in the confined group was due to predators (snakes) getting into the pens. Feed conversion of the CCB birds was similar to other studies on Isa Brown layers (Um and Paik, 1999; Ayanwale et al., 2006; Junqueira et al., 2006). The SO treatment resulted in the highest gross economic returns, as feed costs were zero, but a total of only 121 eggs laid in 180 days by 30 hens are meaningless in reality. The analysis of feed cost / kg eggs produced and egg sale price / kg of eggs showed higher economic returns for SCB compared to SFM hens, due to both their higher egg production and the lower cost of cottonseed cake compared to fishmeal in Burkina Faso. This study shows that fishmeal can be replaced economically by a combination of cottonseed cake and wheat / maize bran in supplementary diets for semi-scavenging laying hens. The CP content of the FM diet was below the requirement for layers, but higher inclusion levels of fishmeal would have increased feed cost, and could have further reduced palatability and intake unless good quality fishmeal had been used (Smith, 2001). Conversely, a higher inclusion level of cottonseed cake and bran would have further reduced feed costs and it would also have been possible to reduce the inclusion level of maize, which is a staple food for the human population in Burkina Faso. The egg tray (30 eggs) sale price in Burkina Faso varies throughout the year, with a mean price of approximately 4.5 USD in 2006. This implies that under real scavenging conditions, where the birds would have been expected to lay more eggs, the CB diet would be economically more efficient. The performance of the confined groups shows that exotic layers could also be reared advantageously in confinement by resource-poor farmers, using locally available feedstuffs such as cottonseed cake and bran as protein ingredients. However, the data from the SO group confirms that feed supplementation results in higher egg production, implying that exotic breeds, which are not particularly well suited to scavenging, should not be reared in full scavenging systems without supplementation in the dry tropics, where the scavenging feed resource base is very limited.

Effect of feeding regime on egg quality

Mean egg weight and shell thickness for both confined and semi-scavenging birds given the CB diet were similar to the data from other studies on Isa Brown layers in Korea (Um and Paik, 1999), Nigeria (Ayanwale et al., 2006) and Brazil (Junqueira et al., 2006). However, egg and shell weight were significantly lower for the SO hens, probably as a result of the low intake of nutrients. No significant difference in Haugh unit and egg shape index was recorded between treatments and the values are in line with data from other studies on Isa Brown layers (Junqueira et al., 2006; Ayanwale et al., 2006). Yolk colour was deeper in the scavenging treatments compared to the confined hens, due probably to the green plant material scavenged from the environment. Data from this study show that feeding and management regime otherwise does not affect egg quality. This view is supported by other authors, for example Mendonça and Lima (1990) and Zimmermann and Andrews (1987).

It is concluded that exotic layers can be reared advantageously in confinement using inexpensive, locally available feedstuffs such as cottonseed cake and bran as protein ingredients. However, exotic breed layers were shown to be unsuitable in scavenging systems in the dry tropics without supplementation.

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