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Evaluation of Some Local Feed Resources

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Abstract

The objectives of the present study were to estimate the nutritional status of scavenging chickens by crop content analysis and to evaluate some locally available feed ingredients under different management regimes for their potential for confined and semi-scavenging growing pullets and laying hens.

The first study showed that the physical composition of the crop contents varied between the two locations and two breeds studied, and the proportions also varied according to seasonal agricultural activities. The chemical composition showed a higher metabolizable energy content in the rainy season and the crude protein content (CP < 12 %) in both areas studied did not meet requirements. The second experiment was carried out on-station with crossbred growing chickens either choice-fed maize and cowpea or given them as a complete mixed feed. Average daily gains were lower for the choice-fed treatments, and providing a vitamin-mineral supplement to the scavenging birds had no effect on performance. It was not economically advantageous to supplement maize and cowpea. In the third experiment, imported fishmeal was replaced by a mixture of local cottonseed cake and bran (wheat-maize) in diets for exotic layers kept under different management systems on-station. Egg production performance, feed conversion and gross margin were higher for the cottonseed cake and bran diet for both the confined and semi-scavenging hens. However, very poor egg production performance was seen for the scavenging only group, implying that supplementation is necessary for egg production. The final study showed CP contents of 23.4, 6.70 and 44.3 % of dry matter (DM), respectively, for traditional beer residue, shea-nut cake and cottonseed cake. True excreta digestibility of DM and the most limiting amino acids in the beer residue and cottonseed cake was high (> 90 %), indicating that these by-products are potentially useful protein supplements. However, more studies should be done, particularly with shea-nut cake, on the improvement of palatability, the optimum level of inclusion in the diets, and the nutritional availability for chickens, of these processed feedstuffs.

Keywords: Amino acids, Burkina Faso, Choice feeding, Cottonseed cake, Cowpea, Crop contents, Digestibility, Fishmeal, Maize, Nutritional status, Scavenging chickens, Shea-nut cake, Sorghum beer residue.

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Dedication

To the memory of my father Amadou Pousga
To my mother Kabore Setou, my sisters
Ami, Bintou, Safi and my brother Karim

Personne ne peut contre la volonté de Dieu !

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I S. Pousga, H. Boly, J.E. Lindberg and B. Ogle. 2005. Scavenging Pullets in Burkina Faso: Effect of Season, Location and Breed on Feed and Nutrient Intake. *Tropical Animal Health and Production,* 37 / 2005, pp. 623-634.

II S. Pousga, H. Boly, J.E. Lindberg and B. Ogle. 2006. Effect of supplementation on feed intake and performance of confined and scavenging crossbred growing chickens in Burkina Faso. *Tropical Animal Health and Production,* 38 / 2006, pp. 323-331.

III S. Pousga, H. Boly, J.E. Lindberg and B. Ogle. 2007. Effect of supplements based on fishmeal or cottonseed cake and management system on the performance and economic efficiency of exotic hens in Burkina Faso. *African Journal of Agricultural Research,* 2 / 2007, pp. 496-504.

IV S. Pousga, H. Boly, J.E. Lindberg and B. Ogle. 2007. Evaluation of Traditional Sorghum (*Sorghum bicolor*) Beer Residue, Shea-Nut (*Vitellaria paradoxa*) Cake and Cottonseed (*Gossypium Spp*) Cake for Poultry in Burkina Faso: Availability and Amino Acid Digestibility. *International Journal of Poultry Science* 6 / 2007, pp. 666-672.

Abbreviations

AA	Amino acids
ADG	Average daily gain
ASH	Total ash
CB	Cottonseed cake and bran
CF	Crude fibre
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
EE	Ether extract
FCR	Feed conversion ratio
FCS	Feed costs / kg weight gain
FM	Fishmeal
LSM	Least-squares mean
ME	Metabolizable energy
MJ	Mega-joule
NFE	Nitrogen-free-extract
OM	Organic matter
PDAV	Projet de developpement de l'Aviculture villageoise
TME	True metabolizable energy

1 Introduction

Village poultry make a substantial contribution to household food security throughout the developing world. It helps diversify incomes and provides high-quality food and fertilizer, and acts as a renewable asset in over 80 % of rural households (FAO, 2004). Irrespective of where the resource-poor areas of the world are located and where scavenging poultry are reared, there are certain aspects that are common: The keepers of scavenging poultry usually maintain a few (2-10) birds, are generally females and children, and are frequently the poorest people in their community (Acamovic *et al.*, 2005).

In the rural areas of Sub-Saharan Africa, 85 % of all households keep poultry, with women owning 70 % of the total number (Gueye, 1998; Branckaert & Gueye, 1999). Smallholder poultry production is primarily from free-ranging birds and there are few or no inputs. These birds are known around the world by different names, including family, scavenging, free range, desi, rural and backyard poultry, and chickens are the main species kept (Acamovic *et al.*, 2005). Many authors have described the indigenous domestic (*Gallus domesticus*) chickens reared in the African rural areas and have given them names, such as African chicken, bush chicken or runner chicken (Berte, 1987; Oluyemi, 1989; Kounta, 1991; Gueye & Bessei, 1997). Village chickens are not pure-bred animals because considerable crossbreeding has taken place (Van Eekeren *et al.*, 1995). These birds seem to be well adapted to their harsh environmental conditions, such as temperature extremes, heavy rain and periodic feed shortages (Gueye, 1998). Three types of village chicken production system have been reported:

The free range system: The birds find the main part of their daily rations by scavenging. There is generally little intervention in the life cycle of the birds (Sonaiya *et al.*, 1999), although feed supplements and water, overnight housing and health care may be provided. Supplementation consists of giving household wastes or cereal grains, generally in the morning or late in the afternoon, according to the farmers' ability (Chrysostome *et al.*, 1995).

The backyard system: This is a system in which the birds are partly-confined within a fenced yard or merely within an overnight shelter, fed and watered, and is sometimes also referred to as the semi-intensive system (Kitalyi, 1999).

The semi-intensive system: Generally found in Asian countries, and in which the chickens are fed formulated diets, either bought commercially or produced from feed mills (Aini, 1999). In this system, flock size varies between 50 and 500 birds on average (Sonaiya *et al.*, 1999). The use of specialised rather than indigenous breeds is common (Roberts, 1999).

The characteristics of African traditional poultry husbandry practices are the following (IEMVT, 1987): The birds range freely during the day and are usually gathered at night into a basic shelter for protection against predators; The feeds are limited to the scavenging feed resources (insects, seeds, and kitchen wastes); Supplementation is done occasionally, according to the availability of the feedstuffs used in the household; Very poor productivity is normal, with low laying and growth performance and important losses in the flocks; Eggs are rarely consumed as they are preferably hatched; Chickens are occasionally consumed and are appreciated for their taste, their relatively tough meat being well adapted to the prolonged cooking practiced in Africa.

Small-scale producers are however constrained by poor access to markets, goods and services, weakness of institutions, and lack of skills, knowledge and appropriate technologies (Gueye, 2002). Under the existing systems, the productivity of scavenging chickens is also limited by both poor nutrition and by health problems. Newcastle disease has been recognized as the greatest constraint to scavenging chicken production (Aini, 1990). The control of the disease by vaccination has, until recently, been ineffective, due to the nature of the scavenging chicken production systems, the epidemiological factors of the disease and heat lability of the vaccine (Spradbrow, 2001). The arrival of the highly pathogenic H5N1 avian influenza on the African continent is also of great concern for human as well as animal health (WHO, 2005). In Africa, as in affected Asian nations, village chickens often mingle freely with wild birds and most such flocks scavenge for food, often entering households or sharing outdoor areas where children play.

In Burkina Faso village chickens subsist from scavenging, with very irregular supplementation. Sonaiya (1995) reported that scavenging chickens in south-western Nigeria receive less than 35g of grain supplement daily, and it is suggested that supplementation of scavenged feed with locally available feed resources will improve chicken productivity (Sonaiya, 1995; Roberts, 1999). For effective supplementation, there is a need to know the quantity of the available scavengeable feed. The concept of the scavengeable feed resource base (SFRB) can be used to determine the quantity of the available scavengeable feed in an environment (Roberts, 1992). It is a starting point in determining the quantity and nutritional characteristics of the feed that is required to supplement.

Objectives

The general objectives of the present study were to develop feed supplementation strategies for chickens kept by resource-poor people in Burkina Faso, based on the use of locally available feedstuffs. The specific objectives were:

- To estimate by crop content analysis the available scavenging feed and nutritional status of scavenging local and improved laying chickens in different locations of Burkina Faso, and in different seasons.

- To compare the response of crossbred chickens to different feeding and management regimes using diets based on maize and cowpea.

- To evaluate the effect of replacing low protein fishmeal by cottonseed cake and wheat-maize bran on egg production and the economical efficiency of exotic confined and semi-scavenging laying hens.

- To determine the variability according to location and time of year in the chemical composition of cottonseed cake, shea-nut cake and local beer residue, and to estimate the digestibility of the dry matter and some essential amino acids in growing cockerels.

2 Background

Burkina Faso is located in the heart of West Africa (Fig.1) and is situated between latitudes 9°20' and 15°05' North, and longitudes 2°20' and 5°30' West. The country is one of the poorest in the world (PNUD, 2007). The surface area is 274 000 km^2 and the population in 2006 was estimated to be around 14 million inhabitants (Index Mundi, 2007). Approximately 94 % of the people under the poverty level live in the rural areas, as reported by Ouedraogo (2002). Extensive crop and extensive livestock production are the main activities of the population. These two activities play a key role in the economy, where livestock products constitute about 19 % of the exports, and more than 86 % of the population obtains at least part of their income from livestock production (MRA, 2003).

The total poultry population in Burkina Faso was estimated at 32 millions (MRA, 2004) (Fig. 2).

Figure 1. Location of Burkina Faso (http://photos.photo.perso.cegetel.net/burkina.faso/)

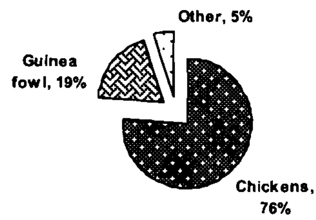

Figure 2. Poultry population in Burkina Faso

Poultry farming is an important part of the daily life of the population, especially the rural farmers, who raise village chickens for several purposes (Kondombo *et al.*, 2003), such as to supply meat and eggs and generate income. Chickens are also commonly used for gifts and sacrifices in social rites.

There are two main poultry production systems in Burkina Faso, the extensive and the intensive system. The former is well spread throughout the country, and virtually all rural farmers keep a few birds (chickens, guinea fowls, ducks, etc.) in the household in order to satisfy the family's financial needs. The intensive system is restricted to some peri-urban areas of the major towns, using exotic breeds, and the main objective is egg production for sale.

Local poultry are preferred because of their flavour. Despite the constraints faced in rural poultry production, such as diseases, and poor feeding and management, village poultry production is still important and widely distributed among smallholder farms. However, little published information is available in Burkina Faso on the effects of improved nutrition, and in general poultry production improvement and research represent only a minor part of the agricultural research and development programmes in the country.

2.1 Poultry Production Systems and Constraints in Burkina Faso

It has been estimated that only 0.8 % of the total poultry population is found in the cities and towns (MARA, 1997).Two dominant production systems have been described, industrial and traditional (Bonkoungou, 2002). The industrial system is a well organised, intensive system with exotic day-old chicks or eggs imported for hatching, and the main objective is egg production, with 200,000 layer and only 40,000 broiler chicks per year (Royer & Vidon, 2001) imported from Europe (France, Belgium, and Netherland) and from neighbouring African countries (Cote D'Ivoire and Ghana) (MRA, 2001). Compared with other West African countries such as Senegal, Ghana and Cote D'Ivoire, there are few industrial broiler units around the cities in Burkina Faso. The greatest proportion of the meat of exotic birds in Burkina Faso is from layers at the end of lay (Ouedraogo & Zoundi, 1999). Intensive production is still embryonic and is practiced in the peri-urban areas by a few relatively wealthy entrepreneurs from the cities. In this system, the production inputs are higher and the constraints are minimized. Importation of feed ingredients, medicines, and equipment is coordinated by an organisation called "Maison de l'Aviculture", which is an association of producers using exotic breeds.

The traditional system is widespread in rural, urban and peri-urban areas, is practiced mainly by resource-poor people and is based on indigenous breeds with low genetic potential. This system is characterised by the free-range production in which the birds have to scavenge to find most of their feed, which is constituted mainly by materials from the environment and household leftovers (Pousga *et al.*, 2005b; Kondombo, 2005), although cereal supplements are often given to the birds in the early morning and late afternoon. The poor genetic potential of the birds, in combination with the harsh environmental conditions and poor nutrition lead to a low production output. The losses are usually higher in the rainy season (Pousga *et al.*, 2005b), due to diseases and predators. This system is also characterised as a traditional farming system where poultry are integrated with crop and livestock production, and where several poultry species of different ages are mixed together in the flock. Although the traditional system is limited by a number of constraints, it provides the main urban centres with poultry products, such as live birds, meat and eggs from chickens and guinea fowl during the breeding season. Village chicken use at farm level was described according to Yameogo (2003) (Fig. 3).

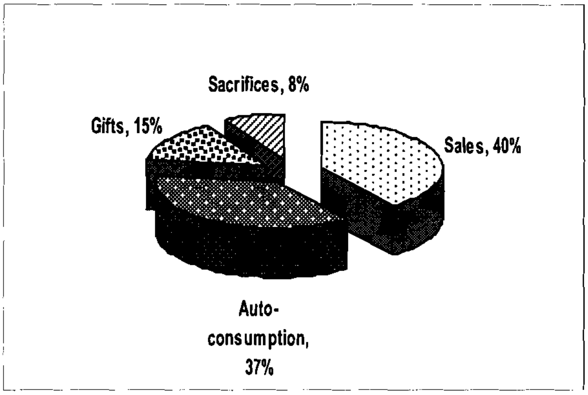

Figure 3. Village chicken utilization at farm level

There is little information on the genetic make-up of local poultry in Burkina Faso. However, Kondombo (2000) characterised chicken breed types according to body size and the colour of the feathers. The changes in the poultry (including chickens and guinea fowl) population in Burkina Faso from 1992 to 2005 are shown in Table 1.

Table *1. Poultry population of Burkina Faso in selected years between 1992 and 2005*

Year	Total number
1992	17 784 900
1996	19 920 000
2000	22 420 318
2003	31 007 000
2004	31 937 000
2005	32 895 000

Source: MRA (2002); Mission Economique (2006)

Poultry are widely distributed throughout the country (MARA, 1997) (Fig. 4).

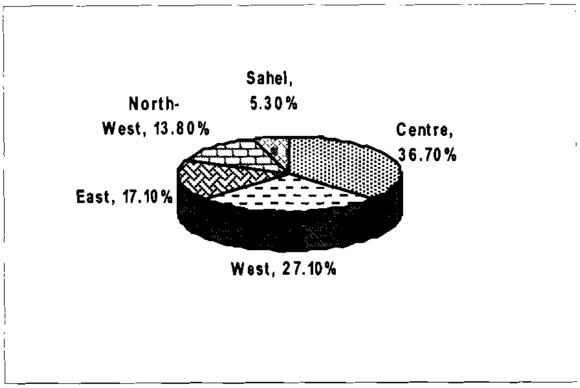

Figure 4. Poultry distribution in Burkina Faso

The average number of birds per household was reported to range between 1 and 50, with only 5 % of the farmers having more than 50 birds (Yameogo, 2003) . The body weight of local chickens reared in scavenging conditions ranges from 1.2 to 2.0 kg for adult males and from 0.9 to 1.2 kg for adult females (MAE, 1991; Ouandaogo, 1997; Pousga *et al.*, 2005 b). Some productivity parameters are presented (Table 2).

Table 2. *Productivity parameters of local chickens in Burkina Faso*

Parameter	Value
Onset of lay	170 ±15 days
Number of eggs per clutch	11 ±5
Number of clutches per year	2-3
Egg production / hen / year	30-45
Hatchability rate	79-85 %
Viability rate of chicks	89.3 %

Source: Yameogo (2003)

In the villages, natural incubation is done by the hens, which brood and hatch the eggs. It was shown that the hatchability of chicken eggs depends on the farming system (Kondombo, 2005).

2.2 Housing Conditions

In rural areas, the nature of the poultry house or shelter depends on the production system. Traditionally, young birds or chicks are generally raised in a large hut made with mud bricks and with a thatched roof. In some areas, farmers build small poultry houses with thatch (Boussini,

1995) to house laying hens and chicks at night, while other birds have to spend the night in the trees. Different poultry species are generally mixed together in the same house. Only 11% of the farmers build improved poultry houses and 80 % of poultry houses are traditional, with 73 % built with mud brick and 7 % with thatch or straw (Boussini, 1995; Bessin *et al.*, 1998).

2.3 Feeding Systems

In general, rural poultry find the main part of their diet by scavenging around the villages. The feeding systems adopted by the farmers depend on the age of the birds. Kondombo (2000) reported that poultry farmers regularly supplement chicks, while mature birds receive supplementary feed only when there is a surplus of cereals. Chicks are often supplemented with termites, and the main energy feedstuffs used as supplements are maize, millet and red sorghum, depending on location. These cereals are also staple foods for humans.

Many feed ingredients are used in standard diets used in intensive production, and the main poultry feed company is coordinated by PDAV through the Ministry of Animal Resources. Feed ingredients are also imported by a private wholesaler called "Maison de l'aviculture", an association of intensive chicken producers. A summary of the most important local and imported feedstuffs used in commercial feeds and the seasonal availability in Burkina Faso is shown in Table 3.

Table 3. *Seasonal availability of poultry feed ingredients in Burkina Faso*

Ingredients	Rainy season	Dry season	Remarks
Maize	**	***	
Wheat bran	**	***	Local and imported
Maize bran	**	***	
Soybean meal	-	-	Mostly imported
Groundnut cake	*	***	
Cottonseed cake	**	***	
Fishmeal	-	-	Imported
Blood meal	-	-	Imported
Mineral premix	-	-	Imported
Oyster shell	-	-	Imported
Bone meal	-	-	Imported sometimes
Sea shells	-	-	Imported
Vitamin premix	-	-	Imported
Lysine	-	-	Imported
Methionine	-	-	Imported

*: Rare

**: Less abundant

***: More abundant

2.4 Health and Mortality

The causes of losses in the traditional system were described by Kondombo *et al.* (2003) (Fig. 5).

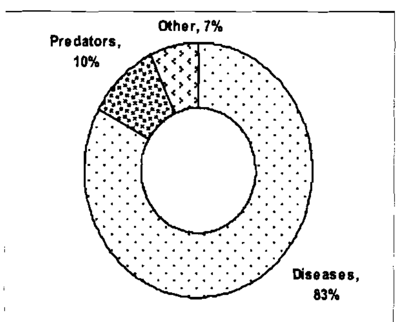

Figure 5. Causes of village poultry losses in Burkina Faso.

Disease control programmes have been adopted but results were generally not successful because these programmes require logistics, such as specialized workers with refrigeration facilities, and because they also require frequent travel to the villages, which is not practicable in the rural areas.

3 Summary of Materials and Methods

3.1 Study Sites and Periods

The feeding trials were carried out at the INAGOR research station, located in Sapone village, around 35 km from Ouagadougou, the capital, in the Central Region of Burkina Faso (experiments in Paper II, III and IV) (Fig. 6).

Figure 6. Study sites

This part of the country is included in the Sudano-Sahelian zone, which lies between the 900 and 600 mm isohyets. From late September to mid-December 2005 (Paper II), average minimum and maximum temperatures of 22.8°C and 31.2°C were recorded and mean relative humidity was 63.4 %. From September 2006 to February 2007 (Paper III), average minimum and maximum temperatures of 15.8°C and 40.0°C, and minimum and maximum relative humidities of 16 and 86 %, were recorded.

The poultry yard in the station has an area of around 1000 m^2 and is dominated by *Vitellaria paradoxa* and *Eucalyptus alba* trees, and various species of grass. The chickens also had access to fields adjacent to the station, where maize, cowpea, sorghum, onion, tomatoes and various legume crops are often cultivated. The experiment in Paper I was carried out in the arid and dry Sahelian zone in the North (Korea village) and in the sub-humid Soudano-guinean zone in the South (Bounouna village) (Fig.6). Bobo-Dioulasso, where samples were collected for the study in Paper IV, is also situated in the Soudano-guinean zone. The Sahelian zone is characterised by high mean temperatures (30 ± 7°C), low annual rainfall (350 ± 80mm), and a long dry season (8 months), while the Soudano-guinean zone is characterized by relatively high mean rainfall (950 ± 50 mm) and a longer rainy season (5 months).

3.2 Experimental Design (Paper I, II, III and IV)

The experiment in Paper I had a 2*2*2 factorial design, with season, location and breed as factors. The experiments in Paper II and III had a completely randomized design, with five treatments and four replicates for Paper II, and four treatments with three replicates in Paper III. The digestibility study in paper IV had a completely randomized design with three treatments (by-products) and six replicates.

3.3 Experimental Procedure

Paper I: In total 128 scavenging chickens (64 local and 64 crossbred) between 5-6 months old were purchased from the farmers in Korea and Bounouna villages, and slaughtered for physical and chemical analysis of the crop contents. The local breeds included various indigenous breeds of Burkina Faso (mainly Noa-kuiguiga and Noa Rigre), while the crossbred birds were the offspring of crossings between Rhode Island Red or Isa Brown and local chickens.

Paper II: This experiment included 100 male and 100 female crossbred birds (local hens x Rhode Island Red cockerels). The chicks were confined and given a commercial starter diet until four weeks of age, when they were divided randomly into 5 treatment groups, with 4 replicates for each treatment (10 birds/replicate, 5 males and 5 females). The dietary treatments were: CMx(+), confined and given a mixed feed *ad-libitum* with a vitamin-mineral premix; CS(+), confined and choice-fed cracked maize and cowpea *ad-libitum* with a vitamin-mineral premix; ScS(+), scavenging from 09.00 to 16.00h and offered the previous diet from 16.00 to 09.00h; ScS(-), same as above, but without the vitamin-mineral premix, and ScO, scavenging only, with no supplement provided.

Paper III: A total of 120 exotic laying hens (Isa Brown) at 28 weeks of age was randomly distributed to four feeding / management regimes, with 3 replicates and 10 birds per replicate. The feeding regimes were: CCB, 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; SCB, scavenging in the daytime (08.00h to 16.00h), with the CB diet available between 16.00h and 08.00h; SFM, management as in SCB, but with fishmeal replacing cottonseed cake and cereal bran (diet FM); SO, scavenging only with no supplement provided.

Paper IV: Sun-dried sorghum beer residue (n = 144) and shea-nut cake (n = 36) samples were collected each month in two different locations during a period of six months (including three months of the rainy season and three months of the dry season), while cottonseed cake samples were purchased monthly in a local market for the same period (n = 24). The by-products were analyzed for chemical composition, and then a force-feeding trial was carried out using crossbred cockerels (n = 36), for the estimation of true excreta amino acid digestibility. Some samples of shea-nut cake and sorghum beer residue from the two locations were pooled, and 8 g of each of the three by-products was tested, with six replications per treatment (2 birds per replication, paired on a weight basis, as fed and fasted).

3.4 Housing and Management (Paper I, II, III and IV)

Paper I: In 4 households in each of the two villages, the birds were allowed to scavenge together during the day time and were confined together at night in the same pen, and leg painted for identification. In each location and season, after 4 weeks of scavenging together, 4 representative local and 4 crossbred pullets were slaughtered for crop content analysis at the end of the dry season (May) and in the middle of the rainy season (August).

Paper II: The birds were vaccinated against Bronchitis, Infectious bursitis, Newcastle disease and Fowl pox. Prophylactic measures were also taken against Coccidiosis and parasites. The chicks were confined and given a commercial starter diet until 4 weeks of age, when they were assigned to the dietary treatments.

Paper III: All the birds were vaccinated against Newcastle disease and Fowl pox, and were also treated against internal and external parasites. The birds in all treatments except CCB were confined at night, and the pens were 2.0 m x 1.5 m, with sawdust as litter. Legs were painted for identification.

Paper IV: In total 36 crossbred cockerels, between 0.5 and 0.6 kg live weight, were paired on a weight basis and placed in individual metabolism cages (0.25 x 0.25 x 0.35 m). The force-feeding trial was carried out according to Likuski & Dorrell (1978) and Sibbald (1979) with respect to the feeding technique, and the estimation of endogenous amino acids was done according to Likuski & Dorrell (1978) and Song *et al.* (2003).

3.5 Feed Ingredients and Diets(Paper II, III and IV)

Paper II: The mixed feed in CMx(+) was a diet consisting of 50 % maize and 50 % cowpea, supplemented with a vitamin-mineral premix (0.2 %). The choice-fed diets [CS(+), ScS(+) and ScS(-)] were cracked maize and cowpea given separately with (+) or without (-) the vitamin-mineral premix.

Paper III: Feed ingredients were maize, wheat-maize bran, cottonseed cake, vitamin-mineral premix, dicalcium phosphate and oyster shell. The CB diet had a crude protein content of 19.3 % of DM and a metabolizable energy level of 14.2 MJ / kg, while the FM diet had a crude protein content of 13.9 % and 15.3 MJ / kg of metabolizable energy. The two diets were balanced according to the Ideal Protein concept for layers.

Paper IV: Samples of sorghum beer residue and shea-nut cake were collected in two locations (Sapone and Bobo-Dioulasso) and were pooled according to ingredient. Cottonseed cake samples from different batches were also pooled, and the amino acid digestibility of each by-product was determined in cockerels.

3.6 Sample Analysis and Calculations(Paper I, II, III and IV)

Feed ingredients were analysed for dry matter (DM), crude protein (CP) (N*6.25), crude fibre (CF), total ash (Ash), and organic matter (OM) using standard AOAC methods (AOAC, 1985). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined according to Van Soest *et al.* (1991) (Paper I and II). ADF in Paper III and IV was determined according to AOAC (1985), and NDF according to Chai & Uden (1998). Crude fat (EE) was measured after extraction with petroleum ether in a Soxtec apparatus (Paper I and II) and after acid hydrolysis (AOAC, 1985) (Paper III and IV). Minerals were determined using spectrometry (FAO, 1980; AOAC, 1985). Amino acids were determined using standard methods (AnalyCen, Lidköping, Sweden). Metabolizable energy (ME) was calculated by an indirect method, using the following equation (INRA, 1987):

True ME (MJ / kg DM) = (3951 + 54.4EE − 88.7CF − 40.8Ash)* 0.004184

Where: EE = % Ether extract, CF = % of Crude fibre, Ash = % of Ash.

Nitrogen Free Extract (NFE) was calculated following the formula:

NFE (%) = 100 % DM − (CP + EE + CF + Ash).

Dressing percentage was calculated according to the formula:

Dressing percentage = (Carcass weight) / (live weight at slaughter)*100

The diets in Paper II and III were formulated by Uneform Software (Thomson, 1997) using Microsoft Excel for Windows 2003.

Apparent and True amino acid digestibility in Paper IV was calculated according to McNab (1994):

$$\text{Total tract AA digestibility} = \frac{\text{AA consumed} - \text{AA in faeces}}{\text{AA consumed}}$$

$$\text{True AA digestibility} = \frac{AAC - (AAF - EAAF)}{AAC}$$

AAC = amino acid consumed

AAF = amino acid in faeces from fed birds

EAAF = endogenous amino acids in faeces from unfed birds.

3.7 Statistical Analysis

The data in all experiments were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of MINITAB Reference Manual Release 13.31 and 14 for Windows 2000. Pair-wise comparisons of means were made using the Tukey test.

4 Summary of Results

4.1 Nutritional Status of Scavenging Local and Crossbred Chickens (Paper I)

Paper I. Visually, and in order of importance, the main components of the crop contents were cereal grains, cereal brans, forages, seeds, insects and worms, kitchen waste, and other household by-products. The mean fresh weight of the crop contents was higher in the dry season compared to the rainy season ($P < 0.05$). The proportion of grain (maize, millet and milo) and seed was higher in the rainy season than in the dry season ($P < 0.05$) (Fig. 7). A higher proportion of grain was found inside the crops of local birds, while a higher proportion of bran was found in the crossbred pullets ($P < 0.05$). The proportion of kitchen waste found inside the local birds was higher than in the crossbred birds ($P < 0.05$), and the proportion of grass and leaves was higher for the crossbred compared to the local breed pullets ($P < 0.05$) (Fig. 8).

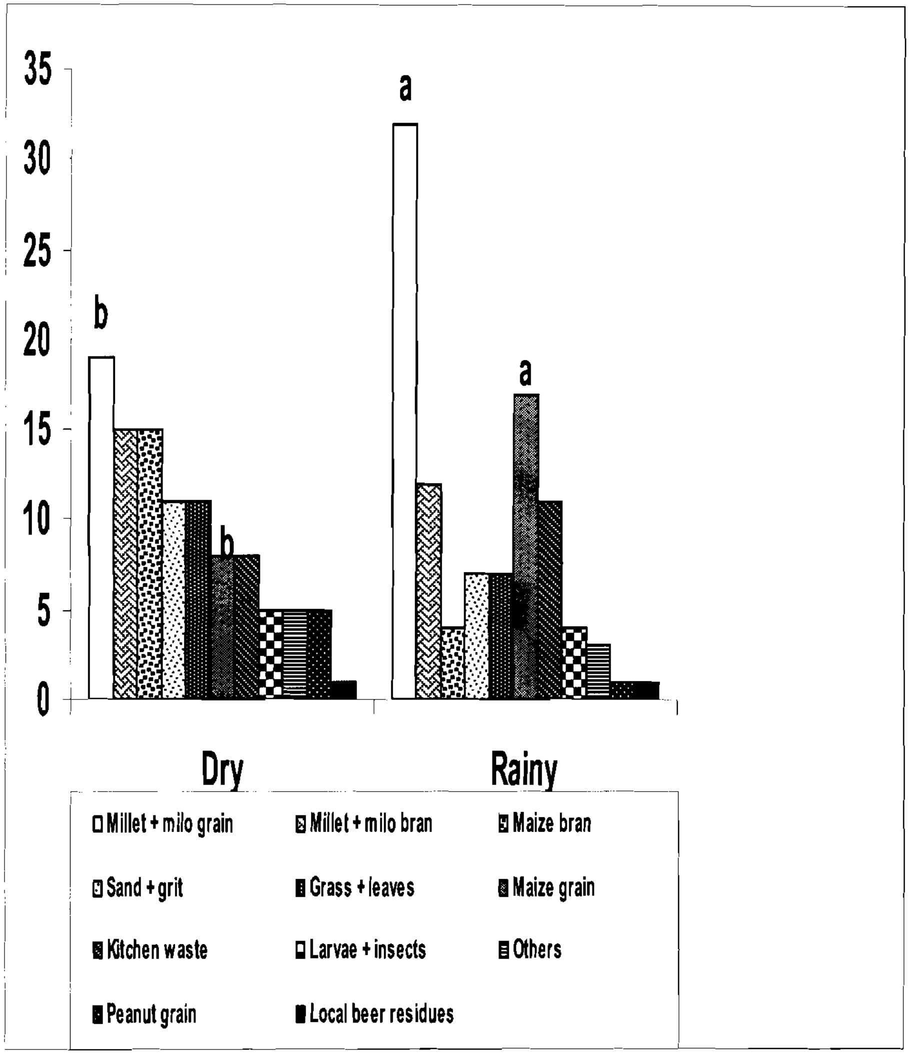

Figure 7. Effect of season on the physical composition of crop contents of scavenging hens (% of total fresh weight)

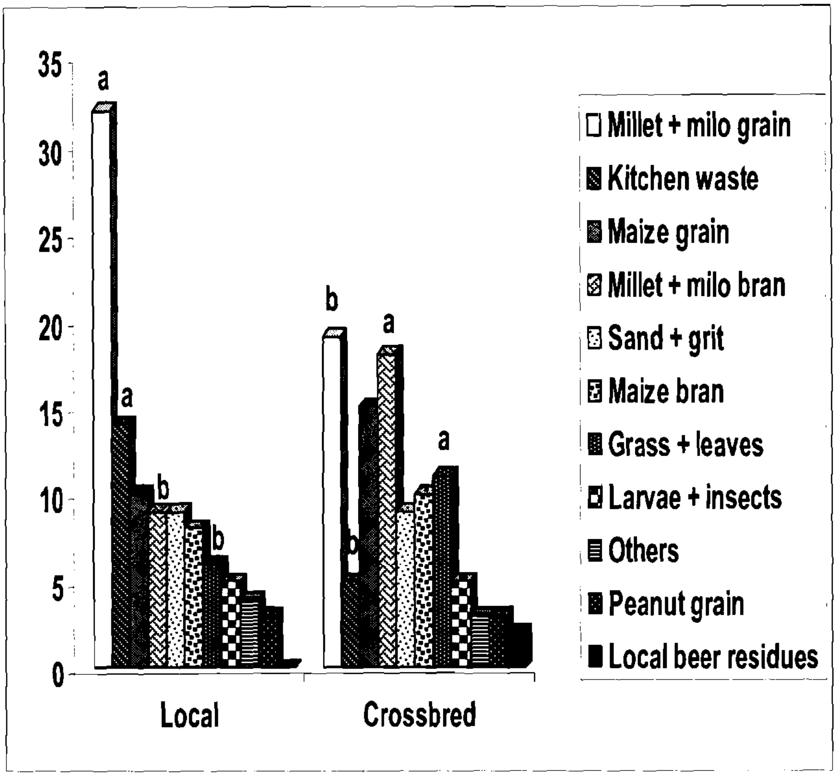

Figure 8. Effect of breed on the physical composition of the crop contents of scavenging hens (% of total fresh weight)

Overall fresh crop content weight was higher in the northern Sahelian village of Korea than in the sub-humid southern village of Bounouna ($P > 0.05$). Millet and milo grain and bran proportions were higher in Korea, while the maize proportion was higher in Bounouna (see Fig. 9). The proportion of kitchen waste was higher in the crops from Bounouna ($P < 0.05$), while the proportion of dry forages was higher in Korea ($P < 0.05$). Rice and local beer residue were not found in the crops from Korea. The chemical composition of the crop contents showed significant differences between seasons ($P < 0.05$), but not between breeds and villages. Dry matter, ash and potassium contents were higher in the dry season ($P < 0.05$), whereas ME concentration was higher in the rainy season than in the dry season ($P < 0.05$).

Overall, mean live weight at slaughter and mean carcass weight were higher in the dry season compared to the rainy season ($P < 0.05$).

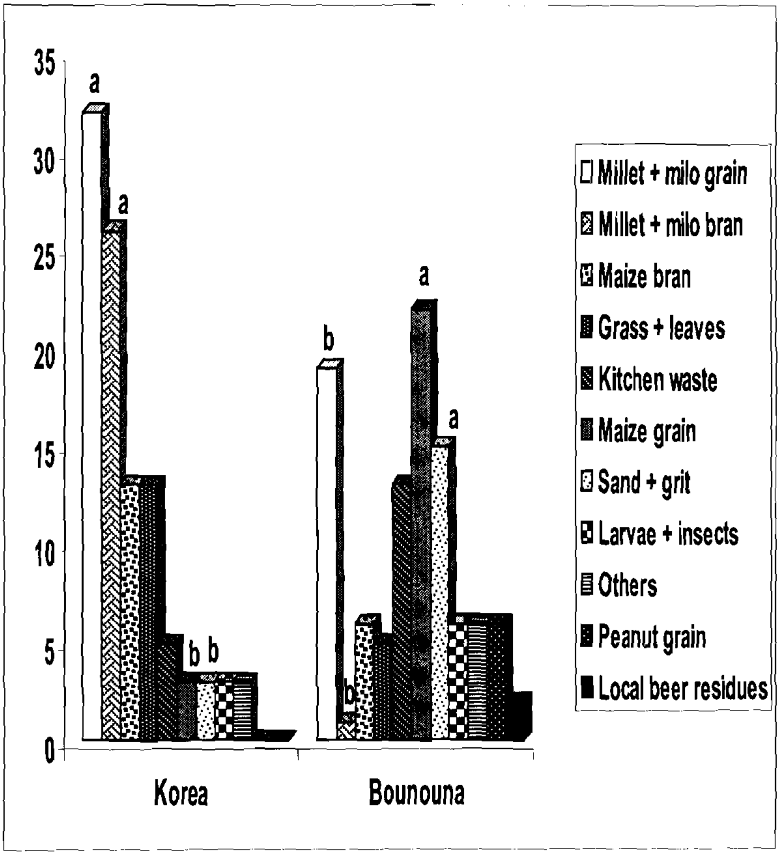

Figure 9. Effect of location on the chemical composition of the crop contents of scavenging hens (% of total fresh weight)

4.2 Source and Composition of Feed Ingredients (Paper II, III and IV)

The maize used in the trials was a local variety of white maize with CP and ME contents of 8.34 % and 15.8 MJ / kg, respectively. The cowpea used (Paper II) was one of the local varieties of black-eye pea, commonly called *Niebe* in West Africa, and contained 23.1 % CP and 11.3 MJ / kg ME. The cottonseed cake used (Paper III and IV) was decorticated expeller, which is locally available in Burkina Faso after oil extraction in the factories. The bran used (Paper III) was a mixture of by-products from small-scale wheat and maize processing mills. Local beer residue (Paper IV) is available in Burkina Faso after home brewing, usually done by women, generally with red sorghum. The local brewing technique is summarised in Fig. 10. Shea-nut cake is a by-product of the indigenous technology for extraction of fat from the kernels of the shea butter tree (*Butyrospermum parkii or Vitellaria paradoxa*). The local technique for the fat extraction is described in Fig. 11.

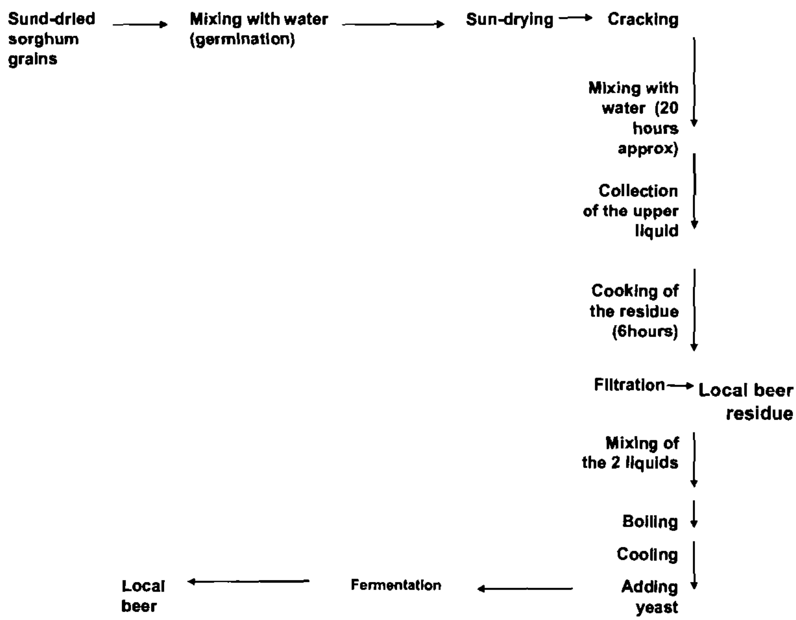

Figure 10. Artisan beer brewing technique in Burkina Faso

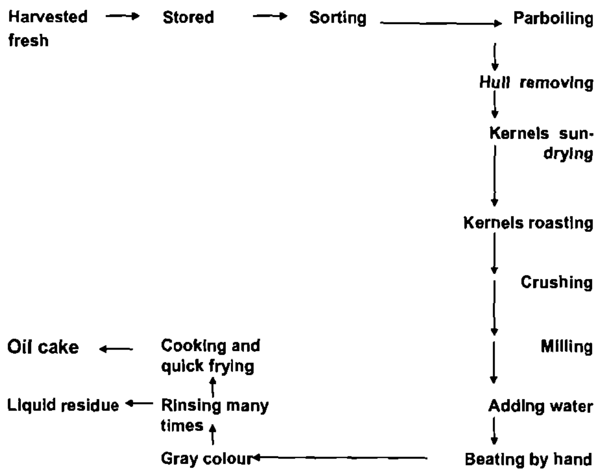

Figure 11. Artisan technique for shea fat extraction in the West of Burkina Faso

4.3 Effect of Supplementation with Local Feed Ingredients on Intake, Growth Performance and Economic Efficiency

Paper II: The highest daily DM intake (43.5 g) was observed in the confined group that was choice-fed maize and cowpea with a vitamin-mineral premix (CS(+)), while the lowest intake (33.6 g) was seen in the confined group given the mixed feed (CMx(+)) ($P < 0.05$), with an intermediate value for the semi-scavenging treatment. In the free-choice treatments the proportion of cowpea of total intake was higher for the semi-scavenging groups receiving the diet with a vitamin-mineral premix (ScS(+)), resulting in higher CP and ME intakes from cowpea in treatment ScS(+) than for CS(+) and the corresponding semi-scavenging treatment without a vitamin-mineral premix (ScS(-)) ($P < 0.05$).

Average daily weight gain (ADG) was significantly higher (8.15 g) for CMx (+) than for all other treatments, and lower in the scavenging only group (ScO) (Fig. 12). Average daily gain and final live weight were higher for the males compared to the females ($P < 0.05$) (Fig. 13). The highest feed conversion ratio (FCR) was observed in CS(+) and the lowest in CMx(+) ($P < 0.05$).

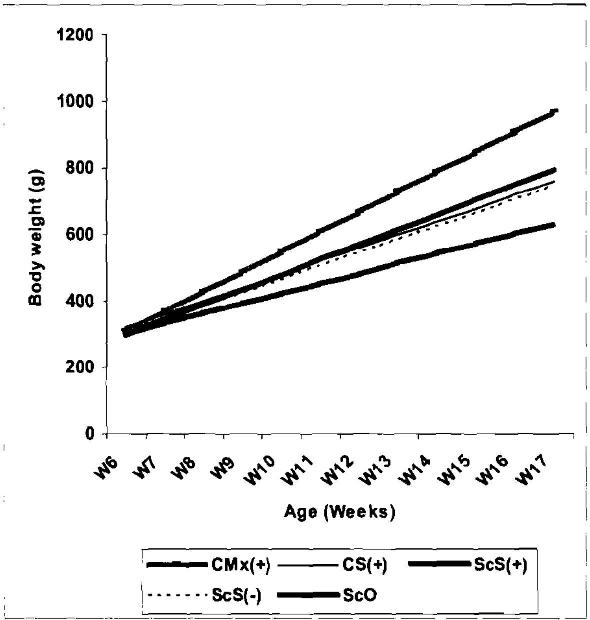

Figure 12. Effect of feeding and management on the growth of crossbred chickens.

CMx(+): Confined, mixed feed *ad-libitum*; CS(+): Confined, choice-fed *ad-libitum*; ScS(+): Semi-scavenging, choice-fed and with a vitamin-mineral premix; ScS(-) same as ScS(+) but without the vitamin-mineral premix; SO: Scavenging only.

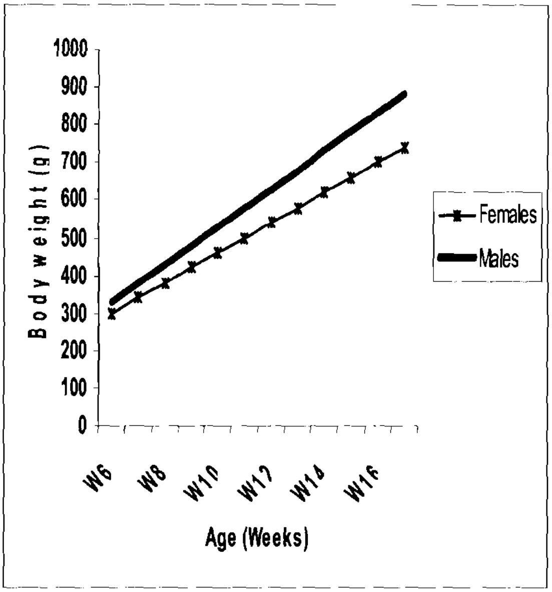

Figure 13: Mean body weight changes of crossbred male and female chickens under different feeding and management regimes

Feed costs (USD / kg of weight gain) were higher in CS(+) (5 USD) and ScS(-) (4 USD) compared to CMx(+) (3 USD) and ScS(+) (3 USD) ($P < 0.05$). Higher mortalities were seen in the scavenging treatments compared to the confined treatments.

Mean live body weight at slaughter was highest for the cockerels in CMx(+) (1048 g) and lowest in ScO (600 g) ($P < 0.05$). No significant difference was found among the other treatments. Carcass percentage was higher in ScS(+) (65.1%) and lower in ScO (53.0 %) than in the other treatments ($P < 0.05$ %). No significant difference in carcass percentage was found between ScS(+) and ScS(-). The highest thigh weight was found in ScS(+), while the lowest value was seen in treatment CMx(+).

4.4 Effect of Replacing a Low-Protein Fishmeal Diet by a High Protein Diet Based on Local Feed Ingredients on the Performance and Economic Efficiency of Semi-Scavenging Exotic Layers

Paper III. Higher daily DM and nutrient intakes were observed in the confined treatment (CCB) (103 g DM) compared to the semi-scavenging groups (52.9 and 66.7 g DM, respectively, for birds scavenging and receiving the fishmeal diet in late afternoon (SFM) and the corresponding scavenging birds that were fed the cottonseed cake and bran diet in late afternoon (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 acids. Daily intakes of ash, calcium and NFE were higher in SFM than in SCB ($P < 0.05$).

Final body weight was lower than initial body weight in SFM and SO, but was higher in SCB and CCB ($P < 0.05$). No significant difference in body weight was found among the semi-scavenging treatments. 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 %, respectively) and SFM (375, 20.8 % and 20.8 %, respectively) ($P < 0.05$), and were lowest in SO (40, 2.30 % and 2.24 %, respectively) ($P < 0.05$). The egg production curves are shown in Fig. 14. Higher mortality was found in the confined treatment compared to the scavenging treatments.

Feed conversion ratio was lower for the confined treatment (CCB: 2.92 kg feed DM / kg eggs) compared to SCB (4.90 kg feed DM / kg eggs). No significant difference was found between the semi-scavenging groups for FCR (5.11 and 4.90 kg feed DM / kg eggs for SFM and SCB, respectively). Feed cost / kg eggs produced was lowest for the confined 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.

No significant difference was noted in mean egg weight and shell thickness between the confined and the corresponding scavenging treatments. In the semi-scavenging groups, these parameters were higher for SCB compared to SFM ($P < 0.05$). The SO hens laid the smallest eggs, and with a deeper yolk colour. Yolk colour was paler in the confined treatments compared to the corresponding scavenging treatments.

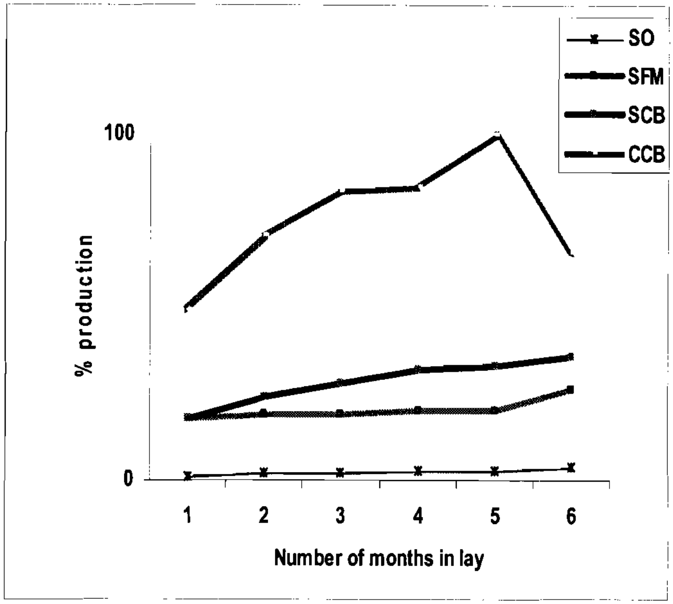

Figure 14. Effect of feeding and management system on the egg production of exotic layers.

SO: Scavenging only; SFM: Scavenging with the fishmeal diet from 16.00h to 08.00h; SCB: Scavenging with the cottonseed cake and bran diet from 16.00 h to 08.00h; CCB: Confined with the cottonseed cake and bran diet *ad-libitum*.

4.5 Chemical Composition and Digestibility of Some Local By-Products

Paper IV. The data showed acceptable crude protein (CP), metabolizable energy (ME) and crude fat (EE) contents for local sorghum beer residue (23.4 %, 13.4 MJ / kg and 5.6 %, respectively). However, mineral and amino acid concentrations were low (0.14 and 0.25 % for calcium and phosphorus, and 0.87, 0.44, 0.41 and 0.63 %, respectively, for lysine, methionine, cystine and threonine). Fibre contents were higher in Sapone, in the Soudano-Sahelian zone, compared to Bobo-Dioulasso, in the Soudano-Guinean zone. Overall, no significant differences were found in proximate composition between the two locations, and higher nutritive values were found from October to December compared to July to September.

The proximate composition of shea-nut cake showed mean values of 6.7 %, 7.3 % and 13.1 MJ / kg, respectively, for CP, EE and ME. No significant difference was found in proximate composition between the two locations, but CP and ME contents were numerically higher in Bobo-Dioulasso compared to Sapone, while ash, CF and EE were higher in Sapone. Mean calcium and phosphorus contents were 0.40 and 0.19 %, and amino acid contents were 0.27, 0.14, 0.09 and 0.23 %, respectively, for lysine, methionine, cystine and threonine.

Analysis data for cottonseed cake showed CP, EE and ME contents of 44.3, 5.9 % and 12.7 MJ / kg, respectively. Mean calcium and phosphorus contents were 0.34 and 1.3 %, and lysine, methionine, cystine and threonine contents were 1.6, 0.80, 0.82 and 1.9 %, respectively. Higher nutritive values for cottonseed cake were found in November and December.

True DM digestibilities were 93, 96 and 91 %, respectively, for beer residue, shea-nut cake and cottonseed cake. Overall, high digestibility values were found for the most limiting essential amino acids in all the three by-products.

5 General Discussion

5.1 Effect of Season, Location and Breed on Feed and Nutrient Intake from Scavenging

The Scavengeable Feed Resource Base (SFRB) was clearly affected by the environment and the availability of the household refuse. The results in Paper I confirmed that the quantity and the quality of the materials consumed by the birds varied according to household socio-cultural activities and religion, and consequently according to location. The variability according to the farmers' activities, such as sowing or harvesting, found by Gunaratne *et al.* (1993) and Goromela *et al.* (2007) was highlighted and confirmed in this study. However, the higher crop content weight found in the dry season compared to the rainy season was unexpected, and was probably due to the fact that the rainy season was earlier in the northern part of Burkina Faso at the time of the study, compared to previous years.

The SFRB in Burkina Faso is of low quality, with poor nutritive value, in particular with respect to crude protein and metabolizable energy contents, as was shown by the chemical data and the live weight gains of pullets between 5-6 months old in Paper I. In addition, the results of the feeding trials in Paper II and III showed that the nutrient intakes from scavenging were insufficient to meet the chickens' requirements for maintenance, growth and egg production. The poor performance and the higher mortality of the scavenging growing chickens in Paper II supported the conclusion of Goromela *et al.* (2006) that starvation was the main cause of the high mortality rates in village chicks and growers in Africa and South-East Asia. This is also in agreement with Sonaiya *et al.* (2002), who found by applying the "bird unit" concept for the estimation of the SFRB that the quantity available for a chick for instance was very low. The poor performance of the semi-scavenging birds in Papers II and III demonstrated that the SFRB was obviously very limited and variable in the regions of Burkina Faso studied, confirming that the SFRB varies effectively according to climate and location. However, other studies in Asia (Minh *et al.*, 2004) and Africa (Smith, 2001; Acamovic *et al.*, 2005) reported higher performance under semi-scavenging conditions compared to the present study. The physical data of the crop contents of local pullets showed that these birds were more selective in scavenging compared to crossbred pullets, and the poor performance of the scavenging birds in Papers II and III supported the conclusion that exotic birds are not well adapted to harsh scavenging conditions. The variability in the quality and quantity of the SFRB can also be linked to the "bird unit concept" of Sonaiya *et al.* (2002), confirming that the availability of the SFRB also varies within a flock according to the category of bird, and also because of competition for the SFRB.

5.2 Availability, Nutritive Value and Digestibility of Some Feedstuffs for Poultry

For improving the nutrient intake and economics of village chicken production, better use should be made of the available local feedstuffs. Because of the inherent low productivity and low feed conversion efficiency of local breeds (Saunders, 1984; Van Eekeren *et al.*, 1995) they are unable to efficiently utilize high quality feeds. In Burkina Faso, some locally available materials that can be fed to village chickens have been described: for example, Ouedraogo (1987) outlined a technique for the production of maggots and termites as protein supplements for chicks, while Ouele (1989) listed groundnut cake, cottonseed cake, soybean, brewery malt, and imported ingredients such as fishmeal, blood meal and milk powder as potential protein feedstuffs for poultry. For chickens kept by resource-poor people in the rural areas of Burkina Faso, supplementation should be based on the use of the cheapest suitable feed ingredients that are available at village level. Consequently, the present study includes evaluations of feedstuffs such as maize, cowpea, wheat-maize bran, sorghum beer residue, cottonseed cake and shea-nut cake, as potential supplements for chickens. In West Africa in general, and in Burkina Faso in particular, cereals (millet, sorghum, maize, fonio and rice) are the staple food crops, and together occupy over 85 % of the cultivated land (Les Editions Jeune Afrique, 1998), and are therefore widely available.

Maize (*Zea mays*) is the preferred cereal for feeding to domestic fowls. White and yellow maize are the common varieties found in Burkina Faso, and their dietary energy concentration is the highest among the most common cereals produced in the country. However, maize is deficient in protein (9 % CP in DM) and the amino acid profile is unbalanced, with deficiencies of lysine and tryptophan (Labrier & Leclercq, 1994). The protein content of the white variety of maize used in the present study was slightly lower (8.3 %), and the metabolisable energy content of 15.9 MJ / kg DM was in agreement with values reported for other varieties of maize in Africa (Dana & Ogle, 2002).

Cowpea (*Vigna unguiculata*) is the most popular legume, and the largest part of total world production originates from Africa. Burkina Faso is one of the most important cowpea producers in Sub-Saharan Africa, with a mean annual production in 2005 of 443,400 tonnes (Mission Economique, 2006). This legume is relatively easy to cultivate in harsh environments, and ensures food security for rural subsistence households (Lambot, 2002). The protein (23 % of CP) in cowpea seed is richer in lysine and tryptophan compared to cereals, but is deficient in methionine and cystine compared to animal proteins (Davis *et al.*, 1991).

In the rural areas of Burkina Faso, cereal and legume seeds are the main supplements for poultry, but are usually only provided on an irregular basis, according to availability. Because of its high nutritive value and ease of cultivation, cowpea is a potentially valuable protein supplement for chickens kept by resource-poor people in the rural areas. However, cowpea should first be treated, for example by boiling for a short time, to increase the palatability and to reduce the anti-nutritional problems linked with the presence of tannins (Martin *et al.*, 1980) and a trypsin inhibitor (Cabezas *et al.*, 1982).

Cottonseed (*Gossypium spp.*) cake and cereal brans (wheat and maize) are the agro-industrial by-products that are the most commonly used as ingredients in poultry feeds in Burkina Faso. Farmers are aware of the importance of these by-products, and many purchase them to supplement to their animals when other feed resources in the immediate environment are limited, in particular in the dry season (Kondombo, 2005). Current market conditions for the agro-industrial by-products in general, and cottonseed cake in particular, determine their availability and price for the farmers. According to Savadogo (2000), agro-industrial by-products were not previously available in Burkina Faso, or were so expensive that farmers could not afford them, although the situation has improved since then. The glandless variety of cotton cultivated in Burkina Faso allows higher inclusion levels of the seed cake in poultry diets. The results in Paper III show that it could completely replace fishmeal in layer diets when combined with wheat-maize bran, because of the higher crude protein content (44 % of DM on average) compared to un-decorticated meals (McDonald *et al.*, 2002; Göhl, 1981).

Virtually all the fishmeal used in livestock feeds in Burkina Faso is imported, and is generally unavailable for rural farmers because of the high cost. In addition, there is considerable variation in quality and nutritive value between batches. For example, to increase profits, sand, sawdust and other materials are sometimes mixed with fishmeal in some countries in West Africa. These practices, in addition to inadequate storage conditions, can explain the poor quality of the fishmeal observed during this study i.e., development of rancidity (personal observation) and probably also the low crude protein content (39 % of DM). In view of these problems it was considered important to find alternatives to fishmeal, and two potential candidates at village level are shea-nut cake and beer residue. Traditional sorghum beer residue has an acceptable nutritive value and is available in the villages throughout the year. However, special measures should be taken to increase its palatability, as Kondombo (2005) found that amounts consumed by chickens were often rather low.

The shea tree grows throughout the semi-arid Sahel region of West Africa, but the largest concentration is in Burkina Faso, where shea butter and unprocessed shea kernels represented the country's third most important export after cotton and livestock in 2000 (Harsch, 2001). The harvesting and processing of shea is primarily an activity of rural women (Elias & Carney, 2007), and its earnings directly benefit some of the poorest villagers, in a country classified as one of the poorest in the world. Shea-nut cake, the by-product after butter extraction was investigated as a potential protein supplement, but the unexpected low crude protein content (Paper IV) indicated only very limited value, in contrast with other studies, where values of 16 – 18 % CP were reported (Morgan & Trinder, 1980; Atuahene *et al.*, 1998; Olorede *et al.*, 1999). The discrepancy can be attributed to the oil extraction technique used at village level in Burkina Faso, which includes repeated boiling and roasting, making the protein susceptible to degradation as a result of the Maillard reaction (Hodgkinson, 2006), confirmed by the dark colour of the traditional shea-nut cake. However, the cake is available almost all the year round, and could be a useful feed for chickens, in particular during periods of feed shortage in the dry season, when women have more free time to produce shea-butter.

Relatively high fibre content was found in cottonseed cake, traditional beer residue and shea-nut cake, but the digestibility values of the dry matter and selected essential amino acids indicate that they could be used as ingredients in chicken feed. The relatively high CP content of local beer residue and cottonseed cake testifies to their potential value for monogastrics, although the low CP content of the shea-nut cake is a major problem. However, these by-products have undergone heat and pressure during processing, which, despite the fact that these processes contribute to inactivating some anti-nutritional factors in the raw material (Gatel, 1994; Nagalakshmi *et al.*, 2007) may induce chemical reactions such as the early Maillard reaction, which may render some of the amino acids nutritionally unavailable for the animal (Hodgkinson, 2006). Methods of evaluation such as bioassays for the evaluation of the real nutrient availability to monogastric animals, and feeding trials to determine the effect of different inclusion levels in the diet on growth and egg production performance are necessary. Shea-nut cake from commercial "press" extraction should also be considered, due to its higher protein content, rather than the cake from traditional oil extraction.

5.3 Effect of Choice-Feeding on Feed Intake and Growth Performance of Crossbred Confined and Semi-Scavenging Chickens

The principle underlying choice feeding (the so-called cafeteria method) of poultry is that individual birds reared in a flock are able to select between various feed ingredients according to individual needs and production capacities, which may increase efficiency when compared to a complete diet (Pousga *et al.*, 2005a). In Paper II, none of the choice-fed birds succeeded in meeting their requirements for protein and essential amino acids, resulting in lower performance compared to other studies (Olver & Malan, 2000; Erener *et al.*, 2003), mainly because of the lower than expected intake of the cowpea, that was intended to supply the necessary protein. The variability in the results reported in choice-feeding studies (Olver & Jonker, 1997; Dana & Ogle, 2002; Cruz *et al.*, 2005) emphasises the challenges facing the application of this feeding technique in poultry. Therefore, it is important to consider the conclusions of Cruz *et al.* (2005), that the adjustment of intakes to meet nutritional requirements not only depends on the ability of the birds to select the correct proportions of the feeds offered, but might also depend on palatability and intake, and also on ingredient quality. The lower cowpea intake in Paper II was attributed to its low palatability, probably due to the presence of anti-nutritional factors reported in other studies, such as trypsin inhibitors (Cabezas *et al.*, 1982) and tannins (Martin *et al.*, 1982).

The slow growth of the birds in the semi-scavenging treatment would have partly been a result of the nutritional poverty of the SFRB in the study site. However, using the results reported in Paper I, where daily DM intake was 35 g in real scavenging conditions, and assuming that the birds fill their crop in four hour cycles of eating (Feltwell & Fox, 1978), it appears that in Paper II the intake from scavenging would have been around 70 g, which would have been expected to increase growth performance. However, this was not the case, probably because of the restricted scavenging conditions in the research station, which did not reflect the real village environment. The poor feed conversion efficiency and the high feed costs lead to the conclusion that it is not economically advantageous to feed untreated cowpea at current market prices to crossbred confined or scavenging chickens during the crop harvesting period at the end of the dry season.

5.4 Effect of Replacing Fishmeal by Cottonseed Cake and Wheat-Maize Bran in Layer Diets

Feed supply is the most important limiting factor in the improvement of poultry production in Sub-Saharan Africa in general and in Burkina Faso in particular. The high cost of imported feed ingredients, such as fishmeal, methionine and lysine necessitate the use of local by-products as replacement for conventional ingredients. Local chickens have low productivity, characterized by poor laying ability, low growth rate (Dessie *et al.*, 2000; Kondombo *et al.*, 2003) and low feed conversion efficiency (Saunders, 1984; Van Eekeren *et al.*, 1995). On the other hand, when local chickens in Burkina Faso were fed a standard commercial feed the result was a very low gross margin per bird, even though biological performance was improved (Kondombo, 2005). The experiment in Paper III was designed to evaluate the replacement of fishmeal by some local by-products, such as cottonseed cake and bran in exotic layer diets under different feeding regimes. Calculations of feed cost / kg eggs produced and sale price / kg eggs showed higher economic returns for a cottonseed-wheat and maize bran diet compared to a fishmeal based diet in semi-scavenging conditions, as a result of higher egg production and the lower cost of cottonseed cake and wheat-maize bran compared to fishmeal. The problems facing the efficient utilization of fishmeal in Burkina Faso are a result of it being imported from the neighbouring countries of Ivory Coast, Senegal and Ghana.

The quality thus is very variable, due to differences in processing technique, transport and storage conditions, confirmed in the present study. The poor quality of the fishmeal used (39 % CP) in the experiment was the main factor behind the poor egg production performance observed. Higher inclusion levels of the fishmeal in order to meet requirements would have increased feed costs, and could have further reduced palatability and intake unless good quality fishmeal had been used (Smith, 2001). Conversely, higher egg production performance and good economic returns were obtained with the cottonseed and bran diet, and increasing the inclusion level of these local by-products would have further reduced feed costs. In addition, this would also have meant that it would have been possible to reduce the inclusion level of maize, which is a staple food for the human population in Burkina Faso.

The evidence of the poverty of the SFRB in the study site was highlighted, and it was obvious that in real-world scavenging conditions, the cottonseed cake and wheat-maize bran diets would have probably given even better egg production performance and superior economic returns compared to the confined groups. The relatively good performance and economic efficiency of the confined birds showed that exotic layers can also be reared advantageously in confinement by resource-poor farmers, using inexpensive, locally available feedstuffs such as cottonseed cake and brans as protein ingredients. The poor performance of the unsupplemented scavenging groups indicates that exotic breeds should not be reared in full scavenging systems without supplementation in the dry tropics, where the SFRB is usually very limited.

6 Conclusions

The scavenging feed resource base, evaluated in two agro-ecological zones of Burkina Faso by crop content analysis, was found to be influenced by the ecology of the poultry yard and immediate environment, and was dominated by grasses, weeds, leaves, insects, worms and seeds. The scavengeable feed also included household leftovers such as kitchen food waste, seeds and cereals and their by-products. There was found to be considerable diversity in the composition of the various feed items found in the crop that varied between seasons and locations and according to breed. Scavenging pullets were estimated to be getting around 60g of feed / day from scavenging, and the chemical analysis of the materials in the crop indicated that scavenging only cannot meet the nutrient requirements of crossbred pullets, in particular with respect to protein. However, it was concluded that scavenging only, without supplementation, was the most economical feeding strategy for crossbred growing chickens, at least during the harvesting period at the end of the rainy season. It was not economically advantageous to provide supplements of maize and cowpea to crossbred growing chickens, because of the lower intake of the cowpea due to its low palatability. This implies that the adjustment of intakes to meet nutritional requirements when birds are given free-choice access to different feedstuffs depends on their palatability and quality.

Evaluation of performance and economic efficiency showed that exotic layers could be reared advantageously in a semi-scavenging system and in confinement by resource-poor farmers, using locally available feedstuffs such as cottonseed cake and brans as protein ingredients. The poor performance of the scavenging only groups implied that exotic breeds are not particularly adept at scavenging and may need a long period of training in order to adapt to the system.

Alternative ingredients to imported protein feeds were evaluated and it was found that cottonseed cake could advantageously replace fishmeal in exotic layer diets when combined with wheat-maize bran, as a result of its high crude protein content, and also because the glandless (gossypol-free) variety commonly cultivated in Burkina Faso allows higher levels of inclusion. Another by-product produced at village level, beer residue, was also found to be potentially useful, due to the fairly high protein content and high digestibility values of some essential amino acids. However, the shea-nut cake resulting from the artisan extraction of the butter was found to have a low content of crude protein.

6.1 Implications and Recommendations

The scavengeable feed resource base in the regions of Burkina Faso that were studied is poor in quantity and quality, particularly during the dry season, which lasts for almost eight months of the year. Inputs for poultry in the rural areas are low, mainly because of the high cost of conventional feeds and also due to competition between humans and chickens for potential feed ingredients such as cereals. Poultry is a class of small livestock that resource-poor people can afford, including neglected groups such as women and the landless, and therefore is one of the most important sustainable sources of income and capital accumulation available to the poor. However, rural poverty persists, due amongst other things to the rapidly increasing human population and natural factors, including diseases such as avian influenza, that negatively influence the expansion of village poultry. Burkina Faso was officially the fifth African country (after Nigeria, Egypt, Niger and Cameroun) to be affected by the highly pathogenic avian influenza (HPAI) virus in April 2006. The affected populations were intensively reared chickens and guinea-fowl, and free-ranging chickens and ducks (OIE, 2006). Some of the measures taken to contain the HPAI included preventative culling of poultry in the infected areas, and a census of traditionally raised poultry and their elimination in a sequestration zone. The smallholder poultry sector was blamed for the spread of the disease, and it was suggested that a higher degree of control should be enforced with respect to smallholder producers. For example the authorities required that smallholders prevent their poultry from scavenging and instead, keep them confined in an enclosure. Taking into consideration smallholders' restricted economic situation, however, and the reality of village conditions, it seems highly unlikely that this ban is realistically feasible. However, the results in this thesis show clearly that confinement and supplementation can lead to better performance as well as improved bio-security, and therefore, to promote poultry production in the rural areas, the following recommendations are suggested:

- Measures to improve disease control

- Evaluation and promotion of confinement systems for small-scale producers

- Government policy should take into consideration the possibility of subsidising agro-industrial by-products for poultry producers in the rural areas.

6.2 Future Research

Further research focusing on poultry production systems suitable for resource-poor people in Burkina Faso and neighboring countries could include:

- Development of bioassay techniques to evaluate the nutritive value of by-products produced at village level.

- Techniques for improving the palatability and intake of cowpea, local beer residue and shea-nut cake should be developed. Then feeding trials should be carried out at village level, to evaluate the effect of inclusion level of these by-products on growth and egg production performance. In addition, studies on the utilisation of shea-nut cake by poultry should be done on oil cake from commercial "press" extraction, due to its higher protein content, rather than the cake from traditional artisan oil extraction.

- Studies should also be carried out in Burkina Faso on disease control in scavenging systems; for example to evaluate the effect of supplementation and improving the scavenging feed resource base on the prevalence of parasites and infectious diseases.

- The feasibility of introducing the so-called "Bangladesh Model" in Burkina Faso should be investigated.

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Stratégies de Supplémentation des Poulets en Système Semi-intensif au Burkina Faso : Evaluation de Certaines Ressources Alimentaires Locales

Résumé

L'objectif général de cette étude visait à estimer le statut nutritionnel des poulets détritivores à partir de l'analyse des contenus de jabot et à évaluer certains ingrédients localement disponibles sur la base d'essais alimentaires. Les objectifs spécifiques consistaient d'une part à analyser l'utilisation de quelques ingrédients locaux (maïs, niébé, mélange son de blé et son de maïs, et farine de poisson) sous différents régimes alimentaires et d'autre part, évaluer certains sous produits tels que la drêche de bière locale de sorgho, le tourteau de coton décortiqué et le tourteau de karité à travers l'analyse chimique, la digestibilité de la matière sèche ainsi que de certains acides aminés, en vue de leur possible incorporation dans les rations de poulets.

La première phase de l'étude focalisée sur l'analyse des jabots a démontré que la ration des poulets détritivores se composait des débris alimentaires présents autour des concessions ainsi que des résidus de ménage. La composition macroscopique du contenu des jabots différait en fonction de la localité et de la race, la proportion des différents éléments variait également selon les activités saisonnières. La composition chimique n'a révélé aucune influence ni de la localité ni de la race. Cependant, la teneur en énergie métabolisable était plus élevée en saison des pluies (13.5 MJ / kg) et le taux de protéine brute (PB < 12 %) dans les deux sites étudiés était inférieur aux besoins.

La seconde étape de l'étude a été conduite en station sur des poulets métisses en croissance sous système intensif, semi-intensif et extensif. Les régimes alimentaires testés concernaient le maïs et le niébé, donnés sous forme de mélanges ou séparément, avec ou sans complément minéral vitaminé. Les résultats ont montré que le système purement extensif était le plus profitable lorsque l'environnement est favorable en débris alimentaires pour les poulets en croissance. En effet, il n'était pas économiquement rentable de supplémenter cette catégorie de poulet avec des régimes à base de maïs et niébé (niébé cru) en fin de saison pluvieuse.

La troisième partie de l'étude qui a été conduite également en station était basée sur des pondeuses (Isa Brown) en système intensif, semi-intensif et extensif. La farine de poisson a été remplacée par la combinaison tourteau de coton et son de blé-maïs dans les rations. L'analyse des performances de ponte, l'indice de consommation ainsi que la marge brute a montré que le tourteau de coton local combiné avec le son (blé-maïs) pouvait remplacer avantageusement la farine de poisson importée dans les rations pour pondeuses élevées aussi bien en confinement qu'en système semi- intensif. En revanche, le système extensif pure n'était pas profitable pour les pondeuses à cause de la pauvreté de l'environnement en ressources alimentaires, mais aussi probablement à cause des difficultés liées à l'adaptation à ce type de système.

La dernière section de l'étude concernait l'évaluation de certains sous-produits locaux. Les taux de protéine brute de 23,4, 6,7 et 44,3 %, respectivement pour la drêche de bière locale, le tourteau artisanal de karité et le tourteau de coton décortiqué ont été trouvés. Une étude parallèle sur la digestibilité vraie de la matière sèche ainsi que de certains acides aminés des sous-produits ci-dessus énumérés a démontré leurs potentialités nutritives pour les poulets et cela, malgré la teneur en fibre relativement élevée. Cependant, ces sous-produits ont été soumis à la pression et ont subi l'effet thermique lors des processus de transformation. Ces processus sont favorables à l'inactivation de certains facteurs anti-nutritionnels, mais par contre pourraient exposer ces produits à la "Réaction de Maillard" précoce qui réduirait la valeur nutritive de certains acides aminés tels que la lysine. De ce fait, des études sur l'augmentation de la palatabilité ainsi que l'effet du taux d'inclusion dans la ration sur les performances doivent être envisagées. De plus, les études sur le tourteau de karité devraient s'intéresser au tourteau obtenu après l'extraction d'huile par les "presses" car ce tourteau semble être plus riche en protéine brute par rapport au tourteau artisanal de karité.

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Scavenging Pullets in Burkina Faso: Effect of Season, Location and Breed on Feed and Nutrient Intake

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ABSTRACT

A study on scavenging local ($n = 64$) and crossbred ($n = 64$) pullets was undertaken in the dry and rainy seasons in two villages in Burkina Faso: Korea in the arid northern Sahelian region and Bounouna in the sub-humid south. After 4 weeks of scavenging, the birds were killed and the crop contents were subjected to physical and chemical analysis. Cereal grains, brans, green and dry forages, insects/worms and household leftovers were the main physical components. The proportion of cereal grains was higher in the rainy season, whereas the proportion of bran, peanut and sand/grit was higher in the dry season ($p < 0.05$). The proportion of kitchen waste and millet/milo grains was higher in local than in crossbred birds, whereas the opposite was the case for millet/milo bran ($p < 0.05$). Rice and local beer residues were not found in the crops of birds from Korea. Dry matter, ash, crude fibre and potassium contents were higher in the dry season ($p < 0.05$), while calculated metabolizable energy content was higher in the rainy season ($p < 0.05$). There were no location or breed effects on chemical composition parameters ($p > 0.05$), except that potassium content was higher in Korea. Mean live weight at slaughter was 806 ± 22.0 g (local breed) and 881 ± 22.0 g (crossbreds) ($p < 0.05$). Digestive organ weights, including contents, were higher for crossbred birds ($p < 0.05$). Gastrointestinal tract percentage was higher in the rainy season and in Bounouna ($p < 0.05$). The nutrient composition of the crop contents indicates the need for supplementation, particularly of protein, for higher levels of production.

Keywords: breed, Burkina Faso, feed intake, locality, scavenging poultry, season

Abbreviations: ADF, acid detergent fibre; CF, crude fibre; CP, crude protein; DM, dry matter, EE, crude fat; LW, live weight; ME, metabolizable energy; NDF, neutral detergent fibre; OM, organic matter; TK, total potassium; TP, total phosphorus

INTRODUCTION

Livestock in Burkina Faso account for approximately 12% of gross domestic product and include over 28 million head of poultry (Ouedraogo, 2002). Around 85% of the population is involved in rearing domestic animals, and in the rural areas almost all families keep poultry, which are usually the responsibility of the women. Village chicken production is characterized by the free-range system, in which birds have to scavenge to find most of their feed. The production output is low because of the poor genetic potential of the birds, inadequate feeding and management, and the harsh environmental conditions. Supplementation with available feedstuffs is sometimes done by giving household wastes and cereal grains, generally in the early morning or late afternoon, according to availability (Bessin *et al.*, 1998).

Improving the diet of scavenging birds is difficult because the type of feed consumed by the birds is not known (Smith, 2001). The scavenging feed resource base is variable, depending on season, location and management. Various authors have reported that the proportion that comes from the environment varies with activities such as land preparation, sowing, harvesting, grain availability in the household, the life cycles of insects or other invertebrates, and the biomass of the village flock (Gunaratne *et al.*, 1993; Dessie and Ogle, 1996; Mwalusanya *et al.*, 2002). The limited supply of nutrients restricts the productive potential of local birds (Dessie and Ogle, 1996); any attempt to supplement local poultry should thus take into consideration estimates of what the birds actually consume. The objective of this study, therefore, was to determine the physical and chemical composition of the crop contents, and thus feed consumed, by scavenging local and improved pullets in different seasons and agro-ecological zones in Burkina Faso.

MATERIALS AND METHODS

Description of study sites

The study was carried out in two agro-ecological regions in Burkina Faso: the Sahelian zone in the north (Korea village) and the Soudano-guinean zone in the south (Bounouna village). The Sahelian zone is between latitudes 13°5′ and 15°3′ N, and is characterized by high mean temperatures (30 ± 7°C) and low annual rainfall of 350 ± 80 mm, although the rainfall was unusually high during this study (703 mm from April to October, 2003). The dry season is long (8 months) and the vegetation is mainly composed of thorny shrub, with millet, sorghum, milo and cowpea being the major crops grown. Korea village, situated 15 km from Dori, the main urban centre, was selected for the study.

The Soudano-guinean zone in the southern part of the country stretches from latitudes 9°3′ to 11°3′ N, and is characterized by relatively high rainfall (950 ± 50 mm). During the study, the total rainfall recorded from April to October was 1125 mm. The mean daily maximum temperatures were 32°C in May, at the end of the dry season, and 24°C in July, in the rainy season. The typical vegetation is savannah with small areas of forest. Rural people depend on agriculture, livestock (mainly poultry and pigs) and fishing for their livelihoods. Food crops grown include maize, peanut, milo, millet, sorghum, rice, fonio, sweet pea, cowpea, bananas, mangoes and oranges. In the south, Bounouna village, situated 10 km from the small town of Banfora, was selected

Selection of farmers

Four farmers were selected in each village, with the criteria for selection being their basic knowledge and skills in poultry management acquired during previous poultry development projects. To prevent possible mixing of the flocks, selected farms were at least 1000 m from each other.

Construction of pens

In each farm, a pen was built to allow the experimental birds to be confined at night after freely scavenging together in the daytime. In order to enable the full participation and close collaboration of selected farmers, each farmer constructed his or her poultry house, although the cost was covered by the project. The house design adopted was circular and the houses were made of locally available building materials such as mud bricks and thatched roof.

Experimental birds

In each village, a total of 48 pullets (24 local breed and 24 crossbred) were bought in the rainy and dry seasons from local farmers. The crossbred birds were the offspring of crossing between Rhode Island Red or Isa Brown and local chickens. The local breeds included various indigenous breeds of Burkina Faso (for example, Noa-Kuiguiga and Noa-Rigre). The birds were 5–6 months old at the beginning of the study, and were identified by painting their legs different colours.

The birds were allowed to scavenge together during the daytime and were confined together at night in the same pen. After 4 weeks of scavenging, 4 representative local and crossbreed pullets on each farm (Table I) were slaughtered for data collection, once in May at the end of the dry season, and once in August, in the middle of the rainy season.

Data collection

Data were collected in each village on two consecutive days, with half of the birds slaughtered per day and farm at 16:00 h. The birds were slaughtered directly after weighing and the feathers were removed after dipping the carcase in hot water. The carcases were dissected, and the gastrointestinal tract, crop, gizzard and proventriculus were weighed, together with their contents. The carcase was weighed after the removal of feathers, lower legs,

TABLE I
Experimental design for data collection for each season and location

Farm	Local breed	Crossbred
A	4	4
B	4	4
C	4	4
D	4	4
Total	16	16
Total number:		
32 × 2 (season) × 2 (location)	64	64
	Total = 128 birds	

gastrointestinal tract, head, and all the viscera. Dressing percentage was determined as follows:

$$\text{Dressing percentage} = \frac{\text{carcase weight}}{\text{live weight at slaughter}} \times 100$$

Crops and gizzards of the sacrificed birds were tagged individually and then immediately frozen. They were transported to the laboratory in chilled containers for analysis.

Physical analysis

Crop contents of each bird were removed and weighed and the constituents were determined through visual observation using a magnifying glass (×10). Components such as seeds, insects, worms and plant parts were isolated. Fresh samples of crop contents were taken and recorded for each individual bird.

Chemical analysis

The collected crop contents were then mixed within breed, farm, season and village, and frozen for later analysis. Samples were analysed chemically for dry matter (DM), crude protein (CP), crude fibre (CF), ash and organic matter (OM) according to AOAC (1985). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined by the method of Van Soest and colleagues (1991). Crude fat (EE) was measured after extraction with petroleum ether in a Soxhlet apparatus. Calcium and potassium were determined by the method of FAO (1980) by spectrophotometry. Total potassium (TK) was determined by flame photometry and calcium (Ca) by atomic absorption. Total phosphorus (TP) was determined by continuous flow analysis. Metabolizable energy (ME) contents were calculated by an indirect method, using the following equation (INRA, 1987):

$$\text{True ME (MJ/kg dry matter)} = 3951 + 54.4\text{EE} - 88.7\text{CF} - 40.8\,\text{ash}$$

Statistical analysis

The 2×2×2 factorial design was analysed using the GLM procedure in MINITAB Software version 13.31 (Minitab Inc., State College, PA, USA). The statistical model used was

$$Y_{ijkl} = \mu + a_i + b_j + c_k + ab_{ij} + ac_{ik} + bc_{jk} + e_{ijkl}$$

where Y_{ijkl} is a given observation; μ is the general mean common to all observations; a_i is the effect of the ith location (2); b_j is the effect of the jth season (2); c_k is the effect of the kth breed (2); ab_{ij} is the effect of interaction between location and season; ac_{ik} is the interaction between location and breed; and e_{ijkl} is the random effects peculiar to each observation.

RESULTS

Physical composition of crop contents

Effect of season. The main components of the crop contents could be categorized visually, in order of importance, into cereal grain, cereal bran, forages, seeds, insects and worms, kitchen waste and other household by-products. The relative proportions of these components varied considerably between individual birds within household and village, and between seasons. The mean fresh weights of the crop contents were 34.2 ± 2.3 g and 26.5 ± 2.3 g for the dry and rainy season, respectively ($p < 0.05$) (Table II), and the fresh weights expressed on a mass-specific basis were also higher in the dry season (3.90% of LW) than in the rainy season (3.24% of LW) ($p < 0.05$). The proportion of grain (maize, millet and milo) and peanut was higher ($p < 0.05$) in the rainy season than in the dry season (Table III). However, there was no effect of season on the proportion of forages, insects and worms ($p > 0.05$).

Effect of breed. There was a significant breed effect on mean fresh weights of crop contents, which were 25.2 ± 2.3 g for the local birds and 35.4 ± 2.3 g for the crossbreds ($p < 0.05$) (Table II). A higher proportion of grain was found inside the crops of local birds, while a higher proportion of bran was found in the crossbred birds ($p < 0.05$) (Table III). The proportion of kitchen waste was 14.3% ± 2.0% for the local birds and 5.3% ± 2.0% for the crossbred birds ($p < 0.05$), and the proportion of grass and leaves was 11.8% ± 1.5% for the crossbred and 6.01% ±1.5% for the local breed pullets ($p < 0.05$).

Effect of location. The mean overall fresh crop content weight was 34.1 ± 3.0 g in the northern Sahelian village of Korea and 26.6 ± 3.0 g in the southern village of Bounouna (Table II) ($p > 0.05$), but the difference was significant ($p < 0.05$) only when expressed on a mass-specific basis (4.05% and 3.05% of LW, respectively). The mean proportions of millet and milo grain and bran were higher in Korea compared to Bounouna, while the mean proportion of maize grains was higher in Bounouna. Rice and local beer residues were not found in the crops from Korea. The proportion of kitchen waste was higher in Bounouna ($p < 0.05$), while the proportion of dry forages was higher in Korea ($p < 0.05$).

TABLE II
Overall fresh crop content weights, fresh basis

	Season			Location			Breed		
FCC*	Dry	Rainy	SE	Korea	Bounouna	SE	Local	Cross	SE
Total weight (g)	34.2^a	26.5^b	2.3	34.1	26.6	3.0	25.2^b	35.4^a	3.2
% of LW	3.90^a	3.24^b	0.2	4.05^a	3.05^b	0.2	3.04^b	3.90^a	0.2

*FCC, fresh crop contents
[a,b]Means with different superscript letters within a row and factor are significantly different ($p < 0.05$)

TABLE III
Effect of season, location and breed on the physical composition of the crop contents (% of total, fresh basis)

	Season			Location			Breed		
Component*	Dry	Rainy	SEM	Korea	Bounouna	SEM	Local	Cross	SEM
Mig	18.6[b]	31.5[a]	3.2	30.5[a]	17.6[b]	3.5	31.5[a]	18.5[b]	2.4
Mg	7.50[b]	17.4[a]	2.4	3.04[b]	21.5[a]	2.4	10.5	15.4	2.4
Mb	14.5[a]	4.03[b]	2.4	13.4	9.52	2.5	8.51	10.3	3.0
Mib	16.4	12.3	3.0	26.4[a]	3.03[b]	3.0	8.51[b]	17.5[a]	0.6
Rice grain	1.05	2.06	0.6	NF	1.52	0.4	1.23	0.81	1.0
Peanut	5.05[a]	1.51[b]	1.0	1.05[b]	5.02[a]	1.2	2.51	3.03	0.8
Lbr	1.06	1.51	0.8	NF	2.03	0.8	1.02	2.04	2.0
Kw	8.04	11.4	2.0	5.51[b]	13.4[a]	2.0	14.3[a]	5.32[b]	1.5
G/L	10.5	7.04	1.5	12.5[a]	4.51[b]	1.6	6.01[b]	11.8[a]	1.0
L/I/W	5.05	4.05	1.0	2.51[b]	6.53[a]	1.0	5.02	5.02	1.0
Sand/grit	9.75[a]	6.75[b]	1.0	3.05[b]	13.4[a]	1.3	8.45	8.32	1.0
Other	2.50	2.05	1.0	2.06	2.02	1.0	2.51	2.01	1.0

*Mig, millet and milo grain; Mg, maize grain; Mb, maize bran; Mib, millet and milo bran; Lbr, local beer residues; Kw, kitchen waste; G/L, grass and leaves; L/I/W, larvae, insects and worms. NF, not found
[a,b]Means with different superscript letters within a row and factor are significantly different ($p < 0.05$)

TABLE IV
Interactions between location and breed, and location and season for the physical components of the crop contents

Physical component	Location × breed	Location × season
Millet/milo grain	**	***
Maize grain	NS	NS
Maize bran	NS	***
Millet/milo bran	NS	NS
Rice grain	NS	NS
Peanut	NS	NS
Local beer residues	NS	NS
Kitchen wastes	NS	NS
Grass/leaves	*	NS
Larvae/insects/worms	NS	**
Sand/grit	NS	*
Other	NS	NS

*Significant at the 5% level; **significant at the 1% level; ***significant at the 0.1% level; NS, not significant

Interaction between breed and location (Table IV). In Korea, there was a significant breed effect on mean weight of fresh crop content, which was higher for the crossbred compared to the local birds ($p < 0.05$), while no significant difference between the two breeds for mean weight of overall crop content was found in Bounouna ($p > 0.05$). The mean millet and milo grain percentage in Korea was higher for the local birds ($p < 0.05$), whereas no significant difference was found between breeds in Bounouna. The mean proportion of grass/leaves in the crops of the local breed in Korea was lower than in Bounouna, whereas the reverse was the case for the crossbred pullets ($p < 0.05$).

Interaction between season and location (Table IV). The mean millet/milo percentage in Korea was lower in the dry season than in the rainy season ($p < 0.05$), whereas in Bounouna in the dry season it was significantly higher. Maize bran percentage also showed significant season and location interactions: in the dry season the mean maize bran percentage was higher in Korea than in Bounouna, whereas the opposite was the case in the rainy season. Also, in the dry season the mean proportion of larvae/insects/worms was higher in Korea than in Bounouna, while this was not the case in the rainy season ($p < 0.05$). The mean percentage of sand/grit in the dry season was lower in Korea than in Bounouna, whereas the opposite was the case in the rainy season ($p < 0.05$).

Chemical composition of crop contents

The chemical composition of the crop contents showed significant differences between seasons ($p < 0.05$), but not between breeds and villages, except for potassium content, which was higher in Korea (Table V). Dry matter, ash and potassium contents were higher in the dry season ($p < 0.05$), whereas ME concentration was higher in the rainy season (13.5 MJ/kg) than in the dry season (11.6 MJ/kg) ($p < 0.05$).

Carcase and organ characteristics

The overall mean live weight at slaughter of the local pullets was 806 ± 22 g (ranging from 449 to 939 g) and for the crossbred birds was 881 ± 22 g (ranging from 663 to 1555 g) (Table VI) ($p < 0.05$). Mean live weight at slaughter in the dry season was 884 ± 21 g, and in the rainy season 803 ± 23 g ($p < 0.05$). No significant differences in carcase percentage were found ($p > 0.05$), although there were differences in carcase weight between seasons: mean carcase weight was higher at the end of the dry season (533 ± 13 g) than in the rainy season (491 ± 16 g) ($p < 0.05$). Crop weight, including contents, was higher for the crossbred (47.6 ± 3.0 g) than for the local pullets (35.7 ± 2.0 g) ($p < 0.05$). Differences were also found between breeds for gizzard plus proventriculus weight (including contents): mean weight was higher for the crossbred (57.2 ± 1.5 g) than for the local breed pullets (46.5 ± 1.0 g) ($p < 0.05$).

TABLE V
Effect of season, location and breed on the chemical composition of the crop contents (% of DM)

Chemical composition	Season			Location			Breed		
	Dry	Rainy	SEM	Korea	Bounouna	SEM	Local	Cross	SEM
DM	97.5^a	94.5^b	0.14	95.7	96.4	2.0	96.8	96.3	3.0
OM	73.7	80.4^a	2.0	73.9	75.6	2.0	73.8	76.5	3.0
Ash	29.5^a	19.7^b	2.0	25.5	24.3	1.0	25.8	22.6	0.7
ADF	26.4	25.3	0.4	26.2	24.7	2.0	24.2	26.4	1.0
NDF	21.5	23.8	2.0	22.2	25.5	0.6	26.3	22.4	0.6
CP	11.5	10.5	0.5	11.3	11.2	1.0	11.4	10.5	1.0
EE	7.04	8.03	0.8	7.01	9.02	0.5	8.01	8.03	0.4
CF	5.02^a	4.01^b	0.4	5.03	4.04	0.1	4.01	5.03	0.1
Ca	0.92	0.61	0.15	1.02	0.73	0.06	0.85	0.82	0.06
TP	0.71	0.61	0.07	0.61	0.71	0.02	0.71	0.61	0.05
TK	0.61^a	0.51^b	0.04	0.61^a	0.51^b	0.05	0.50	0.51	0.05
ME (MJ/kg)	11.6^b	13.5^a	0.40	12.1	12.9	0.50	12.4	12.7	0.50

^{a,b}Means with different superscript letters within a row and factor are significantly different ($p < 0.05$)

TABLE VI
Effect of season, breed and location on carcase and organ characteristics

Carcase traits	Season		Location		Breed	
	Dry	Rainy	Korea	Bounouna	Local	Cross
LW (g)	884^a ± 21.0	803^b ± 23.0	825 ± 23.0	862 ± 23.0	806^b ± 22.0	881^a ± 22.0
Carcase wt (g)	533^a ± 13.0	491^b ± 16.0	497 ± 15.0	527 ± 15.0	494 ± 14.0	530 ± 15.0
Carcase % (g)	60.3 ± 0.53	60.9 ± 0.44	60.1 ± 0.5	61.2 ± 0.5	61.3 ± 0.5	60.1 ± 0.4
Crop wt** (g)	45.1 ± 3.0	38.4 ± 2.5	46.1^a ± 3.0	37.8^b ± 2.0	35.7^b ± 2.0	47.6^a ± 3.0
Gizzard + Prov wt** (g)	53.7 ± 2.0	49.8 ± 1.5	51.3 ± 2.0	52.3 ± 1.0	46.5^b ± 1.0	57.2^a ± 1.5
GIT*, % of LW**	15.4^b ± 0.3	16.1^a ± 0.25	16.2^a ± 0.3	15.4^b ± 0.25	15.1^b ± 0.25	16.4^a ± 0.24

^{a,b}Means with no superscript letters in common within a row and factor are significantly different ($p < 0.05$)
*GIT, gastrointestinal tract; Prov, proventriculus
**Including contents

DISCUSSION

Crop content weights and physical characteristics

Mean crop content weight was higher in the dry season compared to the rainy season, which was unexpected, but which might be explained by the higher prevalence of disease seen during the rainy season. It was observed that the birds with symptoms of disease or with high parasite burdens were reluctant to leave their houses and scavenge. This agrees with the study of Kondombo and colleagues (2003), who found that in Burkina Faso in the rainy season 83% of the mortality in village chickens was due to disease.

From visual observations of the crop contents, it was evident that the scavenged feed was dependent on the surrounding environment, including availability of household refuse. The birds obtained grasses, weeds, leaves, insects, worms and seeds from the environment, while household refuse, consisting of kitchen food wastes, bran, broken seed and grain, when available, was provided by the owners. The availability and composition of the various feed items varied with season. This, as well as, for example, whether it is sowing or harvesting time, has previously been observed to influence the crop contents of scavenging birds (Gunaratne *et al.*, 1993). The higher occurrence of grains found in the crops during the rainy season can be attributed to the fact that the study was carried out at the beginning of the rainy season when farmers were sowing, and when waste grains and seeds were available in the backyard. It should be noted that the rainy season came earlier in the northern part of Burkina Faso at the time of the study compared to previous years. The early onset of the rainy season could explain the high level of consumption by the birds in Korea of young sprouting shoots, which are known to be palatable to poultry (Dessie and Ogle, 1996). The higher percentage of insects found in the crops in Bounouna was mainly due to the large number of ants available and the large populations of worms and grasshoppers that were found in the rainy season. Also, it was observed that farmers sometimes collected termite mounds, which they broke up and gave to their chickens, allowing them access to the termite larvae within.

The higher proportion of bran in the crops of the crossbred birds can be explained by the observation that crossbred birds preferred brans and cracked grains to whole grain. This is supported by the study of Yo and colleagues (1997), who reported a higher intake of maize by broilers when it was offered in ground or cracked form than when it was offered as a whole grain.

The higher proportion of millet grain and bran found in the crops of birds in the north can be explained by the fact that millet is the main food crop grown in this area, and chickens are given free access to the by-products of local hand processing (using mortar and pestle) that are readily available in the backyards. In Bounouna this was the case for maize, which is the staple food crop in the south of the country. The households' sociocultural activities and religion can also influence the quantity and the quality of the materials consumed by the birds. For example, the north of the country is predominantly Muslim, which explains the lack of local beer residues in the crops from Korea. On the other hand, kitchen wastes were more freely available in Bounouna, probably owing to the larger mean family size found in Bounouna than in Korea.

There were obvious differences between households in what they gave to their chickens, which is a result of the farmers' ability to provide supplementation. A survey carried out in Burkina Faso by Bessin and colleagues (1998) showed that in the rural areas, supplements, usually consisting of cereals and termites, were given to their poultry up to three times daily by the majority of farmers.

The higher percentage of dry grasses and leaves in the crops in Korea was probably due to the predominant livestock system, as the northern part of the country is the major area for ruminants, and at the end of the rainy season farmers dry and store forages for feeding to their cattle and goats during the dry season. Scavenging poultry normally have access to this dry forage.

Chemical composition of crop contents

The DM, ash, CF and total potassium contents were significantly higher at the end of dry season compared to the rainy season. The higher ash content would have been due to the higher proportion of sand and grit in the crops in the dry season, and the higher potassium and CF contents were probably due to increased intakes of maize bran and millet/milo brans in the dry season.

The metabolizable energy (ME) concentration of the crop contents was higher in the rainy season compared to the dry season. This is in contrast with the findings of Dessie and Ogle (1996), who were unable to find any significant difference in ME content of the crop contents of scavenging hens between dry and rainy seasons in a study carried out in Ethiopia. The higher ME content in the rainy season is supported by the physical analysis data, which showed that the proportion of energy-rich maize, milo and millet grains was much higher in the rainy season, and the proportion of sand and grit (ash) was lower.

The mean CP percentage in the crop contents was higher during the dry season compared to the rainy season, for both local and crossbred birds, but the difference was not significant. In the present study, occasional showers occurred at the end of dry season, resulting in increased availability of insects and worms, which could explain the slightly higher CP level of the crop contents compared to the rainy season. This finding is supported by Mwalusanya and colleagues (2002), who found lower CP contents in the crops of birds in Tanzania in the rainy season. However, Dessie and Ogle (1996) reported that the CP content in the crops of scavenging hens in the Central Highlands of Ethiopia was significantly higher in the rainy season (10.2% of DM) compared to the dry season (7.6% of DM), mainly as a result of higher intakes of worms and young green plants.

Assuming that the crop contents accurately reflect the composition of the feed ingested, the overall mean CP contents of the diets of the crossbred (10.5% $\pm$ 0.6%) and local pullets (11.4% $\pm$ 0.6%) were below the recommendation of 13.0% CP in the diet (fresh basis) for pullets of 8 weeks of age until the first egg (INRA, 1987). However, the birds in our study were of low genetic potential, and would have almost reached their maximum adult weight at slaughter, and so protein requirements for growth would have been low. On the other hand, although none of the birds had started to lay, most had partly-formed yolks in their ovaries at slaughter, which would imply an increased requirement for protein. Calcium and phosphorous concentrations in the crop (0.82% and 0.61% of DM, respectively, for the crossbred pullets) were only slightly below the recommended levels for pullets of 0.90% and 0.63%, respectively, in the diet (INRA, 1987).

Carcase and organ characteristics

Mean live weight at slaughter was higher in the dry season, probably as a result of the higher prevalence of disease during the rainy season, as it was observed that birds with signs of disease or with high parasite burdens were less active in scavenging. Although crop and gizzard weights were heavier for the crossbred pullets than for the local breed type, all of the difference can be explained by the increased weight of the digesta.

The dietary status of the birds in this study, as assessed from the crop contents, indicates that the crude protein intakes from scavenging would not meet requirements, particularly of the crossbred pullets. For higher levels of growth and production, additional inputs would be needed, and supplementation strategies should be developed to improve scavenging chicken productivity.

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Poulettes détritivores à Burkina-Faso: Effet de la saison, de la localisation et de la race sur l'apport alimentaire et de produits nutritifs

Résumé – Une étude a été entreprise sur des poulettes locales détritivores ($n = 64$) et hybrides ($n = 64$) durant les saisons sèches et pluvieuses dans deux villages de Burkina Faso: à Korea dans la région sahélienne aride du Nord et à Bounouma dans le Sud sub-humide. Après quatre semaines de détritiphagie, la volaille a été sacrifiée et le contenu des cultures soumis à une analyse physique et chimique. Les grains de céréales, les sons, les fourrages verts et secs, les insectes/vers et les restes domestiques ont représenté les principaux composants physiques. La proportion de grains de céréales a été plus élevée durant la saison des pluies, tandis que la proportion de son, de cacahuètes et de sable/gravillons a été plus élevée durant la saison sèche ($p < 0.05$). La proportion de déchets de cuisine et de son de millet/sorgho a été plus élevée dans la volaille locale que dans la volaille hybride, tandis que l'opposé était le cas pour le son de millet/sorgho ($p < 0.05$). Du riz et des résidus de bière locale n'ont pas été trouvés dans les cultures de la volaille de Korea. Les teneurs en matière sèche, en cendre, en fibre brute et en potassium ont été plus élevées durant la saison sèche ($p < 0.05$), tandis que la teneur en énergie métabolisable calculée a été plus élevée durant la saison des pluies ($p < 0.05$). Il n'a pas été noté d'effets de l'emplacement ou de la race sur les paramètres de composition chimique ($p < 0.05$) excepté que la teneur en potassium a été plus élevée à Korea. Le poids vif moyen au moment de l'abattage a été de 806 ± 22.0 g (race locale) et de 881 ± 22.0 g (races hybrides) ($p < 0.05$). Le poids des organes digestifs, leur contenu compris, a été plus élevé chez la volaille hybride ($p < 0.05$). Le pourcentage de maladies du tube digestif a été plus élevé durant la saison des pluies et à Bounouma ($p < 0.05$). La composition en produits nutritifs du contenu des cultures suggère la nécessité d'une supplémentation, en particulier en protéines, pour l'obtention de niveaux de production plus élevés.

Gallinas jóvenes carroñeras en Burkina-Faso: efecto de la estación, localización y raza sobre el consumo de alimento y nutrientes

Resumen – Se llevó a cabo un estudio en gallinas jóvenes carroñeras locales ($n = 64$) y en gallinas jóvenes cruzadas ($n = 64$) en las estaciones seca y lluviosa, en dos pueblos de Burkina Faso: Korea en la región árida y norteña Saheliana, y Bounouna en el sur sub-húmedo. Después de cuatro semanas de vida carroñera, se sacrificaron las aves y analizaron los contenidos de sus buches física y químicamente. Los granos de cereales, salvados, forrajes verdes y secos, insectos y gusanos, y desperdicios caseros fueron los principales componentes físicos. La proporción de granos de cereales fue mayor en la estación lluviosa, mientras que la proporción de salvado, avellana y arena/arenilla fue mayor en la estación seca ($p < 0.05$). La proporción de desperdicios de cocina y granos de mijo/sorgo fue más grande en las aves locales que en las mestizas, mientras que ocurría lo contrario para el salvado de mijo/sorgo ($p < 0.05$). No se encontraron residuos de arroz ni cerveza local en los buches de las aves de Korea. Los contenidos de materia seca, ceniza, fibra cruda y potasio fueron mayores en la estación seca ($p < 0.05$), mientras que el contenido de energía metabolizable calculada fue más alto en la estación lluviosa ($p < 0.05$). No hubo efectos de la localización o la raza en los parámetros de composición química ($p > 0.05$), excepto que el contenido de potasio fue más alto en Korea. El peso medio del animal vivo al sacrificarlo fue de 806 ± 22.0 g (raza local) y 881 ± 22.0 g (raza cruzada) ($p < 0.05$). Los pesos de los órganos digestivos, incluyendo los contenidos, fueron más altos para las aves mestizas ($p < 0.05$). El porcentaje del tracto gastrointestinal fue más alto en la estación lluviosa y en Bounouna ($p < 0.05$). La composición de nutrientes de los contenidos del buche indica la necesidad de suplementación, particularmente de proteína, para conseguir nuos niveles más altos de producción.

II

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ORIGINAL ARTICLE

Effect of supplementation on the feed intake and performance of confined and scavenging crossbred growing chickens in Burkina Faso

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Abstract An experiment was conducted to evaluate the performance of crossbred growing chickens (Rhode Island Red × indigenous Burkina Faso hens) from 6 to 17 weeks of age, under five feeding/management regimes: (1) CMx(+), confined and given a mixed feed containing cracked maize and cowpea and a vitamin–mineral premix *ad libitum*; (2) CS(+), confined and offered *ad libitum* a choice of cracked maize and cowpea with the premix; (3) ScS(+), scavenging from 09:00 to 16:00 with the diet in treatment (2) available from 16:00 to 09:00; (4) ScS(−), treatment (3) but without the premix; and (5) ScO, scavenging only, with no supplements provided. Daily dry matter (DM) intake was highest for CS(+) (43.5 g), and lowest for CMx(+) (33.6 g) ($p < 0.05$), with intermediate intakes for ScS(+) and Sc(−) of 36.7 g and 36.2 g, respectively. The ratios of intakes of cowpea to maize were 50:50, 21:79, 27:73 and 22:78 for CMx(+), CS(+), ScS(+) and ScS(−), respectively ($p < 0.05$). Dietary concentrations of crude protein (CP) were 15.7%, 11.5%, 12.3% and 11.6% of DM for CMx(+), CS(+), ScS(+) and ScS(−), respectively. Average daily gains (ADG) were 8.15 g, 5.24 g, 6.03 g, 5.36 g and 4.45 g for CMx(+), CS(+), ScS(+), ScS(−) and ScO, respectively, and were significantly higher for CMx(+) ($p < 0.05$). Feed conversion ratio was highest for CS(+) and lowest for CMx(+). ADG of the males (6.44 g) was significantly ($p < 0.05$) higher than that of the females (5.86 g). Breast and thigh muscle weights were highest for ScS(+) ($p < 0.05$).

Keywords Burkina Faso · Carcass composition · Chickens · Growth performance · Scavenging · Supplementation

Abbreviations

AA	amino acids
ADG	average daily gain
ASH	total ash
CF	crude fibre
CP	crude protein
DM	dry matter
EE	ether extract
FCR	feed conversion ratio
FCS	feed costs/kg weight gain
LSM	least-squares mean
ME	metabolizable energy
NFE	nitrogen-free extract
OM	organic matter
TME	true metabolizable energy

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SFR scavenging feed resources
USD US dollar

Introduction

In West Africa the dominant village chicken production system is free range, which is characterized by a low level of inputs (Gueye, 1998). Improving the productivity of this system is one of the challenges that developing countries face; when resources are limited, the priority should be to improve village production using locally available resources. When the nutritional status of village chickens is defined, control of feeding can lead to sustainable improvements in productivity (Pousga *et al.*, 2005a), and where possible such feeding strategies should be based on suitable local feedstuffs. In Burkina Faso, cereals (millet, sorghum, maize, fonio and rice) are the staple food crops and occupy over 85% of the cultivated land (EJA, 1998). Cowpea is the most common legume in Africa and is well adapted to stressful environments in which other crops either fail or do not perform well. It is a food security crop in the semi-arid zone of West and Central Africa and ensures farm household subsistence food supply even in dry years (FAO, 1996). In Burkina Faso, cereals and legume seeds are given as a supplement to village chickens, according to availability. Despite antinutritional problems linked to the presence of tannins (Martin *et al.*, 1980) and a trypsin inhibitor (Cabezas *et al.*, 1982), cowpea is given to chickens in the fresh form without any technical processing. The nutritional situation is not usually well known for village chickens, but provision of free-choice diets instead of a complete conventional ration was suggested to have beneficial effects (Pousga *et al.*, 2005a). Choice feeding allows birds a greater opportunity to select the nutrients needed for maintenance and production, with consequent increases in efficiency (Siegel *et al.*, 1997) and will also enable the birds to select the correct proportions of the different supplementary feeds to complement their intake from scavenging. No data are available in Burkina Faso on whether it is necessary to provide a vitamin–mineral supplement to scavenging growing chickens.

An experiment was carried out on-station in Burkina Faso, to evaluate the effects of supplementing with a vitamin–mineral premix and maize and cowpeas, provided either in a mixture or separately, on the performance of confined and semi-scavenging growing crossbred chickens.

Material and methods

Description of site

The study was carried out on a research station located 35 km from Ouagadougou in the Central Region of Burkina Faso. This part of the country is included in the Sudano-Sahelian zone, which lies between the 900 and 600 mm isohyets. Average minimum and maximum temperatures of 22.8 °C and 31.2 °C and a mean relative humidity of 63.4% were recorded during the period of the study (from late September to mid-December). The poultry yard was dominated by *Butyrospermum parkii* and *Eucalyptus alba* trees, and various species of grass. The chickens also had access to fields adjacent to the station, where maize, cowpea, sorghum, onion, tomato and various legume crops were cultivated.

Experimental animals and management

The experimental birds were crosses between Rhode Island Red cockerels and local breed hens (Noa-Kuiguiga and Noa-Rigre). The resulting eggs were collected for incubation, and after hatching 100 male and 100 female chicks were selected for the experiment.

Chick management

Prophylactic measures against some common chicken diseases in Burkina Faso were taken according to the vaccination programme shown in Table I. Piperazine citrate was dissolved in the drinking water for 2 days against digestive tract parasites and Diazypyrin was given for 5 days to prevent coccidiosis.

The chicks were confined and given a commercial starter diet until 4 weeks of age, when they were divided randomly into five treatment groups, with 4 replicates for each treatment (10 birds/replicate, 5 males and 5 females). Data collection started after two weeks of adaptation to the environment and the experimental feeds.

Experimental treatments

1. CMx(+): confined and given a mixed feed *ad libitum* containing cracked maize (50%) and cowpea (50%) and a vitamin–mineral premix (0.2%)

Table 1 Vaccination programme

Age of chicks (days)	Vaccine	Administration
1	Infectious bursitis (Simple)	Oral
4–6	Bronchitis (H120); NCD (HB1)	Oral
14	Infectious bursitis (Strong)	Oral
17	Newcastle disease (Lasota)	Oral
21–28	Bronchitis (H120)	Oral
28–84	Fowl pox (Variovax)	Intra-epidermal
112–119	Newcastle disease (Ita-NEW)	Intermuscular

2. CS(+): confined and offered *ad libitum* a choice of cracked maize and cowpea with the vitamin–mineral premix
3. ScS(+): scavenging from 09:00 to 16:00 and offered the diet in treatment (2) from 16:00 to 09:00
4. ScS(−): treatment (3) but without the vitamin–mineral premix
5. ScO: scavenging only, but housed at night and with no supplements provided.

Drinking water was available *ad libitum* for birds on all treatments.

Data collection

Data on the feed intake and mortality were collected each day. Live weight was measured once weekly and, as the birds were not individually identified, mean live weights were calculated by dividing the total pen live weight by the number of live birds on each weighing occasion. Feed ingredients were analysed chemically for dry matter (DM), crude protein (CP), crude fibre (CF), total ash (Ash) and organic matter (OM), according to AOAC (1985). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined according to Van Soest and colleagues (1991). Crude fat (EE) was measured after extraction with petroleum ether in a Soxtec apparatus. Calcium (Ca) was determined using a spectrophotometeric method (FAO, 1980) and phosphorus (P) by continuous flow analysis. Metabolizable energy (ME) contents of the diets were calculated by an indirect method, using the following equation (INRA, 1986):

$$\text{True ME (MJ/kg dry matter)} = (3951 + 54.4\text{EE} - 88.7\text{CF} - 40.8\text{Ash}) \times 0.004184$$

Economic analysis

Economic analyses for each treatment were carried out using current prices in CEFA Franc (1 USD = approx. 550 CEFA Franc) to compare the mean feed costs per kg live weight gain (FCS).

Statistical analysis

Data were analysed using ANOVA General Linear Model Procedure of MINITAB Reference Manual Release 13.31 (2000). Pair-wise comparisons of treatment means were made using the Tukey test.

Results

Chemical composition and nutritive value of maize and cowpea

Whole cracked maize and cowpea seeds (dried) were purchased in a local market in Ouagadougou. Their chemical composition and that of the mixed feed are given in Table 2. The maize used in the trial was a local variety of white maize with CP and ME contents of 8.34% and 15.8 MJ/kg, respectively. The cowpea used was one of the varieties of black-eye pea commonly called Niebe in West Africa, and contained 23.1% CP and 11.3 MJ/kg ME.

Feed and nutrient intakes

Daily DM, CP, ME and nutrient intakes of the growing chickens are shown in Table 3. The highest daily DM intake (43.5 g) was observed in CS(+), while the lowest intake (33.6 g) was seen in CMx(+) ($p < 0.05$). No significant difference was found in DM intake between the scavenging treatments, and intakes for these were higher than for CMx(+) but lower than for

Table 2 Chemical composition of the mixed feed and supplements (% of DM)

Item	Mixed feed[a]	Maize grain	Cowpea seed
Dry matter (DM)	92.9	92.7	93.0
Organic matter (OM)	96.7	98.6	96.6
Crude protein (CP)	15.6	8.34	23.0
Crude fibre (CF)	5.04	3.8	6.3
Ether extract (EE)	3.2	4.4	1.9
Nitrogen-free extract (NFE)	72.9	82.1	65.4
Ash	3.15	1.4	3.4
Calcium (Ca)	0.12	0.03	0.10
Phosphorus (P)	0.60	0.98	0.14
Lysine[b]	0.75	0.20	1.3
Methionine[b]	0.22	0.16	0.29
Threonine[b]	0.45	0.27	0.64
ME (MJ/kg), calculated	13.60	15.89	11.33

[a]50% maize grain and 50% cowpea seed
[b]Calculated values

Table 3 Effect of supplementation on the dry matter and nutrient intake (% of DM) of confined and scavenging crossbred chickens (LSM ± SEM)

Item	Treatment[1]					
	CMx(+)	CS(+)	ScS(+)	ScS(−)	SEM	*p*-Value
DM (g/bird per day)	33.6[c]	43.5[a]	36.7[b]	36.2[b]	0.84	0.00
OM	96.7[b]	97.0[a]	96.9[b]	97.0[a]	0.004	0.00
CP	15.7[a]	11.5[c]	12.3[b]	11.6[c]	0.13	0.00
CF	5.04[a]	4.32[c]	4.45[b]	4.33[c]	0.022	0.00
EE	3.16[b]	3.88[a]	3.75[c]	3.87[a]	0.022	0.00
NFE	72.9[c]	77.3[a]	76.5[b]	77.2[a]	0.134	0.00
Ash	3.15[a]	3.00[c]	3.03[b]	3.01[c]	0.004	0.00
Ca	0.12[b]	0.15[ab]	0.19[a]	0.05[c]	0.001	0.00
P	0.60[c]	0.87[a]	0.82[b]	0.79[b]	0.007	0.00
Lysine[2]	0.75[a]	0.43[c]	0.44[c]	0.49[b]	0.01	0.00
Methionine[2]	0.22[a]	0.18[c]	0.18[c]	0.19[b]	0.001	0.00
Threonine[2]	0.45[a]	0.34[c]	0.35[c]	0.36[b]	0.003	0.00
ME (MJ/bird per day)	0.45[c]	0.64[a]	0.54[b]	0.52[b]	0.01	0.00

[1]CMx(+), confined and given a mixed feed containing cracked maize and cowpea and a vitamin-mineral premix *ad libitum*; CS(+), confined and offered *ad libitum* a choice of cracked maize and cowpea, with the premix; ScS(+), scavenging from 09:00 to 16:00 with the CS(+) diet available from 16:00 to 09:00; ScS(−), as ScS(+), but without the premix. Premix contained the following per 1000 g premix: vitamins: A 4 000 000 IU; D_3 800 000 IU; E 2 000 mg; K 800 mg; B_1 600 mg; B_2 2 000 mg; niacin 3 600 mg; B_6 1 200 mg; B_{12} 4 mg; choline chloride 80 000 mg
Minerals: dicalcium phosphate (Ca 24.5%; P 17%); iron 1.8%
[2]Calculated values
[a,b,c,d] Means with different superscript letters in the same row are significantly different at $p < 0.05$

CS(+) ($p < 0.05$). The highest CP intake was in treatment CMx(+) (15.7% of DM), followed by SCS(+) ($p < 0.05$), and then ScS(−) and CS(+). A significantly higher ME intake was found in CS(+) (0.64 MJ/bird per day) compared to the other treatments. The proportions of cowpea and maize selected by the birds in the free-choice treatments are shown in Table 4. In all the free choice treatments the proportion of cowpea selected (21–27%) was significantly lower than in the mixed diet (50% of DM). The proportion of cowpea of total intake was higher in ScS(+) (27%) compared to the other choice-feeding treatments (21% and 22% for CS(+) and ScS(−), respectively), resulting in higher CP and ME intakes from cowpea for treatment ScS(+) than for CS(+) and ScS(−) ($p < 0.05$).

Table 4 Effect of supplementation and management on the relative intakes of maize and cowpea and on the proportion of the total protein and metabolizable energy (ME) intake supplied by cowpea

	Treatment[1]					
Item	CMx(+)	CS(+)	ScS(+)	ScS(−)	SEM	p-Value
Cowpea:maize	50:0[a]	21:79[c]	27:73[b]	22:78[c]	0.88	0.00
CP intake from cowpea (% of total)	73.4[a]	38.3[c]	45.0[b]	37.3[c]	1.29	0.00
ME intake from cowpea (% of total)	41.6[a]	16.9[c]	21.6[b]	17.6[c]	0.76	0.00

[a,b,c]Means with different superscript letters in the same row are significantly different at $p < 0.05$
[1]See footnote, 1, Table 2

Table 5 Effect of supplementation strategy on average daily weight gain (ADG), feed conversion ratio (FCR) and feed cost/kg gain (FCS) of confined and scavenging crossbred chickens (LSM ± SEM)

	Treatment[1]						
	CMx(+)	CS(+)	ScS(+)	ScS(−)	ScO	SEM	p-Value
Initial weight (g)	310	320	300	305	300	4.40	
Final weight (g)	920[a]	715[b]	750[b]	700[bc]	630[c]	18.49	0.00
Days on experiment	75	75	75	75	75		
ADG (g)	8.15[a]	5.24[b]	6.03[b]	5.36[bd]	4.45[cd]	0.234	0.00
FCR (g feed/g gain)	4.62[a]	8.36[b]	5.27[c]	6.54[c]	–	0.165	0.00
Mortality (%)	0.00[b]	7.50[ab]	20.0[a]	12.0[ab]	22.0[a]	4.87	0.03
FCS (CEFA/kg weight gain)[2]	1718[c]	2877[a]	1844[c]	2248[b]	–	58.5	0.00

[1]See footnote 1 Table 2. ScO, scavenging only, no supplements provided
[2]1 USD = 550 CEFA (approx.)
[a,b,c,d] Means with different superscript letters in the same row are significantly different at $p < 0.05$

Effect of supplementation and scavenging on growth performance

Data on mean initial and final weights of the birds, average daily weight gain (ADG), feed conversion ratio (FCR) and feed cost/kg of weight gain (FCS) are shown in Table 5. ADG was significantly higher (8.15 g) for CMx(+) than for all other treatments ($p < 0.05$). There was no significant difference in ADG among the choice-feeding treatments. ADG was lower for ScO compared to all other treatments ($p < 0.05$), but the difference was not significant between ScO and Sc(−). ADG and final live weight were higher for the males compared to the females ($p < 0.05$) (Table 6). The highest FCR was observed in CS(+) and lowest in CMx(+) ($p < 0.05$), with intermediate values for ScS(+) and ScS(−). Feed costs (CEFA/kg of weight gain) were higher in CS(+) (2877) and ScS(−) (2248) compared to CMx(+) (1718) and ScS(+) (1844) ($p < 0.05$).

Higher mortalities were seen in the scavenging treatments (22.0%, 20.0% and 12.0% in ScO, ScS(+) and ScS(−), respectively) compared to the confined treatments (7.50 and 0.0 in CS(+) and CMx(+), respectively) ($p < 0.05$).

Table 6 Effect of sex on average daily weight gain (ADG) of growing crossbred chickens (LSM ± SEM)

	Females	Males	SEM	p-Value
Initial weight (g)	300	330	2.784	
Final weight (g)	740[b]	820[a]	11.75	0.000
Days on experiment	75	75		
ADG (g)	5.86[b]	6.44[a]	0.148	0.021

[a,b]Means with different superscript letters in the same row are significantly different at $p < 0.05$

Effect of supplementation on the carcass characteristics of male crossbred chickens

Mean live body weight at slaughter was highest for the cockerels in CMx(+) (1048 g) and was lowest in ScO (600 g) ($p < 0.05$) (Table 7). No significant difference was found in live body weight among the other treatments ($p > 0.05$).

Table 7 Effect of supplementation strategy on the carcass characteristics of male crossbred chickens (LSM ± SEM)

	Treatment[1]						
	CMx(+)	CS(+)	ScS(+)	ScS(−)	ScO	SEM	p-Value
Live body wt (g)	1048[a]	735[b]	761[b]	715[b]	600[c]	35.8	0.00
Carcass wt (% of live wt at slaughter)	56.8[b]	56.5[b]	65.1[a]	59.6[ab]	53.0[b]	2.07	0.004
Breast wt (% of carcass wt)	26.7[ab]	26.0[ab]	31.5[a]	27.0[ab]	25.0[b]	1.95	0.187
Thigh wt (% of carcass wt)	30.0[b]	30.6[b]	38.5[a]	35.2[ab]	33.0[ab]	2.08	0.04

[1]See footnote 1 Table 2
[a,b,c] Means with different superscript letters in the same row are significantly different at $p < 0.05$

Carcass percentage was higher in ScS(+) (65.1%) than in the other treatments ($p < 0.05$). However, no significant difference was found in carcass percentage between ScS(+) and ScS(−) ($p > 0.05$). The lowest carcass percentage was found in ScO (53.0%). A significant difference was found in breast muscle weight (expressed as percentage of carcass weight) between ScS(+) (31.5%) and ScO (25.0%) ($p < 0.05$). The highest thigh weight was found in ScS(+) (38.5% of carcass weight), while the lowest value was seen in treatment CMx(+) (30.0% of carcass weight) ($p < 0.05$). No significant differences were found among the other treatments.

Discussion

Nutritive value of maize and cowpea

Village chickens in Burkina Faso are often given small amounts of cereals, mainly sorghum, millets, milo and maize as supplements to their diets from scavenging, either in the form of kitchen leftovers or supplied directly by the farmers, according to availability. Maize is the staple cereal in the southern part of Burkina Faso, while sorghum and millet are more common in the drier northern regions. The crude protein (CP) content in the white variety of maize used in the study was rather low (8.3% of DM) but the metabolizable energy content of 15.9 MJ/kg DM is similar to that of another variety of white maize found in Ethiopia (Dana and Ogle, 2002). Cowpea has a fairly high protein content, and compensates for the high proportion of carbohydrates that is typical for the diet of rural people in Burkina Faso (Lambot, 2002). It is also relatively rich in lysine and consequently it can be used to balance cereals, which are generally poor in lysine. The CP content of the dried whole raw cowpea used in this study was 23.0%, which is within the range of values reported for other varieties of cowpea in West Africa (Lambot, 2002). The mixed diet was formulated to meet the CP requirement for improved pullets of 14.5% of the diet from 6 weeks of age to first egg (INRA, 1986).

Effect of supplementation on feed and nutrient intake

In the confined groups, daily DM intake was higher for the choice-feed birds compared to those offered the mixed feed. This result is different from other studies (Olver and Malan, 2000; Dana and Ogle, 2002), which showed lower DM intake by choice-fed birds compared to those that received a complete layer mash. This can be explained in our study by the anti-nutritional factors, such as a trypsin inhibitor and tannins, present in the mixed feed owing to the high level of inclusion (50%) of cowpea, which would probably have reduced its palatability (Pusztai *et al.*, 1992). This negative effect on palatability due to the presence of cowpea was confirmed by the significantly lower intake of cowpea in favour of maize in all the choice-fed groups, although it should be pointed out that a high intake of maize is usually seen when it is given separately (Olver and Malan, 2000; Dana and Ogle, 2002).

Dry matter intake was about 16% higher for the CS(+) chickens compared to the corresponding scavenging treatment (ScS(+)), which indicates that the scavenging birds were probably getting 16% of their DM intake from scavenging feed resources (SFR). This proportion is similar to the value found by Minh and Ogle (2005) in a study carried out in Vietnam with crossbred grower chickens, in which it was estimated that around 12% of DM intake came from the SFR.

The proportion of the total diet from scavenging varies and is influenced by a number of factors, one of the most important being season (Pousga *et al.*, 2005b). The present experiment was carried out during the crop harvesting time (September–November) when it was relatively easy for the scavenging birds to find grains and seeds in the surrounding environment.

None of the choice-fed birds succeeded in meeting their requirements for protein and essential amino acids from the supplements, mainly because of the low intake of cowpea that was offered in order to supply the necessary protein. This was also observed in a similar study carried out in Ethiopia in which maize and a protein source with low palatability (noug cake) were offered separately (Dana and Ogle, 2002). In the ScS(+) treatment, the CP intake of 12.3% of total DM was below the requirement of commercial pullets from 6 weeks to first egg of 14.5% (INRA, 1986). However, assuming that the requirements of crossbred chickens are lower than those of improved pullets and that the intake from scavenging will supply a certain amount of protein, it is likely that choice-feeding of maize and cowpea should at least meet the CP requirement of scavenging chickens.

Effect of supplementation on average daily weight gain, feed conversion ratio, mortality and feed costs

Average daily gain was higher in the confined group given the mixed feed compared to the choice fed treatment. This can be explained by the lower protein and essential amino acid intakes by the choice-fed birds as a result of lower than expected intakes of cowpea. Also, ADG was higher for CMx(+) than for the scavenging birds, probably because of their limited access to the supplements. Daily gains were also significantly lower for the birds that were not supplemented (ScO) compared to all other treatment groups, which confirms that scavenging alone cannot meet the nutrient requirements for maintenance and tissue growth of crossbred chickens. This result is in agreement with Tegene (1992), who concluded that the feed that the local chickens consumed as a result of scavenging was critically deficient in nutrients and protein. The observation that ADG values were only marginally lower for the scavenging treatment without the vitamin-mineral premix than for the treatment with the premix indicates that it is not necessary to provide additional vitamins and minerals to scavenging chickens, at least in the harvesting season. Daily gain and final live weight were higher for males than for females, which is in good agreement with other studies (Minh and Ogle, 2005; Pedersen, 2002).

Feed conversion ratio (FCR) and feed costs/kg gain (FCS) were lowest when the mixed feed was given to the confined chickens. However, because of the relatively low daily gains, FCS was still around USD 3.3 /kg gain for CMx(+), and values for the other treatments where cowpea and maize were offered were even higher. This leads to the conclusion that it is not economically advantageous to feed untreated cowpea to either confined or scavenging growing chickens. However, the present study was carried out during the crop harvesting period at the end of the rainy season. The quantity of SFR would probably have been lower in the dry season, as was found by Minh and colleagues (2006) and Dessie (1996), when it is possible that supplementing cowpea and maize would have been more advantageous. The higher mortality that was found in scavenging birds was almost entirely due to predators, in particular snakes, rats and birds of prey.

Effect of supplementation and scavenging on the carcass characteristics of male crossbred chickens

Carcass percentage, and thigh weight as a proportion of carcass weight, were higher for ScS(+) males compared to the two confined groups. This was probably a result of greater abdominal fat deposition by the confined birds at the expense of muscle (Castellini *et al.*, 2002). Among the scavenging treatments, higher breast and thigh muscle proportions were noted for the ScS(+) males compared to the unsupplemented scavenging birds (ScO), probably owing to their failure to find sufficient protein from SFR, as was also found by Minh and Ogle (2005). The observation that thigh muscle percentage was generally higher for the scavenging compared to the confined birds can be explained by the scavenging activities, which increase motor activity and have been shown to enhance the development of muscle mass at the expense of fat (Wattanachant *et al.*, 2004).

It can be concluded that it is not economically advantageous to provide maize, cowpea and vitamin-mineral supplements to crossbred, growing, scavenging chickens in central Burkina Faso, at least during the harvesting season.

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Effet de la supplémentation sur la prise alimentaire et les performances de poulets de croissance enfermés en espace clos et détritivores de races croisées à Burkina Faso

Résumé – Une expérimentation a été menée pour évaluer les performances de poulets de croissance de race croisée (poules Rhode Island rouges × indigènes de Burkino Faso) de 6 à 17 semaines d'âge, sous cinq régimes alimentaires/de gestion : 1) le régime CMx(+), poulets enfermés en espace clos et recevant une alimentation mixte contenant du maïs concassé et de la dolique à oeil noir et un prémélange de vitamines et de minéraux *ad-libitum*; 2) le régime CS(+), poulets enfermés en espace clos et recevant *ad-libitum* un choix de maïs concassé et de dolique à oeil noir avec le prémélange; 3) le régime ScS(+), poulets détritivores se nourrissant de 09.00 à 16.00 avec la nourriture du traitement (2) disponible de 16.00 à 09.00; 4) le régime ScS(−), le traitement (3) mais sans le prémélange et 5) le régime ScO, poulets détritivores uniquement, sans suppléments alimentaires fournis. L'apport journalier en matières sèches (DM) a été le plus élevé pour le régime alimentaire CS(+) (43.5 g) et le plus bas pour le régime alimentaire CMx(+) (33.6 g) ($p < 0.05$), avec des apports alimentaires intermédiaires pour les régimes ScS(+) et Sc(−) de 36.7 g et de 36.2 g respectivement. Les rapports des apports alimentaires de dolique à oeil noir par rapport au maïs ont été de 50:50, 21:79, 27:73 et de 22:78 pour les régimes alimentaires CMx(+), CS(+), ScS(+) et ScS(−) respectivement ($p < 0.05$). Les concentrations alimentaires en protéines brutes (CP) ont été de 15.7, 11.5, 12.3 et de 11.6% de matières sèches pour les régimes alimentaires CMx(+), CS(+), ScS(+) et ScS(−) respectivement. Les gains de poids journaliers moyens (ADG) ont été de 8.15, 5.24, 6.03, 5.36 et de 4.45 g pour les régimes alimentaires CMx(+), CS(+), ScS(+), ScS(−) et SCO respectivement et ont été significativement plus élevés pour les régimes CMx(+) ($p < 0.05$). Le rapport de conversion de l'alimentation a été le plus élevé pour le régime alimentaire CS(+) et le plus bas dans le régime alimentaire CMx(+). L'ADG des mâles (6.44 g) a été significativement plus élevé ($p < 0.05$) que celui des femelles (5.86 g). Les poids des muscles du thorax et des cuisses ont été les plus élevés pour le régime alimentaire ScS(+) ($p < 0.05$).

Efecto de la suplementación en el consumo de alimento y rendimiento de pollos cruzados en crecimiento confinados y sin confinar en Burkina Faso

Resumen – Se llevó a cabo un experimento para evaluar el rendimiento de pollos cruzados en fase de crecimiento (Rhode Island Red × gallinas indígenas de Burkina Faso) de 6 a 17 semanas de edad, bajo cinco regímenes de alimentación y manejo: 1) CMx(+), confinado y dado un alimento mezclado consistente en maíz cascado y caupí y una mezcla ya hecha de vitamina y mineral *ad-líbitum*; 2) CS(+), confinado y ofrecido *ad-líbitum* una opción de maíz cascado y caupí con la mezcla ya hecha de vitamina-mineral; 3) ScS(+), carroñero de 9.00 a 16.00 hr con la dieta en el tratamiento (2) disponible de las 16.00 a las 9.00; 4) ScS(−), carroñero con tratamiento (3) pero sin la mezcla de vitamina-mineral; y 5) ScO, carroñero sólo, sin ninguna suplementación. El consumo de materia seca diaria (MS) fue máximo para CS(+) (43.5 g), y más bajo para CMx(+) (33.6 g) ($p < 0.05$), con consumos intermedios para ScS(+) y Sc(−) de 36.7 y 36.2 g, respectivamente. Los porcentajes de consumo de caupí a maíz fueron de 50:50, 21:79, 27:73, y 22:78 para CMx(+), CS(+), ScS(+) y ScS(−), respectivamente ($p < 0.05$). Las concentraciones dietéticas de proteína cruda (PC) fueron 15.7, 11.5, 12.3 y 11.6% de MS para CMx(+), CS(+), ScS(+) y ScS(−), respectivamente. Las ganancias medias diarias (GMD) fueron 8.15, 5.24, 6.03, 5.36 y 4.45 g para CMx(+), CS(+), ScS(+), ScS(−) y ScO, respectivamente, y fueron significativamente más alta para CMx(+) ($p < 0.05$). El cociente de conversión alimenticia fue máximo para CS(+) y mínimo en CMx(+). La GMD de los machos (6.44 g) fue significativamente más alta ($p < 0.05$) que la de las hembras (5.86 g). Los pesos de los músculos de las pechugas y los muslos alcanzaron valores máximos para ScS(+) ($p < 0.05$).

III

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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 conditions to meet the increasing demand for eggs of the urban population, and in addition to increase the in-comes of women and young people in the rural areas. Improvement of smallholder chicken production in rural areas should take into account improved feeding, with diets formulated 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°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 *Vitellaria 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%, respect-tively) 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 Gõhl (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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IV

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Evaluation of Traditional Sorghum (*Sorghum bicolor*) Beer Residue, Shea-Nut (*Vitellaria paradoxa*) Cake and Cottonseed (*Gossypium Spp*) Cake for Poultry in Burkina Faso: Availability and Amino Acid Digestibility

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Abstract: The present study aimed to evaluate the nutritive value for chickens of some local by-products in Burkina Faso and to estimate their true amino acid digestibility in cockerels. Sun-dried sorghum (*Sorghum bicolor*) beer residue (n = 144) and shea-nut (*Vitellaria paradoxa*) cake (n = 36) samples were collected in two different locations during six months, while cottonseed (*Gossypium spp*) cake samples were purchased monthly in a local market for the same period (n = 24). Mean Dry Matter (DM) content of beer residue was 94.7% and Crude Protein (CP), Ether Extract (EE), Crude Fibre (CF), Calcium (Ca), Phosphorus (P) and Metabolizable Energy (ME) contents were 23.4, 5.6, 8.5, 0.14 and 0.25% of DM and 13.4 MJ/kg, respectively. Mean lysine, methionine, cystine and threonine contents were 0.87, 0.44, 0.41 and 0.63%, respectively and the corresponding true excreta digestibility values were 92, 98, 95 and 97%. Mean DM content of shea-nut cake was 95.6% and CP, EE, CF, Ca, P and ME contents were 6.7, 7.3, 10.9, 0.40 and 0.19% and 13.1 MJ/kg, respectively. Lysine, methionine, cystine and threonine contents were 0.27, 0.14, 0.09 and 0.23% and the true digestibility values were 96, 78, 88 and 77%, respectively. Mean DM, CP, EE, CF, Ca, P and ME contents of cottonseed cake were 94.8, 44.3, 5.9, 9.9, 0.34 and 1.3% and 12.7 MJ/kg. Lysine, methionine, cystine and threonine contents were 1.6, 0.80, 0.82 and 1.9% and the true digestibility values were 89, 97, 98 and 94%. Overall, higher nutritive values were found for samples collected between October and December and no difference was found between locations.

Key words: Amino acid digestibility, beer residue, Burkina Faso, cockerels cottonseed cake, shea-nut cake

Introduction

Studies on the nutritional status of village chickens in Burkina Faso show that scavenged feeds are mainly a source of energy and therefore any supplementation should be done with protein-rich feedstuffs (Pousga *et al*., 2005; Kondombo, 2005). However, in West Africa conventional poultry feed ingredients, particularly protein supplements, are expensive and not always readily available (Olorede *et al*., 1999). According to FAO (1984), when feed resources are limited, the best approach is to utilize crop residues and agro-industrial by-products more efficiently. The main locally available potential protein feeds for poultry in Burkina Faso, which are not in competition with humans, are shea-nut cake, local beer residue and cottonseed cake. Burkina Faso is the first cotton producer in Sub-Saharan Africa, the second shea-nut producer and sorghum production in the country is the highest among the cereals grown (Mission Economique, 2006). Annual production was estimated to be 750,000, 122,100 and 1,552,900 tonnes, respectively, for cotton, shea-nut and sorghum (Mission Economique, 2006). Many developing countries are self-sufficient in monogastric meat but few are self-reliant, since they have to import most of the inputs (FAO, 1995). Very little research has been done in Burkina Faso to find alternative feeds to cereals and imported fishmeal and soybean meal. Thus, there is a need to develop alternative feeding systems in the country, based for example on cottonseed cake, shea-nut cake and local beer residue. Cottonseed cake is a fairly common poultry feed ingredient in Burkina Faso, but shea-nut cake and beer residue are rarely used non-conventional feedstuffs and there is little information on their nutritive value and digestibility.

All dietary components, such as amino acids, vitamins and minerals are important when formulating feeds for poultry, but critical attention should be given to the dietary amino acids, as approximately 25% of the cost of practical poultry diets can be accounted for by amino acids (McNab, 1994). Methods to estimate the digestibility of amino acids in chickens have been developed and tested by numerous authors (Likuski and

Dorrell, 1978; Sibbald, 1979; Song *et al.*, 2003). However, there is still debate as to the accuracy and suitability of the different methods used. According to Borin *et al.* (2002), besides the scientific aspects, the appropriateness of the methods to be used must be based on the local context and available facilities and be economically viable. A review by McNab (1994) of the different methods used for determination of amino acid digestibility concluded that the digestibility values based on the excreta from normal intact birds have the decided advantage of simplicity over those taken from caecectomized birds or of values based on ileal concentrations. The overall objectives of this study were to determine the proximate composition and amino acid digestibility of three local by-products in Burkina Faso collected in different locations and at different times of the year.

Materials and Methods

Site: This study includes collection and analysis of three locally available by-products in Burkina Faso and a digestibility trial. Samples of sorghum (*Sorghum bicolor*) beer residue and shea-nut (*Vitellaria paradoxa*) cake were collected in two different locations, Sapone in the Central Region and Bobo-Dioulasso in the South, while cottonseed (*Gossypium spp*) cake was bought in a local market in Ouagadougou. Bobo-Dioulasso is situated at around 365 km from Ouagadougou, in the Sub-humid zone, while Sapone is in the Soudano-Sahelian zone. The digestibility trial was carried out in the INAGOR Research Centre, situated in Sapone, around 35 km South of Ouagadougou.

Sample collection: Three locally available by-products, shea-nut cake, beer residue and cottonseed cake were evaluated. The crops from which they originated are harvested only once per year: From October to December for sorghum and cotton and from June to September for shea-nut. Shea-nut cake and beer residue were collected, already sun-dried, from three households in each of the two locations (Sapone and Bobo-Dioulasso) from July to December, representing three months of the rainy season (July to September) and three months of the dry season (October to December). Cottonseed cake samples were collected in the same period. Sample collection was done four times per month, according to the by-product availability.

Experimental animals: Thirty six crossbred cockerels (RIR×local hens) of between 0.5 and 0.6 kg live weight were paired on a weight basis and placed in individual metabolism cages (0.25×0.25×0.35m).

Experimental assay for amino acid digestibility determination: A force-feeding trial was carried out according to the procedures of Likuski and Dorrell (1978), Sibbald (1979) and Song *et al.* (2003) concerning the feeding technique and the estimation of endogenous amino acids. Samples of shea-nut cake and sorghum beer residue from the two locations (Sapone and Bobo-Dioulasso) were pooled and each of the three by-products was tested with six replications of two birds per treatment (paired on a weight basis, designated fed and fasted). The birds were starved for 24 hours prior to the beginning of the experiment, but given free access to water. Thereafter, one of each pair was randomly selected and force-fed 8 g of its respective sample and returned to the cage over a clean excreta collection tray and was allowed to stay for a further 48 hours. The other member of each pair continued without feed for the same period and was referred to as the fasted member, while the former was the fed member. Both the fed and fasted birds had free access to water. Excreta were collected for 48 hours after force-feeding, three times per day and stored at 4°C, then oven dried at 60°C. Excreta samples were pooled per group of three birds and per feedstuff, then ground in a Cyclotec grinder to pass through a 1 mm screen and stored in air-tight sample bottles for amino acid analysis.

Chemical analysis of the feedstuffs collected: The collected samples were pooled within feedstuff, to get two samples per month and stored for analysis. Samples were analyzed for proximate composition using standard methods: Dry Matter (DM) was determined after drying at 60 and 103°C and the Kjeldahl method (AOAC, 1985) was used for determination of Crude Protein (CP) (N*6.25). ADF was determined according to AOAC (1985), NDF according to Chai and Uden (1998) and Ether Extract (EE) was determined after acid hydrolysis. Total Ash was determined by burning at 550°C (3 hours) and minerals by flame spectrometry. Amino acids were determined using standard methods (AnalyCen, Lidköping, Sweden). Metabolisable energy was calculated according to INRA (1987) using the following formula:
True ME (MJ/kg dry matter) = (3951+54.4EE-88.7CF-40.8Ash) *0.004184.

Amino Acid (AA) digestibility: The AA digestibility coefficients were calculated according to McNab (1994):

$$\text{Total tract AA digestibility} = \frac{\text{AA consumed} - \text{AA in faeces}}{\text{AA consumed}}$$

$$\text{True AA digestibility} = \frac{\text{AAC} - (\text{AAF} - \text{EAAF})}{\text{AAC}}$$

AAC = amino acid consumed
AAF = amino acid in faeces from fed birds
EAAF = endogenous amino acids in faeces from unfed birds

Table 1: Chemical composition of sorghum beer residue from two areas of Burkina Faso (% of DM) (n = 144)

Item	Bobo-Dioulasso*	Sapone**	SEM	P-value
Dry matter	94.7	94.8	0.4	0.89
Organic matter	92.5	93.3	0.36	0.101
Ash	7.5	6.7	0.36	0.101
Crude protein	23.3	23.6	0.45	0.57
Ether extract	5.5	5.7	0.23	0.53
Crude fibre	7.9^b	9.0^a	0.24	0.004
NDF	40.1^b	49.5^a	1.6	0.00
ADF	20.7^b	31.3^a	0.83	0.00
ME (MJ/kg)***	13.5	13.3	0.12	0.24

*Sub-humid zone, **Soudano-Sahelian zone, ***Calculated values, according to INERA, 1995.

Statistical analysis: Data were subjected to the GLM procedure in MINITAB 14 (Minitab, 2000). Pairwise comparisons were made using the Tukey Test to compare the effect of location and month on the chemical composition of the by-products.

Results

Availability of the by-products: Local beer residue is available in Burkina Faso after home brewing, usually done by women. Normally red sorghum, yeast and water are the sole ingredients, although red sorghum is often replaced by millet and milo, according to tradition and availability.

Shea-nut cake is a by-product of the indigenous technology for extraction of fat from the kernel of the shea butter tree (*Butyrospermum parkii* or *Vitellaria paradoxa*). The Shea tree is a sacred tree in the Sahel region of Africa and is 15 to 20m high with a stout trunk and large leathery oval leaves (Göhl, 1981). It grows only in the wild, is very difficult to cultivate and can live for several hundred years (Kariderm, 2006). Harvesting the nuts and making the butter have traditionally been womens' work. The processing technique includes boiling, roasting and frying.

Cottonseed cake is available in Burkina Faso after oil extraction in the factories. Two types of cottonseed cake are produced: decorticated expeller, which is fed to monogastric animals and non-decorticated expeller cake, which is fed to ruminants. Only samples of decorticated expeller cake were collected in this study.

Chemical composition of the by-products: The proximate composition of the beer residues from the two locations and according to month is shown in Table 1 and 2. The data show acceptable Crude Protein (CP), Metabolizable Energy (ME) and Ether Extract (EE) values, but mineral and amino acid concentrations were low. Mean Dry Matter (DM), CP, EE, Crude Fibre (CF) and ME contents were 94.7, 23.4, 5.6, 8.5% and 13.4 MJ/kg, respectively. The contents of CF, NDF and ADF were significantly higher in Sapone (9.0, 49.5 and 31.3% of DM, respectively) compared to Bobo-Dioulasso (7.9, 40.1 and 20.7%, respectively). No significant differences were found between the two locations for the other proximate components. The DM content of sun-dried beer residue was significantly higher in October and November (95.9 and 95.8%), than in August (92.2%). Ether extract was highest in October, November and December (7.0, 8.7 and 6.5%, respectively) and lowest in July and August (4.7 and 3.8%, respectively). No significant location and month effects were found for Organic Matter (OM), CP and Ash content. The overall values for mineral and amino acid contents are shown in Table 3. Mean calcium and phosphorus contents were 0.14 and 0.25% and lysine, methionine, cystine and threonine contents were 0.87, 0.44, 0.41 and 0.63% of DM, respectively.

The proximate composition of shea-nut cake collected from the two locations is presented in Table 4. Mean DM, CP, EE, CF and ME contents were 95.6, 6.7, 7.3, 10.9% and 13.1 MJ/kg, respectively. No significant difference was found in proximate composition between the two locations. However, OM, CP and ME contents were numerically higher in Bobo-Dioulasso (94.5 and 7.4% and 13.3 MJ/kg, respectively) compared to Sapone (93.3 and 5.9% and 12.9 MJ/kg, respectively), while Ash, CF and EE were higher in Sapone (6.7, 11.5 and 8.0%, respectively) compared to Bobo-Dioulasso (5.4, 10.3 and 6.6%, respectively) ($p>0.05$). Mean calcium and phosphorus contents were 0.40 and 0.19%, respectively. Amino acid contents were 0.27, 0.14, 0.09 and 0.23%, respectively, for lysine, methionine, cystine and threonine (Table 3).

Analysis data for cottonseed cake are given in Table 5. Mean DM, CP, EE, CF and ME contents were 94.8, 44.3, 5.9, 9.9% and 12.7 MJ/kg, respectively. No significant differences were found according to month of collection for DM and OM content. However, Ash and fibre contents were higher from July to October, while CP and ME were highest in November and December ($p<0.05$). Mean calcium and phosphorus contents were 0.34 and 1.3%, respectively and lysine, methionine, cystine and threonine contents were 1.6, 0.80, 0.82 and 1.9%, respectively (Table 3).

Amino acid digestibility of local beer residue, shea-nut cake and cottonseed cake in cockerels: Apparent and true DM and amino acid digestibility data are shown in Table 6. True digestibility coefficients show that 93% of the DM in local beer residue was digestible and the most important amino acids, lysine, methionine, cystine and threonine, were 92, 98, 95 and 97 percent digested, respectively. In shea-nut cake DM digestibility was 96% and lysine, methionine, cystine and threonine were 96, 78, 88 and 77% digested, respectively.

Dry matter digestibility in cottonseed cake was 91% and lysine, methionine cystine and threonine digestibility values were 89, 97, 98 and 94%, respectively.

Table 2: Monthly variation in the chemical composition of local sorghum beer residue (% of DM) (n = 144)*

Item	July	Aug	Sep	Oct	Nov	Dec	Mean	Max	Min	SEM	P-value
DM	94.4	92.2[b]	95.1	95.9[a]	95.8[a]	95.2	94.7	97.5	83.7	0.70	0.010
OM	94.5	92.3	92.7	91.7	92.5	93.5	92.8	95.8	88.4	0.62	0.055
Ash	5.47	7.7	7.21	8.3	7.51	6.4	7.1	11.5	4.1	0.62	0.055
CP	21.6	24.0	22.6	23.3	24.8	24.4	23.4	29.5	18.2	0.78	0.064
EE	4.7[b]	3.8[b]	3.0b	7.0[a]	8.7[a]	6.6[a]	5.6	10.5	2.0	0.41	0.00
CF	8.5	8.5	8.9	8.3	8.1	8.7	8.5	11.3	6.9	0.42	0.85
NDF	48.6[a]	48.9[a]	49.7[a]	38.6[b]	35.3[b]	34.8[b]	44.8	64.0	26.3	2.78	0.003
ADF	22.8	29.6	26.2	25.7	26.6	25.2	26.0	39.5	16.0	1.44	0.072
ME (MJ/kg)**	13.5	12.9[bc]	12.7[b]	13.6	14.2[a]	13.6[ac]	13.4	14.8	11.6	0.21	0.00

*Total samples from Sapone and Bobo-Dioulasso, **Calculated values, according to INRA, 1987

Table 3: Mineral and amino acid composition of the by-products, maximum, minimum and mean values (% of DM) (n = 12)

	Sorghum beer residue				Shea-nut cake				Cottonseed cake			
Item	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD
Calcium	1.20	0.03	0.14	0.04	0.55	0.30	0.40	0.10	0.65	0.20	0.34	0.08
Phosphorus	0.32	0.15	0.25	0.07	0.30	0.11	0.19	0.07	3.50	0.50	1.3	0.20
Magnesium	0.17	0.04	0.10	0.04	0.30	0.11	0.15	0.04	0.80	0.42	0.72	0.09
Potassium	0.16	0.05	0.11	0.03	0.90	0.10	0.54	0.27	2.30	0.65	1.8	0.33
Sodium	0.02	0.001	0.06	0.05	0.21	0.01	0.05	0.04	1.30	0.24	0.35	0.09
Lysine	1.01	0.65	0.87	0.12	0.32	0.19	0.27	0.5	2.50	0.90	1.6	0.25
Methionine	0.54	0.33	0.44	0.13	0.17	0.10	0.14	0.22	1.50	0.40	0.8	0.09
Cystine	0.53	0.26	0.41	0.10	0.12	0.07	0.09	0.15	1.70	0.40	0.82	0.08
Threonine	0.90	0.47	0.63	0.30	0.29	0.17	0.23	0.42	3.50	1.10	1.90	0.40

Table 4: Chemical composition of traditional shea-nut cake from two climatic zones of Burkina Faso (% of DM) (n = 36)

Item	Bobo-Dioulasso*	Sapone**	Mean	Max	Min	SEM	P-value
Dry matter	95.1	96.1	95.6	98.0	87.3	1.03	0.47
Organic matter	94.5	93.3	93.9	97.3	89.1	0.76	0.30
Ash	5.4	6.7	6.1	10.3	2.6	0.76	0.30
Crude protein	7.4	5.9	6.7	10.3	2.5	0.89	0.29
Ether Extract	6.6	8.0	7.3	9.6	5.3	0.37	0.29
Crude fibre	10.3	11.5	10.9	11.0	7.8	0.33	0.98
NDF	34.0	35.9	34.9	42.0	28.2	1.46	0.39
ADF	28.7	29.4	29.0	41.5	18.6	2.17	0.84
ME (MJ/kg)***	13.3	12.9	13.1	14.1	12.4	0.15	0.65

*Sub-humid zone, **Soudano-Sahelian zone, ***Calculated value, according to INRA, 1987

Table 5: Monthly variation in the chemical composition of decorticated expeller cottonseed cake (% of DM) (n = 24)

Item	July	Aug	Sep	Oct	Nov	Dec	Mean	Max	Min	SEM	P-value
DM	94.2	94.6	95.3	95.5	94.0	95.6	94.8	97.4	88.5	0.62	0.56
OM	91.0	90.8	91.0	91.0	92.7	92.9	91.5	94.2	87.6	0.48	0.66
Ash	9.0[a]	9.20[a]	9.0[a]	8.9[a]	7.3[b]	7.1[b]	8.4	10.5	4.2	0.50	0.027
CP	44.3	45.4	41.1[b]	43.0	46.3[a]	45.9[a]	44.3	57.3	39.8	1.60	0.045
EE	5.5[b]	5.5[b]	5.5[b]	5.5[b]	6.8[a]	6.8[a]	5.9	8.2	4.3	0.04	0.001
CF	10.5[a]	11.0[a]	11.5[a]	10.4[a]	7.4[b]	8.5[b]	9.9	12.8	6.5	0.40	0001
NDF	20.3[a]	21.0[a]	20.5[a]	20.8[a]	17.7[b]	17.4[b]	19.6	22.6	15.4	0.50	0.001
ADF	15.3[a]	15.8[a]	15.9[a]	16.3[a]	12.2[b]	12.6[b]	14.6	17.7	10.5	0.50	0.001
ME (MJ/kg)*	12.3[b]	12.1[b]	12.0[b]	12.3[b]	14.0[a]	13.7[a]	12.7	14.8	12.2	0.22	0.00

*Calculated values, according to INRA, 1987

Discussion

Local beer, called "dolo", is an important alcoholic drink in Burkina Faso. Little published data are available on the utilisation of the residue after local alcohol preparation and traditionally, beer residue is given to pigs in the rural areas (Bosma *et al.*, 2004). Kondombo (2005) carried out a feeding trial with chickens using sorghum beer residue and found that it was not very palatable. Shea-nut residue after oil extraction is not used as a feed for livestock in Burkina Faso and there is little data concerning the utilization of this by-product in the country. Traditionally, the residue is used by women as a fuel and as source of potassium for traditional soap manufacture (Kariderm, 2006). The most common variety of cotton cultivated in Burkina Faso is gossypol-free (a glandless variety) and the seeds are used in both

Table 6: Dry matter and apparent and true essential amino acid digestibility in young cockerels of sorghum beer residue, shea-nut cake and cottonseed cake in Burkina Faso (% of DM)

	Sorghum beer residue		Shea-nut cake		Cottonseed cake	
Item	Apparent	True	Apparent	True	Apparent	True
Dry matter	63	93	83	96	83	91
Lysine	86	92	75	96	82	89
Methionine	91	98	62	78	82	97
Cystine	76	95	57	88	91	98
Threonine	88	97	53	77	83	94

human nutrition and for livestock (Schwartz, 1993; INERA, 1995). The cottonseed cake which is used in monogastric animal feeding is decorticated expeller, while the non-decorticated expeller is given to ruminants.

The chemical composition of traditional sorghum beer residue in this study is similar to the data obtained in Ethiopia by Demeke (2007) for traditionally brewed beer residue. However, proximate composition data show higher nutritive content compared to values reported for dried brewer's grain in Africa (Göhl, 1981), in particular for DM, CP, calcium and phosphorus. This difference was probably a result of differences in the type of cereal used for beer brewing and also due to differences between traditional and commercial brewing techniques. The differences obtained in fibre content between the two locations in this study can be explained by possible differences in sorghum processing after harvesting the cereal, or due to the different varieties of sorghum used in the two locations, as there are more than thirty varieties of sorghum grown in Burkina Faso (Sereme *et al.*, 1994). The higher DM and EE content from November to December can be attributed to the fact that sorghum is harvested between October and November in Burkina Faso and is stored and used over the following 12 months. Therefore, the chemical components may undergo some changes during storage. The differences seen in chemical composition can also be a result of variations in brewing techniques. Despite the relatively high nutritive value of sorghum beer residue, it is important to note that it may contain high tannin levels and varieties with high tannin levels (more than 0.2%) are generally used in Burkina Faso for local alcoholic drinks (Sereme *et al.*, 1994).

The mean CP content of shea-nut cake (6.7%) was lower compared to data from other studies showing CP contents of between 16-18% (Morgan and Trinder, 1980; Göhl, 1981; Atuahene *et al.*, 1998; Olorede *et al.*, 1999). The mean EE content in our study (7.3%) was higher compared to the data of Morgan and Trinder (1980) and Göhl (1981), who reported values of around 4%. The differences seen in the chemical composition of shea-nut cake in this study compared to other reports, especially regarding CP and EE contents, can be explained by possible differences in the variety of shea tree, in the processing method or contamination. The traditional oil extraction in Burkina Faso includes roasting and frying for several hours to separate the oil from the nut and this can lead to protein degradation, as indicated by the black colour of the cake. It was also reported that traditional artisan methods leave a higher proportion of oil in the residue compared to commercial techniques (Niess, 1983), as was found in the present study. The differences observed between the two locations can also be explained by differences in processing method or by contamination. Unlike local beer residue, shea-nut residue is not available on a regular basis in the same household. Oil extraction is done on an irregular basis at different-times by groups of women according to time availability. This explains the absence of data on the chemical composition of shea-nut cake in different months in the present study. Several authors found that shea-nut cake is unpalatable to livestock due to its bitter taste and it has been shown to contain anti-nutritional factors such as saponins and theobromine (Atuahene *et al.*, 1998) which can be deleterious to chick health (Owusu-Domfeh *et al.*, 1978; Clarke and Clarke, 1979).

The nutrient composition of cottonseed cake used in monogastric feeds in Burkina Faso is similar to values found for glandless cottonseed cake and expeller cake in India (Nagalakshmi *et al.*, 2007) and is also similar to the data of Smith (2001). The higher level of ash and fibre from July to October can be attributed to the long period of storage and possible contamination of the seeds, as cotton is harvested from November to December and the seeds are stored and used throughout the following 12 months for oil extraction. This can also explain the higher level of ME and CP in samples from November to December compared to July to October. However, another possible explanation could be the difference in growing conditions between 2005 and 2006 for the crop harvested in November-December.

Based on chemical analysis, the by-products analyzed in this study seem to be potentially useful in chicken nutrition, although proximate analysis has been shown to be of limited value in defining feed quality and therefore digestibility data should also be taken into account (Morgan and Trinder, 1980).

Cottonseed cake amino acid digestibility values are close to values found by Perez-Maldonado (2000) in

Australia. Despite the relatively high fibre contents of the by-products, the digestibility values of the important essential amino acids indicate that they could be of value as ingredients in chickens feed. In particular the protein content of local beer residue and cottonseed cake indicates their potential value for monogastrics, although the CP content in shea-nut cake is too low for it to be useful. However, these feedstuffs have been exposed to heat and pressure during processing, which are necessary to inactivate some antinutritional factors in the raw material (Gatel, 1994; Nagalakshmi *et al.*, 2007), but result in chemical reactions between protein-bound amino acids and reducing compounds present in the feed matrix, which may render some of the amino acids nutritionally unavailable for the animal (Hodgkinson, 2006). Lysine is the amino acid which is most affected by processing as it is more exposed to early Maillard reactions, which provoke the formation of a reacted lysine (Amadori compounds) which is partially absorbed from the gut but has no nutritional value to the animals (Hurrell and Carpenter, 1981). Moreover, a proportion of the reacted lysine derivatives are acid labile and can revert back to lysine during the acid hydrolysis step of conventional amino acid analysis, but this does not occur in the animal's digestive tract (Rutherfurd *et al.*, 1997a; Moughan, 2005). Consequently, the lysine concentrations of the feed and excreta, determined by conventional amino acid analysis, will be overestimated and the conventional true digestibility assay will overestimate the amounts of available lysine and possibly other amino acids for the animal. This can explain the higher digestibility coefficients (92, 96 and 89%, respectively, for beer residue, shea-nut cake and cottonseed cake) obtained in this study. Therefore, other methods of evaluation, such as bioassays (Rutherfurd *et al.*, 1997b) and feeding trials are necessary to evaluate the effect of different inclusion levels in the diet on growth and egg production performance. In addition, studies on the utilisation of shea-nut cake by poultry should be done on oil cake from commercial "press" extraction, due to its higher protein content, rather than the cake from traditional oil extraction.

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Acta Universitatis Agriculturae Sueciae

Doctoral Thesis No. 2007:116

The scavenging feed resource base in Burkina Faso was found, by crop content analysis, to vary with season and location, and was insufficient to meet the requirements of free-range chickens. When scavengeable feed is available, it is not economically advantageous to supplement crossbred growing chickens with maize and cowpea. Local ingredients such as cottonseed cake and wheat/maize bran can replace fishmeal in diets for semi-scavenging and confined layers. Traditional beer residue and shea-nut cake are also potentially valuable supplements.

Salimata Pousga received her undergraduate degree in Chemistry and Biology at Ouagadougou University, Burkina Faso (DEUG). She graduated in Veterinary Medicine (DVM) at Cheick Anta Diop University in Dakar, Senegal.

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