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Research Article
Nutrient Values and Effects of Incorporating African Baobab (*Adansonia digitata* L.) Seed Cake in Finishing and Grower Diets on Zootechnical and Economic Performances of Broilers in Dakar Region, Senegal

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Abstract

Objective: This study aimed to evaluate the effects of incorporating *Adansonia digitata* seed cake into the diets of broilers on zootechnical and economic performances. **Materials and Methods:** The finishing (5-7 weeks of age) and growing phases (3- 4 weeks old) were conducted from November to December 2014 and from February to March 2015 respectively. A total of 288 chickens of 4 weeks old and 372 chicks of 2 weeks old of $cobb_{500}$ strains were distributed after weighing in a completely randomized design in 4 batches of 72 subjects each with 3 replicates of 24 birds in finishing vs. 93 subjects per batch with 3 replicates of 31 birds in growing trial. Each of the 4 batches of broilers was fed with one of the 4 experimental finishing or growing diets (AD_0, AD_5, AD_{10} and AD_{15}) containing 0, 5, 10 and 15% of *A. digitata* seed cake as substitution of groundnut cake. The obtained data were analyzed using a one-way ANOVA followed by the Duncan multiple range test using IBM-SPSS-v.23 software. Differences of $p<0.05$ were considered statistically significant. **Results:** The incorporation of baobab seed cake up to 15% in broilers diets, in both finishing and growing phases, had no significant ($p>0.05$) adverse effect on their average live weight (ALW), average daily gain (ADG), daily feed intake (DFI) and feed conversion ratio (FCR) which remained almost similar to those of the control birds. Also, weights and dressing carcass and organ of broilers remained similar between dietary treatments, except for AD_5 in growing phase which were significantly improved compared to those of AD_0, AD_{10} and AD_{15}. Individual feed costs for broilers treated with baobab seed cake were proportionally, if not significantly, higher than those of the control group. However, the incorporation of this seed cake in both finishing and growing diets increased the gross profit margins per kg carcass that were similar between treatments, except for AD_{15} in finishing phase which remained significantly lower. **Conclusion:** Broilers can consume up to 15% of African baobab seed cake in their finishing or growing diets without negatively impacting their growth performance, or even the profitability of breeding operations, even the profit margin at 5% level of inclusion was equal or higher than that of the control.

Key words: Baobab seed cake, broilers, diets, growth performance, profit margins, Senegal

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Poultry farming, because of its many assets and its important role in poverty reduction and fighting food insecurity (short reproduction and production cycle, rapid return of investment, good nutritional quality products at relatively low prices and more accessible to all people), is one of the livestock sub-sectors that has been promoted the most in developing countries of Africa, where its production has increased by 76% compared to 23% in developed countries over the past few decades[1,2]. In the livestock sector, poultry contributes 17% of the GDP, in the Senegalese primary sector, poultry remains the most economically dynamic sub-sector and is an important source of protein to fight against malnutrition (3.8 kg year^{-1} of poultry products consumed per capita) and create employment opportunities for young people[3-5]. However, there are still various limitations to its development, most notably the high cost of feeding. In Senegal, poultry feeding is mainly based on imported resources, which vary in price depending on the international market. As some of these resources are detours to biofuel production, this leads to a continuous increase in feed costs, which can reach 70-80% of production cost[6,7]. Researchers are now increasingly turning to rational use of alternative or unconventional local feed resources in poultry feed in order to maintain good poultry productivity while keeping production costs below inflation[8-10].

African baobab (*Adansonia digitata* L.), a robust and giant tree of the Bombacaceae family that grows densely throughout Senegal, is used as an alternative feed resource[11]. While the fruits of the baobab tree called "monkey bread" (with an estimated production of 2,000 t year^{-1}) are widely used to make local drinking juice and the leaves are consumed by animals and/or humans, the seeds of this tree are still little exploited[12,13], except for their oil which is used for cosmetics by certain industrial companies such as baobab fruit company of Senegal (BFCS), which regularly generates huge tons of baobab seed cake. Baobab seed cake is a relatively nutrient-rich feed resource (17-28% crude protein, 5-9% lipid, 21-28% crude fiber, 0.9% phosphorus and important trace micro-elements), with a high gross energy content (4400-4700 kcal kg^{-1} DM) and almost without toxic or anti-nutritional factors[11,14-18]. Both baobab seed cake and seeds have even been used in diets at relatively high levels (5-30%) as a substitute for protein in poultry[19-25], rabbits and pigs[26,27] and in ruminants with relatively satisfactory zootechnical results that varied according to the incorporation rate, the process applied or animal species[14,17,28]. Although, baobab cake and seeds are available in Senegal, no previous studies have been carried out to investigate their use in animal feed, particularly in poultry. So the main objective of this study was to investigate the nutritive value of baobab seed cake and the effects of its incorporation in finishing and growing diets on the zootechnical performance and economic profit margins of broilers in Senegal.

MATERIALS AND METHODS

Proximate analyses, formulation and manufacturing of experimental diets: The feed resources used in the experimental diets (finishing and growth) were maize, wheat bran, groundnut cake, fish meal, baobab seed cake, vegetable oil, oyster shell meal, phosphate and mineral and vitamin supplement. The oil was purchased from the Dakar market, the baobab seed cake was acquired locally from a baobab oil production company, BFCS located in Thiès region and the other ingredients were obtained from AVISEN company. Before using in the diets, the baobab seed cake was ground in a mill to reduce its size from large to medium. Samples of some feed resources such as baobab seed, groundnut cakes and fish meal were analyzed at the Laboratory of feed analyses and animal nutrition (LANA) of EISMV-Dakar. Chemical analyses was performed to determine the dry matter (DM), crude mineral matter or ash (MM), crude protein (CP), ether extract (EE), crude fiber (CF), calcium (Ca) and phosphorus (P). The DM content of the different samples was obtained according to the standard method of the French Association for Standardization, AFNOR[29] while those of ash and CP based on the Kjeldhal method (N × 6,25) were made according to AFNOR[30]. The EE was determined based on reflux extraction method under diethyl ether by using the Soxhlet apparatus according to AFNOR[31] and the CF content based on the Wende's method according to AFNOR[32]. Calcium, sodium and potassium contents were determined according to AFNOR[33] using flame photometric atomic absorption method, while phosphorus was measured using the spectrophotometric absorption method at 430 nm[31]. The metabolizable energy (ME) of the diets used was calculated using the following regression equation and described by Sibbald *et al.* and cited by Leclercq *et al.*[34]:

$$\text{ME (kcal kg}^{-1}\text{ DM)} = [3951+(54.4\times EE)-(40.8\times MM)-(88.7\times CF)] \quad (1)$$

The chemical analyses of baobab seed and groundnut cakes, fish meal and those reported for the other feed resources by Ayssiwede *et al.*[35] were used to formulate 4

Table 1: Feed resources composition and nutrient values of finishing and growing experimental diets used containing 0 (AD_0), 5 (AD_5), 10 (AD_{10}) and 15% (AD_{15}) of baobab (*Adansonia digitata)* seed cake in broilers at finisher and grower phases in Dakar region, Sénégal

		Finishing experimental diets				Growing experimental diets			
Ingredients or feed resources used	Price (FCFA kg^{-1})	AD_0	AD_5	AD_{10}	AD_{15}	AD_0	AD_5	AD_{10}	AD_{15}
Maize	175-180*	62.40	55.96	51.64	50.09	53.05	49.37	46.28	42.39
Wheat bran	125	0.00	2.16	2.62	0.00	-	-	-	-
Groundnut oil	1100	1.50	2.70	3.50	3.80	3.29	3.97	4.05	4.82
Baobab (*A. digitata*) seed cake	125	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00
Groundnut cake	210	30.99	29.00	27.00	25.88	34.00	31.70	30.00	28.05
Fish meal	550-510*	2.56	2.50	2.50	2.50	7.22	7.70	7.30	7.53
L-lysine (99%)	2600	0.28	0.28	0.37	0.37	0.31	0.30	0.37	0.36
DL-methionine (99%)	3600	0.18	0.18	0.18	0.19	0.17	0.16	0.19	0.19
Oyster shell meal	80	0.70	0.80	0.87	0.86	1.38	1.40	1.42	1.40
Tricalcium phosphate	100-120*	1.32	1.17	1.06	1.07	0.34	0.15	0.14	0.00
Broilers MVS-0.25%	3000	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total (kg)		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient values									
Dry matter, DM (%)		90.18	90.40	90.56	90.64	90.44	90.58	90.68	90.83
Crude protein, CP (%)		20.00	20.00	20.00	20.00	21.35	21.40	21.46	21.50
Crude fiber, CF (%)		3.52	4.59	5.47	6.04	3.40	4.19	5.06	5.94
Metabolizable energy, ME (kcal kg^{-1})		2912.00	2912.00	2907.00	2900.00	3000.00	3000.00	3000.00	3000.00
Ratio [ME/CP] (kcal g^{-1})		14.56	14.56	14.53	14.50	14.05	14.02	13.98	13.95

*Ingredients price used for the determination of experimental diets prices during the growing phase trial in broilers, FCFA: Local money of french community of Africa (1€ = 655.957 FCFA)

experimental diets for broilers in finishing and growing phases. There were four diets (AD_0, AD_5, AD_{10} and AD_{15}), each of which contained 0, 5, 10 and 15% of baobab seed cake as a partial substitute for groundnut cake, main protein source in the diets (Table 1). In order to produce each of these experimental diets, the raw materials were mixed manually after weighing, starting with small quantities (MVS, lysine, methionine, oyster shell meal and tricalcium phosphate) to obtain a premix.

After mixing, the ingredients in medium and large quantities (baobab seed and groundnut cakes, wheat bran, ground maize) were added to ensure a homogeneous floury diet. These two types of experimental diets (finishing and growing) were packaged and stored in adapted bags for their use during the experimental periods.

Animals and experimental design: Experiment was conducted in two trials at the EISMV farm located in Keur Ndiaye LO, Sangalkam, about 30 km from Dakar. The experimental procedures, animal handling and the collection of samples were reviewed and approved by the Ethics and Animal Welfare Committees of EISMV of Dakar. The study was conducted from November to December 2014 and from February to March 2015 respectively for the finishing and growing phases. These trials were carried out in a semi-open building with a double-sloped roof made in aluminum sheeting. Two weeks before starting, the building and the rearing equipment (feeders, drinkers, wire frames) were cleaned with soapy water and disinfected with bleach and a virucidal solution (Virunet 10%). Before the chicks arrival, the brooding area was set up and delimited by wire frames (previously brushed with a layer of quicklime) and covered with a thick layer (about 3 cm) of wood shavings. A radiant heater of 1400 kW suspended about one meter from the ground was used to heat the living area to an ideal temperature (31-33°C) measured by the thermometer installed. In addition to the footbath filled with cresyl solution installed at the entrance, a scale and data collection sheets were placed in the coop building. The chicks were checked for number, live weight, homogeneity, umbilical condition, legs and liveliness before being placed in the brooding house according to a density of 40 birds m^{-2} at the starter, 20 birds m^{-2} during the grower and 10 subjects m^{-2} in the finishing phase.

The finishing trial involved 292 chicks of $cobb_{500}$ strain reared in mass for four weeks during which they were fed, respectively with two commercial feeds crumb in starter (1-2 weeks) and pelleted in grower phase (3-4 weeks old). At the end of the grower phase, 288 chickens were weighed individually and randomly divided into 4 batches of 72 birds each (with 3 repetitions of 24 birds having relatively similar live weight) corresponding to the 4 experimental finishing diets AD_0, AD_5, AD_{10} and AD_{15}. From 5th week to the end of the trial (7 weeks old), each of the 4 batches of broilers were fed with each of these 4 experimental finishing diets previously produced. Concerning the growing trial, 372 chicks of $cobb_{500}$

Table 2: Medical prophylaxis program applied to broilers during the experiment in Dakar region, Senegal

Age (days)	Sanitary or medical interventions	Veterinary products administrated
d_1	1st vaccination against newcastle disease	Imopest (IM) + HB1ND (beak dipping)
$d_{2\text{-}4;\ 10\text{-}13}$	Administration of stress prevention drugs	TetracolivitND (oral tract in drinking water)
d_9	1st vaccination against gumboro disease	AVIB-IBD Inter (oral tract, drinking water)
$d_{15\text{-}17\ ;\ 26\text{-}28}$	Administration against avian coccidiosis	ANTICOX (oral tract in drinking water)
d_{21}	2nd vaccination against newcastle disease	NEW LASOTAND (oral tract in drinking)
d_{24}	2nd vaccination against gumboro disease	AVIB-IBD Inter (oral tract, drinking water)
$d_{22\text{-}25\ ;\ 29\text{-}35}$	Administration of stress prevention drugs	Amin totalND (oral tract, drinking water)
d_{34}	Administration against intestinal parasites	Citrate-Piperazine (oral tract in drinking)

strain were collectively reared for 2 weeks during which they were fed a commercial crumb starter diet. At the end of this starter phase, the chicks after individual weighing, were divided according to a randomized design into 4 batches of 93 subjects each (with 3 repetitions of 31 birds having similar live weight) and corresponding to the 4 grower diets (AD_0, AD_5, AD_{10} and AD_{15}) containing baobab seed cake at the same level as the finishing diets. Thus, during 3-4 weeks of age, each of the 4 batches of broiler chicks was fed with each of these four experimental grower diets. From 5-6 weeks of age, broilers in all dietary treatments were fed with a commercial finishing diet. The different batches and repetitions per dietary treatment delimited by the grid frames according to the previous standards density, were identified and arranged in an alternating way throughout the poultry house to avoid block and wall effects. From the 25th to 28th and 12th to 14th day of age, a linear feeding transition was carried out, consisting of a progressive reduction of the usual feed in favor of the new feed to be distributed to the birds respectively in finishing and growing trials. Drinking tap water and feed were provided *ad libitum* to birds. During the starter and grower phases, feed was served 3-4 times per day to broilers compared to twice per day during finishing phase. The poultry housing was permanently illuminated with natural light during the day and electric lighting at night throughout the trials. Throughout their life cycle, the birds used in these two trials were vaccinated against Newcastle and Gumboro diseases, treated preventively against avian coccidiosis and received vitamins according to the medical prophylaxis program shown in Table 2.

Data collection and zootechnical and economic parameters determination: The main data collected during the trials were ambient temperature in poultry house (regularly measured with the thermometer installed), live weights (LW), feed intake (FI), mortalities, carcass and organ weights and economic data, i.e. ingredients prices, transport costs, feed production costs, selling revenues.

Birds were weighed individually with an SF-400 electronic scale at reception (day 1) and then on a weekly basis until the end of the trials, while the measurement of FI and mortality were carried out on daily basis. At the end of the trials, 24 chickens (6 birds finishing^{-1} dietary treatment) and 40 chickens (10 subjects growing^{-1} dietary treatment) were randomly selected and slaughtered by severing the jugular vein of the neck in order to assess their carcass and organ characteristics. After plucking with hot water and evisceration during which the crop and intestine were removed, the carcasses of chickens without heads but containing some organs (liver, gizzard, spleen) and detached organs were individually weighed per dietary treatment. The data collected were recorded in a Microsoft Excel spreadsheet which was used to calculate zootechnical parameters including average live weight (ALW), average daily gain (ADG), daily feed intake (DFI), feed conversion ratio (FCR), average carcass weight (CW) and dressings carcass (DC) and organ (DO) according to the following formulas:

$$\text{ADG (g day}^{-1}) = \frac{\text{Live weight gain of the period (g)}}{\text{Length of the period (days)}} \quad (2)$$

$$\text{DFI (g bird}^{-1}\ \text{day}^{-1}) = \frac{\text{Quantity of feed offered - Quantity of feed refused day}^{-1}}{\text{Number of birds}} \quad (3)$$

$$\text{FCR} = \frac{\text{Feed intake during a period (g)}}{\text{Weight gain of the period (g)}} \quad (4)$$

$$\text{MR (\%)} = \frac{\text{Initial number of birds-Final number of birds}}{\text{Initial number of birds}} \times 100 \quad (5)$$

$$\text{DC (\%)} = \frac{\text{Carcass weight of the bird}}{\text{Live body weight of the bird}} \times 100 \quad (6)$$

$$\text{DO (\%)} = \frac{\text{Total organ weight in bird}}{\text{Live body weight of the bird}} \times 100 \quad (7)$$

These technical results were then used to determine the profit margins per dietary treatment in each of the two trials (at finishing and growing phases) based on an economic evaluation made from feed costs and income from the sale of slaughtered chicken carcasses (1700 FCFA kg^{-1} carcass). Thus,

the economic parameters studied were calculated per dietary treatment for both finisher and grower trials in a similar way according to the following formulas:

$$\text{Feed cost bird}^{-1}\text{ (FCFA)} = \text{Commercial diet cost} + \text{FCR}\times\text{Feed price kg}^{-1}\times\text{LW gain (kg) during trial period} \quad (8)$$

$$\text{Feed cost kg}^{-1}\text{ carcass (FCFA)} = \frac{\text{Feed cost bird}^{-1}}{\text{Carcass weight of bird (kg)}} \quad (9)$$

$$\text{Gross selling revenue (GSR) bird}^{-1}\text{ (FCFA)} = \text{Carcass weight of bird (kg)}\times\text{Selling price kg}^{-1}\text{ carcass} \quad (10)$$

$$\text{Gross margins feed (GMF) bird}^{-1}\text{ (FCFA)} = \text{Gross selling revenue bird}^{-1}\text{ carcass-Feed cost bird}^{-1} \quad (11)$$

$$\text{Gross margins feed (GMF) kg}^{-1}\text{ carcass (FCFA)} = \text{Selling price kg}^{-1}\text{ carcass-Feed cost kg}^{-1}\text{ carcass} \quad (12)$$

Statistical analysis: Data were analyzed using one-way analysis of variance (ANOVA), followed by Duncan's Multiple-Range (DMR) test using the SPSS version 23 Statistical Software Program (SPSS, Inc., IBM, Chicago, Illinois, USA). Differences of $p < 0.05$ were considered statistically significant.

RESULTS

Nutrient composition of baobab seed cake, ambient temperature and broilers mortality: Table 3 shows that baobab (*Adansonia digitata*) seed cake was rich in crude fiber (CF) (24.82%), crude protein (CP) (24.5%), lipid or ether extract (EE) (6.9%) and gross energy (GE) (4568 kcal kg^{-1} DM). However, the CP content is barely half that of groundnut cake, with which it has been substituted but it is richer in CF, nitrogen free extract (NFE) and even in phosphorus and potassium than groundnut cake (Table 3).

During the trial, average ambient temperatures recorded ranged from 20.63 to 28°C in finishing and from 26.5°C to 28°C in grower phase, with peaks generally observed in the middle of day. The incorporation of baobab seed cake into finishing and growing diets did not adversely affects birds' health. During the three and two weeks of trials respectively in finishing and growing stages, no cases of disease or mortalities were recorded in broilers when they were fed with diets containing various levels of baobab seed cake.

Growth performance of broilers fed African baobab seed cake based diets in finishing and grower phases: Table 4 shows the growth parameters such as average live body weights (ALW), average daily weight gains (ADG), daily feed intake (DFI) and feed conversion ratios (FCR) obtained in broilers per dietary treatment during the finishing and growing phases. It appears from the latter that during the finishing phase (5-7 weeks of age), the incorporation of baobab seed cake at different levels in the broilers diet had no significant ($p>0.05$) adverse effect on growth parameters, which remained almost the same as those of the control birds. There was a slight decrease in live weights of the chickens at 7 weeks of age with an increase in baobab seed cakes rate in the diet but no significant differences were observed between the ALW of the chickens in these dietary treatments. Also, during the 6th week of age, if the broilers in AD_{15} treatment had significantly higher DFI (168 g day^{-1}) than those of the other dietary treatments (162.5 g day^{-1}), the incorporation of baobab seed cake, overall did not lead to any significant difference between DFI of birds in different dietary treatments during the 3 weeks of trial in finishing phase.

Concerning the growth phase (3- 4th week of age), apart from the chickens in AD_{15} treatment which had a significantly lower ALW at 3 weeks of age ($p<0.05$) than those of the birds in AD_0, AD_5 and AD_{10} treatments, the incorporation of baobab

Table 3 : Nutrient composition of African baobab (*Adansonia digitata*) seed and groundnut cakes used in experimental diets for broilers in Dakar region, Senegal

Nutrients determined	Bobab seed cake used	Baobab seed cake (MV[4])	Baobab seeds (MV[9])	Groundnut cake used
Dry matter, DM (%)	92.85	92.19 (90-96)	93.21 (90-96.50)	91.10
Crude protein, CP (%DM)	24.50	20.28 (17-23)	21.21 (16.6-28.9)	50.33
Ether Extract, EE (%DM)	6.89	6.39 (5-9)	15.58 (4-25.3)	5.83
Crude fiber, CF (%DM)	24.82	25.63 (21-28)	13.34 (8-23)	7.16
Nitrogen free extract (%DM)	37.32	41.19 (37-48)	44.11 (31-50)	20.82
Ash or mineral matter (%DM)	6.46	5.69 (4-7)	5.76 (3-11)	15.86
Gross energy (kcal kg^{-1} DM)*	4568	4563 (4445-4705)	5119 (4400-6332)	4514
Metabolizable energy (kcal kg^{-1} DM)*	1860	1793 (1600-1800)	3357 (2610-3650)	2986
Calcium, Ca (%DM)	0.03	0.29 (0.2-0.35)	0.33 (0.21-0.52)	0.11
Phosphorus, P (%DM)	0.83	0.86 (0.7-1.0)	0.47 (0.13-0.92)	0.52
Sodium, Na (%DM)	0.13	0.35 (0.1-0.70)	0.11 (0.03-0.25)	0.01
Potassium, K (%DM)	1.79	1.62 (1.5-1.75)	0.96 (0.35-1.50)	1.05

MV[4]: Mean values of results from 4 authors[11,14,17,27], MV[9]: Mean values of results from 9 authors[16,22,26,36-41], (): In parentheses are the ranges of variation of the means and *means calculated values

seed cake in the diet also had no significant ($p>0.05$) adverse effect on ALW, ADG, DFI and FCR of the birds. Different parameters recorded in chickens fed diets containing baobab seed cake during their growing phase were not affected by increasing levels of its incorporation and remained similar to those recorded in control broilers.

Carcass characteristics and economic results of broilers fed African baobab seed cake diets in finishing and grower phases: Table 5 shows the carcass and organs (liver, gizzard, heart, spleen) weights, dressing carcass and organ as well as economic results obtained in broilers fed baobab seed cake based diets during finishing and growing phases. Results showed that the incorporation of baobab seed cake up to 15% in the diet in finishing (5-7 weeks) and growing (3-4 weeks of age) phases respectively, had no significant adverse effect on carcass and organ weights, dressing carcass and organ of broilers which remained similar to those of the control subjects, except in growing phase where carcass weights and dressings carcass and organ significantly improved in chickens fed AD_5 diet compared to the AD_0, AD_{10} and AD_{15} dietary treatments.

As a result of increasing baobab seed cake incorporation in rations compared to the control, the price of the experimental diets and feed costs increased significantly and this was observed only with finishing diets. Thus, although selling revenues (incomes) and gross margins feed (GMF) per chicken were similar between these finishing dietary treatments, at the end of the trial (at 7 weeks of age) the gross profit margin per kg carcass for birds fed AD_{15} ration was significantly lower than those of subjects fed AD_0, AD_5 and AD_{10} dietary treatments. However, in growing phase, although the selling revenues and gross margins for feed per bird were similar for AD0 and AD5 treatments and significantly higher than those of birds fed AD_{10} and AD_{15} diets, the gross profit margins per kg carcass of birds in different dietary treatments were similar to the control at the end of the trial.

DISCUSSION

Although, the baobab seed cake used is low in calcium, its nutritional and energy values are similar to those reported by other authors[11,14,17,27]. In comparison to the latter, our seed cake was slightly lower in CF (24.82% vs. 25.63%) but higher in CP (24.5% vs. 20.3%) and even metabolizable energy (ME) (1860 vs. 1793 kcal kg^{-1} DM). Results of the previous studies showed that average nutrient contents of baobab seeds are significantly richer in lipid (15.6% vs. 6.9%), NFE (44.1% vs. 37.3%) and GE (5119 kcal vs. 4568 kcal kg^{-1} DM) than their cake, which contained relatively more CF[16,22,26,36-41]. Sauvant *et al.*[42] and Bourdon *et al.*[43] have studied the nutrient composition of leguminous oil plant seeds and seed cakes have reported similar results. The average ambient temperatures recorded during the two trial periods (20.6-28°C in finishing and 26.5-28°C in growing), were overall similar to those (19-27°C) recommended by ITAVI[44] and obtained (19.5-30.6°C) in Senegal[45], Nigeria[21] and Zimbabwe[25] but lower than those (28-35.5°C) reported by Ayssiwede *et al.*[8] in the same region. However, in broilers, they are still slightly higher than the thermal comfort zone recommended for finishing (15-20°C) and growing (20-25°C) phases, which could negatively affect birds' performance as a result of heat stress[46]. These temperature variations observed between different studies could be due to the periods during which the trials were implemented. Indeed, our trials were conducted from November to March, coinciding with the cool season in Senegal (from November to April) with average temperatures ranging from 22-30°C.

The observed average live weights (ALW) and average daily gains (ADG) between dietary treatments in both finishing and growing phases were similar to those reported by Chimvuramahwe *et al.*[24] in Zimbabwe using the same rates (0-15%) of baobab seed cake and Bale *et al.*[21] in Nigeria, who incorporated 0, 10, 20 and 30% of baobab seed meal in broiler diets. Furthermore, Adeosun *et al.*[19] and Sola-Ojo *et al.*[22] in Nigeria observed significant improvement in ALW and ADG of broilers fed rations containing 2.5-7.5% and 4-12% of dehulled and roasted baobab seed meal, respectively, compared to the control, with the highest values of 7.5 and 12% dietary treatments. However, our results are contrary to those of Saulawa *et al.*[20] who increased the incorporation rate and noted a significant decrease in ALW when broilers were fed starter diets containing 0, 5, 10, 15 and 20% of baobab seed meal. In contrast, Mwale *et al.*[25] also reported a significant decrease in ADG in guinea fowl fed rations containing 0-15% of baobab seed meal in Zimbabwe, compared to the control and 5% dietary treatment and Oladunjoye *et al.*[26] observed a decrease in ADG in rabbits fed diets containing these same levels of baobab seed meal, particularly at 15%. These differences can be explained by the age of animal, type of seeds used or animal species (chicken, guinea fowl, rabbit). Indeed, Saulawa *et al.*[20] used young subjects (chicks) and offered them diets containing the same levels of raw (untreated) versus roasted baobab seeds, while in the current study the broilers were 2 and 4 weeks older for growth and finishing trials respectively and fed with baobab seed cake. However, we recorded the similar ALW and ADG at 6 weeks of

Table 4: Growth parameters of broilers fed during the finishing and growing phases with diets containing 0 (AD_0), 5 (AD_5), 10 (AD_{10}) and 15% (AD_{15}) of african baobab (*Adansonia digitata*) seed cake in Dakar region, Senegal

Trial period or phases	Zootechnical parameters	Age (week)	Experimental dietary treatments				SEM	p-values
			AD_0	AD_5	AD_{10}	AD_{15}		
Finishing phase trial (November-December, 2014)	Average live weight, ALW (g)	4th	1072.40±33.8	1061.70±17.0	1060.70±22.1	1049.40±12.9	6.14	0.60
		5th	1491.70±36.0	1443.80±32.15	1459.40±58.4	1453.30±20.1	11.07	0.50
		6th	1910.20±65.7	1881.70±28.99	1877.90±43.6	1866.40±3.9	11.43	0.60
		7th	2387.30±58.2	2367.80±12.9	2368.30±37.2	2330.50±82.2	14.70	0.60
	Average daily weight gain, ADG (g day^{-1})	5th	59.90±2.35	54.59±4.59	56.95±6.54	57.70±4.44	1.29	0.60
		6th	59.78±5.95	62.55±0.5	59.78±2.52	59.01±2.88	0.96	0.60
		7th	68.14±1.23	69.43±3.28	69.69±1.56	65.38±9.83	1.40	0.70
		5-7th	62.61±2.58	62.19±0.38	62.12±1.39	60.45±2.56	0.54	0.60
	Daily feed intake, DFI (g day^{-1})	5th	159.57±1.91	159.87±5.10	161.93±3.4	161.87±7.7	1.28	0.80
		6th	162.50±2.34[a]	162.51±1.74[a]	161.23±1.98[a]	167.94±3.09[b]	0.97	0.03
		7th	141.25±1.04	140.94±1.05	140.66±0.14	140 .78±0.46	0.20	0.80
		5-7th	154.44±1.11	154.44±1.05	154.60±1.07	156.86±1.92	0.45	0.14
	Feed conversion ratio, FCR	5th	2.66±0.13	2 .93±0.17	2.86±0.31	2.81±0.19	0.06	0.50
		6th	2.74±0.33	2.59±0.02	2.69±0.09	2.84±0.08	0.05	0.40
		7th	2.07±0.05	2.03±0.07	2.01±0.04	2.18±0.33	0.05	0.60
		5-7th	2.46±0.12	2.48±0.02	2.48±0.05	2.59±0.08	0.03	0.20
Growing phase trial (February-March, 2015)	Average live weight, ALW (g)	2nd	312.33±11.9	326.33±11.0	331.33±14.84	312.00±15.9	4.21	0.27
		3rd	635.33±27.5[b]	650.00±27.6[b]	641.33±15.5[b]	587.33±15.5[a]	9.17	0.04
		4th	1215.00±24.4	1235.30±6.0	1245.70±27.2	1188.00±29.1	8.81	0.07
		6th	1827.00±36.7	1820.00±60.4	1807.00±16.1	1791.30±22.7	10.18	0.69
	Average daily weigt gain, ADG (g day^{-1})	3rd	45.67±4.04	45.66±5.13	43.67±0.57	39.00±1.0	1.16	0.11
		4th	82.33±0.57	83.00±3.0	85.67±4.51	85.33±4.04	0.94	0.56
		3-4th	64.00±2.0	64.33±1.15	65.00±2.0	62.00±2.64	0.60	0.36
		5-6th	43.33±1.15	41.33±4.04	39.67±0.57	42.66±1.52	0.70	0.27
	Daily feed intake, DFI (g day^{-1})	3rd	26.00±1.0	27.33±4.72	30.66±7.23	34.66±2.88	1.51	0.17
		4th	99.33±2.88	94.67±2.31	101.66±3.51	95.67±5.68	1.27	0.17
		3-4th	62.33±5.05	60.67±1.52	66.00±10.39	65.00±2.64	1.52	0.65
	Feed conversion ratio, FCR	3rd	0.57±0.06	0.61±0.16	0.71±0.16	0.89±0.11	0.08	0.44
		4th	1.20±0.04	1.14±0.07	1.18±0.09	1.11±0.02	0.03	0.97
		3-4th	0.98±0.05	0.94±0.04	1.02±0.16	1.04±0.06	0.15	0.08

Table 5: Carcass characteristics and economic results in broilers fed during finishing and growing phases with diets containing 0 (AD_0), 5 (AD_5), 10 (AD_{10}) and 15% (AD_{15}) of african baobab (*Adansonia digitata*) seed cake in Dakar region, Senegal.

		Experimental dietary treatments					
Trial period or phases	Parameters studied	AD_0	AD_5	AD_{10}	AD_{15}	SEM	p-values
Finishing phase trial (November-December, 2014)	**Carcass and organ at 7 weeks old**						
	Carcass weight, CW (g)	2046.6±49.9	2073.0±11.3	2041.5±32.1	2049.7±71.8	12.30	0.785
	Dressing carcass, DC (%)	85.73±2.48	87.55±1.04	86.20±2.00	87.39±0.75	0.39	0.296
	Liver weight (g)	41.6±5.6	49.0±10.7	45.2±4.8	44.8±5.8	1.58	0.484
	Gizzard weight (g)	61.0±5.15	62±6.20	53.6±5.37	56.2±7.36	1.48	0.136
	Heart weight (g)	8.8±1.48	9.4±1.82	8.4±0.84	9.8±0.84	0.30	0.274
	Spleen weight (g)	2.8±0.84	2.6±0.55	2.5±1.34	2.4±0.89	0.19	0.892
	Dressing organs, DO (%)	5.38±0.85	5.10±0.96	4.70±0.69	4.74±0.62	0.18	0.500
	Economical parameters						
	Prices of diets used (FCFA kg^{-1})	227	233	239	241	1.65	-
	Feed cost (FCFA $bird^{-1}$)	14001±5^{a}	1420±5^{ab}	1442±6^{b}	1465±22^{c}	7.86	0.001
	Gross selling revenues (FCFA $carcass^{-1}$)	3479±85	3524±19	3471±55	3462±122	20.91	0.785
	Gross margin feed, GMF (FCFA $bird^{-1}$)	2079±90	2104±15	2028±60	1997±103	22.35	0.356
	GMF (FCFA/kg carcass)	1015±19^{b}	1015±20^{b}	993±14^{ab}	980±17^{a}	5.75	0.046
Growing phase trial (February-March, 2015)	**Carcass and organ at 6 weeks old**						
	Carcass weight, CW (g)	1611.0±32.10^{ab}	1673.10±55.41^{b}	1599.37±14.31^{a}	1569.3±11.41^{a}	14.10	0.034
	Dressing carcass, DC (%)	88.94±0.32^{c}	91.88±0.92^{d}	88.47±0.55^{bc}	87.57±26^{a}	4.87	0.003
	Liver weight (g)	51.8±8.94	51.2±8.86	50.3±7.75	51.5±7.24	1.25	0.98
	Gizzard weight (g)	34.5±5.82	43.2±9.24	37.8±7.30	37.5±5.0	1.18	0.06
	Heart weight (g)	11.0±1.13^{b}	9.7±1.16^{ab}	9.3±1.76^{a}	10.6±1.50^{ab}	0.25	0.048
	Spleen weight (g)	3.2±0.92	3.0±0.66	2.9±1.10	3.3±0.48	0.13	0.069
	Dressing organs, DO (%)	5.52±0.17^{a}	5.94±0.12^{b}	5.53±0.15^{a}	5.68±0.04^{a}	0.06	0.014
	Economical parameters						
	Prices of diets used (FCFA kg^{-1})	260	264	263	268	0.86	-
	Feed cost (FCFA $bird^{-1}$)	929±11	927±6	946±38	946±10	5.77	0.554
	Gross selling revenues (FCFA $carcass^{-1}$)	2739±55^{ab}	2844±95^{b}	2719±24^{a}	2668±34^{a}	24.10	0.034
	Gross margin feed, GMF (FCFA $bird^{-1}$)	1809±53^{ab}	1916±100^{b}	1772±57^{a}	1721±44^{a}	27.15	0.038
	GMF (FCFA kg^{-1} carcass)	1122±12	1145±22	1108±28	1097±14	7.33	0.078

age, which are in line with those reported by Ayssiwede *et al.*[47] who substituted up to 100% maize with sorghum in broilers diet but still much higher (1587-1803 g bird^{-1}, 24-42 g day^{-1} and 49-51 g day^{-1}) than those reported by Ayssiwede *et al.*[8] and Zotomy[45] who incorporated up to 15% rosella (*Hibiscus sabdariffa*) seed meal and sesame (*Sesamum indicum*) cake in the diet of broilers strain in Senegal.

In the current study, daily feed intake (DFI) and feed conversion ratio (FCR) recorded in finishing phase (154-157 g per day and 2.46-2.59) was significantly higher than those recorded in growing phase (60-65 g per day and 0.94-1.04). This could be due to the difference in age of chickens used. Younger birds naturally consume less than adults and the FCR deteriorates with the age of birds. The similarity between DFI and FCR of chickens was noted in different finishing and growing dietary treatments. This result is in agreement with a previous study conducted by Bale *et al.*[21] in Nigeria who showed that incorporation (0-30%) of baobab seed meal in the diet had no negative effect on DFI and FCR of the birds which increased non-significantly ($p>0.05$) with the increasing of incorporation rate, although their FCR were higher (2.73-3.21 in finishing and 1.96-2.14 in growing) than those recorded in the present study. In Nigeria, Oladunjoye *et al.*[26] also reported similar DFIs between dietary treatments in rabbits fed rations containing these same rates (0-15%) of baobab seed meal. Furthermore, Adeosun *et al.*[19] and Sola-Ojo *et al.*[22], compared to the control, have recorded a significant increase in DFI and FCR in broilers fed diets containing 2.5-7.5% and 4-12% of hulled and roasted baobab seed meal respectively. According to Booth and Wickens[48], African baobab seeds or seed cake has a good aroma that improved feed intake and a slight increase in DFI was noted in broilers fed AD_{10} and AD_{15} diets in both the finishing and growing phases. However, these observations are contrary to those of Chimvuramahwe *et al.*[24] in Zimbabwe who had recorded after 2 weeks of age, a significant and proportional decrease in DFI in chickens fed diets containing baobab seed cake (5-15%) compared to control subjects until the end of the trial at 9 weeks of age. Saulawa *et al.*[20] reported that broilers fed diets containing 0, 5, 10, 15 and 20% baobab seed meal, in the starter phase, showed a significant decrease in DFI and FCR but only in subjects fed with 15 and 20% baobab seed diets compared to the control. Similar results were reported by Magonka *et al.*[27] in Tanzania who observed a significant decrease in DFI in growing pigs fed diets containing 5 and 10% baobab seed cake. But these decreases in DFI and FCR observed in previous studies contradict with the results of the present study, this contradiction could be due to the energy level of their rations or by the type of baobab seed cake or seeds used which could contain more residual anti-nutritional factors. This DFI reduction was due to the increase in the diet's energy content with the inclusion of a fatter baobab cake, which generally decreases the feed intake of monogastric animals[46], whereas here our experimental diets were all iso-energetic. Baobab seeds contain anti-nutritional factors (oxalates, phytates, nitrates, alkaloids, tannins and cyanogenetic heterosides) which, when found in high levels in the diet, reduce animal performance, including protein digestibility, taste, DFI and FCR[17,18,36,40]. Heat treatment processes (boiling, industrial extraction of oil by hot continuous high pressure, roasting) reduce the anti-nutritional factors but do not completely eliminate them[16,18], in the previous studies[16,24,27], there may be more residual amounts of these compounds in the seeds and meal than those used in the present study. However, FCR recorded in the present study clearly showed that our chickens got more value from their diets than those recorded in the previous studies, for these baobab seed cake incorporation rates.

The higher carcass weights of broilers in finishing compared to the growing phase can be explained by the age at slaughter of birds, respectively 49 vs. 42 days. Dressing carcass at the end of the finishing phase in broilers were similar to those (85-88%) reported by Ayssiwede *et al.*[8] and Zotomy[45] in Senegal but lower than those (87-90%) reported by Sola-Ojo *et al.*[22] who recorded similar values in growing phase. In growing phase, a significant decrease was observed in carcass weights and dressing carcass in AD_{15} treatment, this result is consistent with a previous study conducted by Saulawa *et al.*[20] who reported a significant decrease ($p<0,05$) in these parameters from 15% incorporation rate after feeding broilers, in starter phase, with diets containing 0-20% baobab seed meal. The liver and gizzard weights in different finishing and growing dietary treatments were similar, however, this result contradict with the observations of Saulawa *et al.*[20] where the weights of these organs were significantly increased compared to the control. According to these authors, these high weights were the result of an increase in gizzard muscle activity caused by a greater presence of crude fiber in the diet and baobab seed incorporation and the detoxification activity of the liver to neutralize anti-nutritional factors contained in these seeds used in the diets. Based on the results of the current study, baobab seed cake incorporated up to 15% in finishing and growing diets caused no mortality or adverse effects on organ weights or dressings (liver and spleen in particular) in chickens. Overall, organs were developed proportionally to the live body weights of the chickens in different dietary treatments. Results of the present study are in agreement with the findings of Alli *et al.*[23] who

reported that the baobab seed cake incorporation at the same rate (0-15%) in the ration of growing guinea fowl had no adverse effect on the biochemical parameters values (total protein, albumin, creatinine, uric acid, bilirubin, ALAT, ASAT, GOT, GTP) and hematological parameters (hemoglobin, red blood cells, leukocytes, neutrophils, lymphocytes, mononuclear cells, eosinophilic and basophilic cells), which remained similar to the specific normal values in poultry, showing good health status of these birds. However, According to Sola-Ojo *et al.*[49], for these same parameters in chickens, the incorporation rate of baobab seed meal should not exceed 5% of the diet to ensure good health status.

Feed prices and feed costs increased with an increase in baobab seed cake incorporation, this result contradicts with the findings of Adeosun *et al.*[19] and Bale *et al.*[21] in Nigeria and Chimvuramahwe *et al.*[24] in Zimbabwe in broilers and Magonka *et al.*[27] in Tanzania in pigs, who recorded a decrease in these costs. This difference can be explained by taking into account the prices of baobab seed cake and oil incorporated into the diet with the increase in the rate of the cake to balance the energy level, as the oil is relatively more expensive. The similar or even significantly higher gross margins feed recorded for broilers in AD_0 and AD_5 compared to the other dietary treatments (AD_{10} and AD_{15}) can be explained by the fact that these first treatments allowed for relatively lower feed costs. Although the overall gross margins feed per kg carcass recorded across dietary treatments were similar for both finishing (except for AD_{15}) and growing trials, only the profit margin for AD_5 remained higher or equal to that of the control AD_0. However, Adeosun *et al.*[19] observed that this feed profit margin increased significantly when roasted baobab seed meal was incorporated in the diet of these chickens in Nigeria. These observations are in line with those of Chimvuramahwe *et al.*[24] who incorporated these same rates of baobab seed meal in broiler diet and recorded similar but slightly higher gross margins feed for AD_5 and AD_{10} treatments, in contrast, Magonka *et al.*[27] and Saulawa *et al.*[20] had noted a decrease in profit margins with incorporation rate. From these results, it is clear that baobab (*A. digitata*) seed cake can be incorporated up to 15% in both finishing and grower feed for broilers without any negative effect on their zootechnical performance and profitability.

CONCLUSION

The incorporation of baobab seed cake up to 15% in the broilers diets during both finishing (5-7 weeks) and growing (3-4 weeks old) phases, had no significant ($p>0.05$) adverse effect on their live body weights, average daily gains, daily feed intake and feed conversion ratios which remained almost similar to those of the control birds. Also, carcass and organ weights and their dressings in broilers remained similar between dietary treatments, except for AD_5 in growing phase for which they were significantly improved compared to AD_0, AD_{10} and AD_{15} treatments. Baobab seed cake incorporation in both finishing and growing diets, allowed to achieve overall similar gross margins feed per kg carcass between dietary treatments, except for AD_{15} in finishing phase which remained significantly lower. It can be incorporated up to 15% in the finishing and growing diets for broilers without negatively impacting their zootechnical performance or even profitability of breeding activity. Using baobab seed cake in the ration therefore appears to be an alternative way of improving poultry feeding in Senegal and even in sub-Saharan Africa. However, for a rational use of this local feed resource in poultry or animal feed, it would be desirable that other trials should be carried out to evaluate the optimum level of its incorporation in the diet and its effects on growth performance of broilers during their starter phase or during a relatively longer period including the entire rearing cycle in these birds.

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