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# Research Article

# Growth and Economic Performance of Broilers Fed at the Starter Phase with Diets Containing African Baobab (*Adansonia digitata*, L.) Seed Cake in Dakar Region, Senegal

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## Abstract

**Objective:** The purpose of this study was to evaluate the effect of African baobab (*Adansonia digitata*) seed cake on the growth and economic performance of broiler chickens when added to their starter diet. **Materials and Methods:** This study was conducted from February to March 2017 at the EISMV farm located in Sangalkam (Dakar region), a total of 300 day-old unsexed chicks of the Cobb500 strain were randomly divided into 4 batches of 75 subjects (with 3 replicates of 25 subjects). Four dietary treatments ($ADC_0$, $ADC_3$, $ADC_6$ and $ADC_9$) were formulated such that baobab seed cake was included at 0, 3, 6 and 9% dietary levels respectively. For the first two weeks of the trial (starter phase), chicks were fed experimental diets. After that, they were fed commercial diets until the end of the trial at six weeks. The obtained data (live weight, average daily gain, feed intake, feed conversion ratio, carcass weight and dressing and economic margins) were analyzed using one-way ANOVA. Differences among means were tested using Duncan multiple range test with the help of IBM-SPSS-v.23 software. Differences of $p<0.05$ were considered statistically significant. **Results:** A starter ration containing 3% ($ADC_3$) baobab seed cake significantly improved live weight, average daily gain, daily feed intake and feed conversion ratio of the birds compared to control ($ADC_0$), whereas $ADC_6$ and $ADC_9$ deteriorated at start-up and even for the rest of the trial (except feed conversion ratio) including carcass weights, dressings and profit margins. **Conclusion:** Baobab seed cake can be included in the diet of broiler chicks up to 9% without adverse effects on their health or mortality. But the incorporation of 3% baobab seed cake in the starter diet was alone the adequate level to optimize growth performance and profitability in broiler farming.

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

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Competing Interest: The authors have declared that no competing interest exists.

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

## INTRODUCTION

As in the other parts of sub-Saharan Africa, poultry farming in Senegal has grown significantly in recent decades and plays an undeniable role in reducing poverty and combating food insecurity. There are 17% of livestock GDP generated by this sector, making it the most dynamic subsector of the primary sector from an economic point of view and is an effective way to create employment opportunities for young people in this country[1-4]. However, it still faces a various of constraints, of which feed (generally based on imported feed resources at prices heavily dependent on the international market) is the biggest issue, moreover, the price of conventional local raw materials constantly on the rise and feed costs reach 70-80% of production costs[5,6]. In order to improve the productivity and profitability of livestock farming in the current context of detouring some livestock feed resources to biofuel production, researchers need to increasingly focus on the rational and increasing use of alternative or unconventional local resources in animal feed[7-9].

In this regard, the African baobab (*Adansonia digitata* L.), a robust, giant plant of the Bombacaceae family, is a prominent alternative resource and grows densely throughout Senegal. Besides its pulp, commonly known as "monkey bread", which is widely used to make local juice and its leaves are consumed by animal and human, its seeds are still little exploited[10,11], except for their oil, which is used for cosmetics by some industrial companies such as Baobab Fruit Company of Senegal (BFCS), which regularly generates huge tons of baobab seed cake. This 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 or with low level of toxic or anti-nutritional factors such as phytates, oxalates, tannins, saponins[12-17]. The baobab seeds as cake have even been used as protein substitutes at relatively high levels (2.5-30%) in poultry and fish[18-25], in pigs and rabbits[26,27] and in ruminants[13,16,28] with relatively satisfactory zootechnical results that varied according to the level of incorporation, the treatment process applied and animal species. In Senegal, Ayssiwede *et al.*[12] have also shown that baobab seed cake can be incorporated up to 15% in both finishing and grower diets for broilers, without adversely affecting their growth performance and profitability. The aim of this study was to evaluate the effects of incorporating baobab seed cake at different rates in starter diets on growth performance and profit margins of broiler chickens in Senegal.

## MATERIALS AND METHODS

**Proximate analyses, formulation and manufacturing of experimental diets:** Maize, Groundnut and baobab (*Adansonia digitata*) seed cakes, fish meal, groundnut oil, oyster shell meal, phosphate, synthetic amino acids and a mineral and vitamin supplement (MVS-0.25%) were the main ingredients used. The baobab seed cake was purchased from a baobab seed oil production company (BFCS) located in Thiès region and the other ingredients were obtained from a poultry feed company (AVISEN) in Dakar, groundnut oil was obtained from the market. 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 and groundnut cakes, fish meal and experimental rations were analyzed at the Laboratory of feed analyses and animal nutrition (LANA) of EISMV-Dakar. Samples were chemically analyzed for dry matter (DM), crude ash or mineral matter (MM), crude protein (CP), fat or ether extract (EE), crude fiber (CF) and some mineral elements, particularly Calcium and Phosphorus.

The DM content was determined according to the standard method of the French Association for Standardization, AFNOR[29], while crude ash content was obtained according to AFNOR[30]. Crude protein content was determined using the same standard based on the Kjeldahl method - Nx6.25[31], while EE content was obtained using the reflux extraction method with ethyl ether using the Soxhlet apparatus as described by AFNOR[32]. Crude fiber content was determined based on Wende's method according to AFNOR[33]. Phosphorus content was determined basing on absorption spectrophotometric method at 430 nm as described by AFNOR[34] while calcium content was measured using the flame atomic absorption spectrophotometric method of AFNOR[35]. The Metabolizable energy (ME) was calculated using the following regression equation described by Sibbald and cited by Leclercq *et al.*[36], i.e.:

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

Thus, based on the results of the proximate analyses of baobab and groundnut cakes, fish meal and other feed resources reported by Ayssiwede *et al.*[37], four experimental starter diets ($ADC_0$, $ADC_3$, $ADC_6$ and $ADC_9$) were formulated and produced for broiler chicks. As a partial replacement for groundnut cake, these starter diets containing respectively 0, 3, 6 and 9% baobab seed cake were iso-protein (≈235 g CP $kg^{-1}$) and iso-calorific (≈2900 kcal ME $kg^{-1}$).

Table 1: Feed resources composition and calculated nutrient values of starter experimental diets used containing 0 ($ADC_0$), 3 ($ADC_3$), 6 ($ADC_6$) and 9% ($ADC_9$) of baobab (*Adansonia digitata)* seed cake in broilers in Dakar Region, Senegal

| | | Starter experimental dietary treatments | | | |
|---|---|---|---|---|---|
| Ingredients or feed resources used | Price (FCFA* $kg^{-1}$) | $ADC_0$ | $ADC_3$ | $ADC_6$ | $ADC_9$ |
| Maize | 160 | 55.54 | 53.63 | 51.46 | 49.54 |
| Groundnut oil | 1100 | 1.00 | 1.00 | 1.30 | 1.40 |
| Baobab (*A. digitata*) seed cake | 200 | 0.00 | 3.00 | 6.00 | 9.00 |
| Groundnut cake | 185 | 31.22 | 30.07 | 29.10 | 27.82 |
| Fish meal | 550 | 10.00 | 10.00 | 10.00 | 10.00 |
| L-lysine (99%) | 2400 | 0.30 | 0.30 | 0.30 | 0.35 |
| DL-methionine (99%) | 3600 | 0.16 | 0.20 | 0.15 | 0.20 |
| Oyster shell meal | 80 | 1.53 | 1.40 | 1.44 | 1.44 |
| Tricalcium phosphate | 110 | 0.00 | 0.15 | 0.00 | 0.00 |
| Broilers MVS-0.25% | 2200 | 0.25 | 0.25 | 0.25 | 0.25 |
| Total (kg) | | 100.00 | 100.00 | 100.00 | 100.00 |
| **Calculated nutrient values** | | | | | |
| Dry matter, DM (%) | | 90.36 | 90.41 | 90.47 | 90.53 |
| Crude protein, CP (%) | | 23.50 | 23.50 | 23.50 | 23.50 |
| Ether extract, EE (%) | | 5.18 | 5.23 | 5.58 | 5.73 |
| Crude fiber, CF (%) | | 3.35 | 3.86 | 4.38 | 4.88 |
| Crude ash (%) | | 8.97 | 8.83 | 8.87 | 8.85 |
| Metabolizable energy, ME (kcal $kg^{-1}$) | | 2966.00 | 2936.00 | 2925.00 | 2902.00 |
| Calcium, Ca (%) | | 1.05 | 1.03 | 1.00 | 1.00 |
| Phosphorus, P (%) | | 0.73 | 0.77 | 0.76 | 0.77 |

*FCFA: local money of french community of Africa (1€ = 655.957 FCFA)

To produce each of these experimental diets, the different raw materials were mixed manually after weighing, starting with small quantities (MVS, lysine, methionine, oyster shell meal and tricalcium phosphate) to obtain a premix. To this end, baobab seed cake was first ground in a mill to reduce its large particles to smaller or medium ones, before being included in the diets. To the premix, the relatively medium to large ingredients (baobab seed cake, oil, fish meal, groundnut cake, maize) were then added to obtain a homogenous floury diet after complete mixing. The diets produced were packaged and stored in adapted bags for their use during the experimental periods. The ingredient composition of these different starter experimental diets is shown in Table 1.

**Animals and experimental design:** Experiment was conducted at the EISMV farm located at 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 in Research and Training of EISMV-Dakar. The trial was undertaken during the period from March to April 2017 in a semi-open building with a double-sloped roof made of aluminum sheeting. Two weeks before trial starting, the building and rearing equipment (feeders, drinkers and wire frames used to make up chicks' batches) were cleaned, disinfected and sanitized with soapy water and bleach. One week before chick's arrival, poultry house, wire frames and all rearing equipment were washed and disinfected with a virucidal solution (VIRUNET-10%), with the house and wire frames brushed with a layer of quicklime. On the eve of chicks' arrival, the brooding area was set up and delimited and partitioned into 4 groups by the wire frames and covered with a thick layer (about 3 cm) of wood shavings litter. Two radiant heaters of 1400 kW suspended about one meter from the ground were used to heat the living area to an ideal temperature (31-33°C), measured by two thermometers specially installed. Lighting in the building was permanent throughout the trial and was provided by natural light during the day, completed by night lighting with solar lamps. In addition to the footbath filled with cresyl solution installed at the entrance of poultry house to ensure compliance with sanitary prophylaxis, a scale and data collection sheets were also placed in the coop building.

The trial involved 300 one-day-old chicks of $Cobb_{500}$ strain purchased from the local EMAAP hatchery. After weighing, they were randomly divided into four batches of 75 chicks of similar live body weight, each subdivided into 3 sub-batches or repetitions of 25 according to a density of 25 chicks $m^{-2}$ including feeder and waterer space. On receipt, the chicks were checked for number, live weight, vivacity, homogeneity, umbilical condition, legs and liveliness, before being placed in the brooding house. Each batch of chicks was fed with one of the four experimental starter diets ($ADC_0$, $ADC_3$, $ADC_6$ and $ADC_9$) for two weeks (14 days), corresponding to the start-up

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) +HB1[ND] (beak dipping) |
| $d_{2-4,\ 10-13}$ | Administration of stress prevention drugs | Neoxyvital[ND] (oral tract in drinking water) |
| $d_9$ | 1st vaccination against Gumboro disease | AVIB-IBD Inter (oral tract, drinking water) |
| $d_{15-17,\ 26-28}$ | Administration against Avian coccidiosis | ANTICOX (oral tract in drinking water) |
| $d_{21}$ | 2nd vaccination against Newcastle disease | HB1[ND] (beak dipping) |
| $d_{24}$ | 2nd vaccination against Gumboro disease | AVIB-IBD Inter (oral tract, drinking water) |
| $d_{22-25,\ 29-35}$ | Administration of stress prevention drugs | Amin total[ND] (oral tract, drinking water) |
| $d_{34}$ | Administration against intestinal parasites | Citrate-Piperazine ( oral tract in drinking) |

phase of broilers. 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 growth (3rd week of age) to finishing phase (6 weeks of age), the brooding house was expanded in line with the required density standards (15-10 birds $m^{-2}$), with batches and repetitions of birds maintained as defined at start-up. From the 15th to the 19th day of age, a linear feed transition was carried out, gradually reducing the experimental starter diet usually served in favor of a new commercial grower diet. After this transition, the broilers were fed respectively in the growth phase (15-28 days of age) with a commercial growth diet, then in the finishing phase (29-42 days of age) with a commercial finishing diet, both were presented in pelleted form. Drinking tap water and feed were provided *ad libitum* to birds. During the starter phase, experimental diet was served 3-4 times per day to broilers compared to 2-3 times per day for commercial feed during growth and finishing phases. Throughout their life cycle, the birds used in these 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 monitored and measured with the thermometers 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, while the measurement of FI and mortalities were carried out on daily basis until the end of the trial (42 days of age).

At the end of the trial, 12% of the chickens (i.e., 36 birds at a rate of 9 birds/dietary treatment) of a similar weight to the average for the sub-group, were randomly selected and slaughtered by severing the jugular vein of the neck in order to assess carcass and organ characteristics of the birds between treatments. After plucking with hot water and evisceration, during which the crop and intestine were removed, the carcasses of headless chickens containing some organs (liver, gizzard, spleen) and detached organs were individually weighed. All data collected per dietary treatment were recorded in a Microsoft Excel spreadsheet, which was used to calculate zootechnical parameters including average live weight (ALW), average daily gain (ADG), average daily feed intake (DFI), feed conversion ratio (FCR), mortality rate (MR), carcass weight (CW) and dressings carcass (DC) and organ (DO) according to the following formulas.

$$\text{ALW (g bird}^{-1}) = \frac{\text{Sum of live weights of birds per group (g)}}{\text{Number of birds in the group}} \quad (2)$$

$$\text{ADG (g/day)} = \frac{\text{Live weight gain of the period (g)}}{\text{Length of the period (days)}} \quad (3)$$

$$\text{DFI (g bird}^{-1}\text{/day)} = \frac{\text{Quantity of feed offered - Quantity of feed refused/day}}{\text{Number of birds}} \quad (4)$$

$$\text{FCR} = \frac{\text{Feed intake during a period (g)}}{\text{Weight gain of the period (g)}} \quad (5)$$

$$\text{MR (\%)} = \frac{\text{Initial number of birds - Final number of birds}}{\text{Initial number of birds}} \times 100 \quad (6)$$

$$\text{DC (\%)} = \frac{\text{Carcass weight of the bird}}{\text{Live body weight of the bird}} \times 100 \quad (7)$$

$$\text{DO (\%)} = \frac{\text{Total organ weight in bird}}{\text{Live body weight of the bird}} \times 100 \quad (8)$$

These technical results were used to determine the gross margins (GM) generated per dietary treatment based on an economic evaluation made from feed costs and incomes from the sale of slaughtered chicken carcasses (1700 FCFA $kg^{-1}$

carcass) at the end of the trial. Feed costs were calculated on the basis of the chickens' overall feed consumption and the cost prices of experimental starter feed and commercial feed used in growth and finishing phases. Thus, all the economic parameters studied were calculated per dietary treatment in a similar way, according to the following formulas 9-13.

$$\text{Feed cost/bird (FCFA)} = \text{FCR} \times \text{Feed price kg}^{-1} \times \text{LW gain (kg) during starter phase} + \text{Commercial diets cost} \quad (9)$$

$$\text{Feed cost kg}^{-1}\text{ carcass (FCFA)} = \frac{\text{Feed Cost/bird}}{\text{Carcass weight of bird (kg)}} \quad (10)$$

$$\text{Gross selling revenue (GSR)/bird (FCFA)} = \text{Carcass weight of bird (kg)} \times \text{Selling price kg}^{-1}\text{ carcass} \quad (11)$$

$$\text{Gross margins feed (GMF)/bird (FCFA)} = \text{Gross selling revenue/bird carcass} - \text{Feed cost/bird} \quad (12)$$

$$\text{Gross margins feed (GMF) kg}^{-1}\text{ carcass (FCFA)} = \text{Selling price kg}^{-1}\text{ carcass} - \text{Feed Cost kg}^{-1}\text{ carcass} \quad (13)$$

**Statistical analysis:** Zootechnical and economic 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 $p<0.05$ between dietary treatments were considered statistically significant.

## RESULTS

**Nutrient composition of baobab seed cake and experimental diets used and ambient temperature during trial:** Table 3 shows that baobab (*Adansonia digitata*) seed cake is a relatively rich feed resource in terms of crude fiber- CF (21.15%), crude protein - CP (22.75%), lipid or ether extract-EE (6.47%) and even metabolizable energy-ME (1901 kcal kg$^{-1}$). As for the starter experimental diets, they are globally iso-protein (22-23%) and iso-energetic (3388-3415 kcal kg$^{-1}$) with relatively similar [ME/CP] ratios (≈15), even if the control diet ($ADC_0$) seems to have a slightly higher CP content, than those of the other rations. Throughout the trial, average ambient temperatures varied from 24.8- 30°C, with peaks generally observed in the middle of the day, while lower temperatures values were recorded in the morning (24.8°C) and evening (27°C).

**Mortality, growth performance, carcass characteristics and economic results of broilers fed baobab seed cake based diets in starter phase:** The incorporation of baobab seed cake into starter diets did not adversely affects birds' health. During the two weeks of trial, no case of disease was recorded in broilers when they were fed with starter diets containing various levels of this baobab seed cake. One death was recorded for $ADC_3$ and $ADC_9$ treatments, (≈0.88% mortality rate for all baobab seed cake-based diets), no mortality was recorded in birds fed the control (AD0) diet. Also, autopsies of these 2 died birds during this phase revealed no pathognomonic lesions of disease. However, at the end of the 6-weeks rearing period, an overall mortality rate of 2.22% was obtained, with 0, 2.67, 1.33 and 2.67%, respectively for $ADC_0$, $ADC_3$, $ADC_6$ and $ADC_9$ dietary treatments.

Table 4 shows zootechnical parameters such as average live body weights (ALW), average daily weight gains (ADG), daily feed intake (DFI) and feed conversion ratios (FCR), carcass and organs (liver, gizzard, heart, spleen) weights, dressing carcass and organ as well as economic results obtained in broilers at the end of the trial per dietary treatment. It appears from the latter that the incorporation of baobab seed cake into the starter diet significantly improved ($p<0.05$) ALW, ADG and DFI of $ADC_3$ birds, while those of chickens fed $ADC_6$ and $ADC_9$ diet were significantly reduced compared with the control ($ADC_0$). The FCR during the starter phase was also significantly improved in birds fed $ADC_3$ ration (1.94), in

Table 3: Nutrient composition of baobab (*Adansonia digitata*) seed cake and starter experimental diets used containing 0 ($ADC_0$), 3 ($ADC_3$), 6 ($ADC_6$) and 9% ($ADC_9$) baobab seed cake for broilers in Dakar Region, Senegal

| Nutrient contents determined | Baobab seed cake used | Starter experimental dietary treatments $ADC_0$ | $ADC_3$ | $ADC_6$ | $ADC_9$ |
|---|---|---|---|---|---|
| Dry matter, DM (%) | 91.95 | 92.65 | 92.54 | 92.21 | 92.92 |
| Crude protein, CP (%) | 22.75 | 23.00 | 22.27 | 22.19 | 22.87 |
| Ether Extract, EE (%) | 6.47 | 5.07 | 5.24 | 5.39 | 5.59 |
| Crude Fiber, CF (%) | 21.15 | 2.41 | 2.65 | 2.76 | 3.08 |
| Crude Ash (%) | 5.97 | 7.55 | 7.59 | 7.43 | 7.54 |
| Metabolizable energy, ME (kcal kg$^{-1}$)* | 1901.00 | 3415.00 | 3397.00 | 3388.00 | 3395.00 |
| Ratio [ME/CP] (kcal g$^{-1}$) | 8.36 | 14.85 | 15.25 | 15.27 | 14.84 |
| Calcium, Ca (%) | 0.06 | 1.03 | 0.98 | 0.97 | 0.98 |
| Phosphorus, P (%) | 0.72 | 0.69 | 0.71 | 0.69 | 0.68 |

(*): ME calculated values

Table 4: Growth parameters, carcass characteristics and economic results in broilers fed during the starter phase with diets containing 0 ($ADC_0$), 3 ($AD_3$), 6 ($ADC_6$) and 9% ($ADC_9$) of African baobab (*Adansonia digitata*) seed cake in Dakar Region, Senegal

| Zootechnical and economic parameters | Age (week) | Experimental dietary treatments $ADC_0$ | $ADC_3$ | $ADC_6$ | $ADC_9$ | SEM | p-values |
|---|---|---|---|---|---|---|---|
| Average live weight, ALW (g) | 1st | 115.4±17.1$^{c}$ | 124.1±19.5$^{d}$ | 110.1±14.2$^{b}$ | 101.9±12.0$^{a}$ | 1.037 | 0.000 |
| | 2nd | 265.5±52.2$^{c}$ | 312.0±55.5$^{d}$ | 226.7±37.0$^{b}$ | 204.1±30.8$^{a}$ | 3.535 | 0.000 |
| | 6th | 2218.3±292.5$^{b}$ | 2413.8±291.5$^{c}$ | 17792.0±322.6$^{a}$ | 1775.0±347.6$^{a}$ | 24.243 | 0.000 |
| Average daily weight gain, ADG (g/day) | 1st | 10.77±2.44$^{c}$ | 12.01±2.79$^{d}$ | 10.02±2.03$^{b}$ | 8.84±1.72$^{a}$ | 0.148 | 0.000 |
| | 2nd | 21.45±7.61$^{b}$ | 26.85±8.09$^{c}$ | 16.66±6.04$^{a}$ | 14.60±4.70$^{a}$ | 0.478 | 0.000 |
| | 1st-2nd | 16.11±3.73$^{c}$ | 19.43±3.97$^{d}$ | 13.34±2.65$^{b}$ | 11.72±2.20$^{a}$ | 0.252 | 0.000 |
| | 3-6th | 69.74±10.36$^{c}$ | 75.06±10.24$^{d}$ | 55.90±11.58$^{a}$ | 63.93±21.48$^{b}$ | 0.920 | 0.000 |
| Daily feed intake, DFI (g/day) | 1st | 19.30±0.02$^{c}$ | 19.46±0.00$^{d}$ | 18.96±0.01$^{b}$ | 17.54±0.13$^{a}$ | 0.044 | 0.000 |
| | 2nd | 46.93±0.81$^{b}$ | 49.70±0.47$^{d}$ | 47.43±0.93$^{c}$ | 46.50±0.89$^{a}$ | 0.072 | 0.000 |
| | 1st-2nd | 33.20±0.47$^{b}$ | 34.58±0.23$^{d}$ | 33.12±0.37$^{c}$ | 32.02±0.57$^{a}$ | 0.053 | 0.000 |
| | 3-6th | 125.82±0.77$^{c}$ | 128.60±0.43$^{d}$ | 93.18±0.97$^{b}$ | 90.19±1.10$^{a}$ | 1.039 | 0.000 |
| Feed conversion ratio, FCR | 1st | 1.90±0.48$^{ab}$ | 1.73±0.53$^{a}$ | 1.98±0.46$^{bc}$ | 2.08±0.54$^{c}$ | 0.030 | 0.000 |
| | 2nd | 2.60±1.41$^{a}$ | 2.15±1.20$^{a}$ | 3.54±2.56$^{b}$ | 3.63±1.54$^{b}$ | 0.108 | 0.001 |
| | 1st-2nd | 2.25±0.70$^{b}$ | 1.94±0.61$^{a}$ | 2.76±1.21$^{c}$ | 2.85±0.76$^{c}$ | 0.054 | 0.000 |
| | 3-6th | 2.54±0.97 | 2.34±0.87 | 2.62±0.98 | 2.57±1.14 | 0.058 | 0.349 |
| Carcass weight, CW (g) | 6th | 1909.6±262$^{b}$ | 2111.2±270$^{c}$ | 1550.1±288$^{a}$ | 1518.3±303$^{a}$ | 21.78 | 0.000 |
| Dressing carcass, DC (%) | 6th | 86.03±1.41$^{ab}$ | 87.39±1.51$^{c}$ | 86.44±1.71$^{b}$ | 85.52±2.50$^{a}$ | 0.113 | 0.000 |
| Prices of diets used (FCFA kg$^{-1}$) | | 243 | 245 | 247 | 251 | 0.173 | - |
| Feed cost (FCFA/bird) | | 998±12$^{ab}$ | 1005±13$^{c}$ | 1002±24$^{bc}$ | 994±8$^{a}$ | 0.937 | 0.001 |
| Feed cost (FCFA kg$^{-1}$ carcass) | | 533±78$^{b}$ | 485±66$^{a}$ | 672±143$^{c}$ | 684±150$^{c}$ | 8.367 | 0.000 |
| Gross selling revenues (FCFA/carcass) | | 3246±445$^{b}$ | 3589±459$^{c}$ | 2635±489$^{a}$ | 2581±515$^{a}$ | 37.03 | 0.000 |
| Gross margin feed, GMF (FCFA/bird) | | 2248±445$^{b}$ | 2584±459$^{c}$ | 1633±489$^{a}$ | 1587±515$^{a}$ | 36.92 | 0.000 |
| Gross margin feed, GMF (FCFA kg$^{-1}$ carcass) | | 1167±78$^{b}$ | 1216±66$^{c}$ | 1029±143$^{a}$ | 1016±150$^{a}$ | 8.367 | 0.000 |

$^{a,b,c,d}$Means with different superscript letters on the same line are significantly different at the 5%, SEM: Standard error mean, FCFA: Local money of french community of Africa (1€ = 655.957 FCFA)

contrast to those similar but significantly deteriorated ($p<0.05$) in birds fed $ADC_6$ (2.76) and $ADC_9$ (2.85) diets, compared to the control (2.25). It is noteworthy that these differences in ALW, ADG and DFI observed at start-up between dietary treatments were maintained, even though the birds were all fed the same commercial pelleted feed during the growing and finishing period (3-6 weeks of age) of the trial with the $ADC_3$ subjects leading followed by $ADC_0$, $ADC_6$ and $ADC_9$ except for ADG which was lower with $ADC_6$. However, during the same period, the FCRs recorded (2.34-2.62) in these birds were almost identical between dietary treatments. In addition, incorporation of baobab seed cake into the starter diet significantly improved carcass weight and dressing at the end of the trial in broilers fed $ADC_3$ treatment (2111 g and 87.4%), in contrast to those fed $ADC_6$ (1550 g and 86.4%) and $ADC_9$ (1518 g and 85.5%) compared with the control ($ADC_0$) birds, (1910 g and 86%).

Table 4 also shows that the price of starter diet increased by 2, 4 and 8 FCFA kg$^{-1}$ with the incorporation of baobab seed cake respectively for $ADC_3$, $ADC_6$ and $ADC_9$ compared with the control (243 FCFA kg$^{-1}$). Feed costs were similar and significantly higher for broilers fed $ADC_3$ (1005 FCFA) and $ADC_6$ (1002 FCFA/bird) than those of birds fed $ADC_0$ (998 FCFA) and $ADC_9$ (994 FCFA/bird). But only the $ADC_3$ dietary treatment achieved a significantly lower feed cost per kg carcass (485 FCFA) than the control (533 FCFA kg$^{-1}$), unlike $ADC_6$ (672 FCFA kg$^{-1}$) and $ADC_9$ (684 FCFA kg$^{-1}$) treatments, where these feed costs were significantly higher. As a result, broilers chicken in $ADC_3$ treatment have generated a significantly higher income or selling revenue (3589 FCFA/bird) and gross margin feed profit (1216 FCFA kg$^{-1}$ CW) than control birds (3246 and 1167 FCFA), which in turn were higher than those in $ADC_6$ (2635 and 1029 FCFA) and $ADC_9$ (2581 and 1016 FCFA) treatments. Clearly, the incorporation of baobab seed cake at 3% level in the starter diet is still recommended to optimize growth performance and profit margins in broiler chickens, even though 9% incorporation rate had no adverse effects on birds health.

## DISCUSSION

Apart from its low calcium content, the baobab seed cake used in this study, has a nutritional and energy values broadly similar to that reported by other authors[13,16,26,38]. Admittedly, these nutrient contents, compared with the average results reported by these authors, showed that this feed resource remains slightly lower in crude fiber (21.2% vs. 23.6%) but higher in crude protein (22.8% vs. 18.7%) and even in metabolizable energy (1901 vs. 1653 kcal $kg^{-1}$). Whatever the incorporation rate of baobab seed cake, the starter experimental diets used were overall iso-nutritional, with a relatively constant ratio [ME/CP ≈13-15] in line with the recommendations for feed intended for broiler chickens at start-up[39].

The average temperatures obtained (24.8-30°C) during the trial were similar to those (19.5-30.6°C) recorded by Ayssiwede *et al.*[12] in Senegal, Bale *et al.*[21] in Nigeria and Mwale *et al.*[25] in Zimbabwe but lower (28-35.5°C) than those reported by Ayssiwede *et al.*[7] in the same region. However, they remain higher (15-25°C) than those corresponding to the limits of the thermal comfort zone recommended during growth-finishing phases in broiler chickens, which could have a negative impact on bird performance as a result of heat stress[40]. These temperature differences observed between authors can be explained by the areas and periods of trial; ours was conducted from March to April, a cool period (November to April) in Senegal, with average temperatures between 22°C and 30°C in this study area.

Incorporation of baobab seed cake up to 9% in starter diet of broiler chickens had no adverse effects on birds' health. It was harmless, as demonstrated by the low mortality rate of chicks in baobab seed cake and control (0.88% vs. 0%) dietary treatments. This is in line with the findings of Chisoro *et al.*[14] who reported that the levels of anti-nutritional factors in baobab seeds or seed cake are enough clearly low to cause serious toxic effects on poultry health. The incorporation of baobab seed cake at 3% ($ADC_3$) led to a significant improvement in live weight, average daily gain (ADG), daily feed intake (DFI) and feed conversion ratio (FCR) in chickens compared with control ($ADC_0$) and those in $ADC_6$ and $ADC_9$ treatments, whereas, these parameters were significantly deteriorated at start-up and even over the rest of the trial. These observations are similar to those reported by Saulawa *et al.*[20] in broiler chicks in Nigeria, Mwale *et al.*[25] in guinea fowl and Oyetunji *et al.*[18] in fish, where live weight performance declined in parallel with increasing levels of baobab seeds or seed cake in the diet, except at the lowest levels. For the same parameters, Mwale *et al.*[25] obtained similar results in these birds at 5 and 10% baobab seed cake incorporation level, with feed intake (32-35 g $day^{-1}$) very similar to ours; whereas at 15 and 20% these performances were significantly deteriorated. In Senegal, Ayssiwede *et al.*[7] and Diaw *et al.*[41] had also reported the same effects in broilers fed diets containing 0-15% rosella (*Hibiscus sabdariffa*) seeds and glandless cotton beans respectively. However, our observations are contrary to those of Ayssiwede *et al.*[12] in Senegal, Chimvuramahwe *et al.*[24] in Zimbabwe and Bale *et al.*[21] in Nigeria, who noted no significant adverse effects on live weight, DFI and FCR of broilers fed diets containing 0-15% of baobab seed cake and 0-30% baobab seeds meal respectively.

Similar results were reported by Adeosun *et al.*[19] and Sola-Ojo *et al.*[22], who noted a significant improvement in these parameters in broilers fed diets containing hulled (2.5-7.5%) and roasted (4-12%) baobab seed meal respectively compared with the control. While the latter authors consider hulling and roasting to be the main factors, the former have justified their results by citing the richness in aromatic compounds of baobab seeds or meal[16,25,42], which would have favoured the ingestion of diets containing them and even the birds' performance. However, as dry heat treatment processes-roasting, industrial hot oil extraction using continuous high pressure - only slightly reduce anti-nutritional factors (tannins, oxalates, phytates, cyanogenetic heterosides, saponins) compared to wet heat treatment-boiling and soaking-boiling[15,17,43], these compounds could still be in residual quantities in the baobab seed cake used in these chicks' diets. The significant drop in ADG and DFI, accompanied by the FCR deterioration in chicks in $ADC_6$ and $ADC_9$ rations, could therefore be explained by the proportional increase in the levels of these anti-nutritional factors with baobab seed cake incorporation, which would have led to a drop in diet digestibility and efficient nutrient utilization[14,25,44]. The fact that the significant differences noted between starter dietary treatments for these parameters were maintained until the end of the trial, clearly shows that the delayed growth at start-up of chicks fed $ADC_6$ and $ADC_9$ rations could not be made up, even though during the growth-finishing period these birds were all fed the same commercial feed. The significant drop in carcass weights and dressings observed in $ADC_6$ and $ADC_9$ birds compared with the control ($ADC_0$), unlike those in $ADC_3$, is in line with the results of Ayssiwede *et al.*[12] and Saulawa *et al.*[20], who reported similar effects on these parameters in broilers fed growing diets containing 0-15% baobab seed cake and starter diets containing 0-20% baobab seed meal, from 10 and 15% incorporation respectively. Dressings carcass obtained in broilers in this study are similar to those (85-88%) reported by Ayssiwede *et al.*[7] but lower than those (87-90%) recorded by Ayssiwede *et al.*[12] in Senegal and Sola-Ojo *et al.*[22] in Nigeria for the same type of broiler chickens. The rise in feed costs noted with the increase of baobab seed cake incorporation rate is in line with the observations of Ayssiwede *et al.*[12] who fed broilers with diets containing up to 15% of the same cake during the finishing and grower phases in Senegal. However, this increase is contrary to the findings of Adeosun *et al.*[19] and Bale *et al.*[21] in Nigeria, Chimvuramahwe *et al.*[24] and Mwale *et al.*[25] in Zimbabwe for broilers and guinea fowl respectively and Magonka *et al.*[26] in Tanzania for pigs, who had recorded a reduction in these costs. This difference can be explained by taking into account the prices of baobab seed cake and oil incorporated into the ration to balance the energy level, with oil being more costly than baobab seed cake. The significantly higher gross profit was recorded for broilers in $ADC_3$ treatment compared with that of control birds ($ADC_0$), which was higher than that of $ADC_6$ and $ADC_9$ subjects and can be explained by the better performance of $ADC_3$ birds, which is the only one to enable significantly higher revenue and lower feed load per kg carcass weight. This confirms the observations of Sola-Ojo *et al.*[45] and Saulawa *et al.*[20] who recommended that, for good health and performances, incorporation rates of hulled and roasted or raw baobab seed meal or even seed cake should not be exceeded 5-10% in chick diets. These results are in agreement with those reported by Ayssiwede *et al.*[12] in Senegal in finishing and growing broilers and in Tanzania by Magonka *et al.*[26] in pigs, respectively by incorporating 0-15% and 5-10% of baobab seed cake in their diets. However, they are contrary to those of Adeosun *et al.*[19] and Saulawa *et al.*[20], who recorded a significantly increased margin feed profit with the incorporation of up to 12% roasted seed meal and a margin feed similar to the control at 10% raw baobab seed meal in the diet of these chickens in Nigeria.

## CONCLUSION

Incorporating up to 9% baobab seed cake into the starter diet of broilers had no adverse effects on bird's health or mortality. At 3% incorporation ($ADC_3$), it led to a significant improvement in live weight, average daily gain, feed intake, feed conversion ratio, carcass weight and dressing and economic results for the birds, compared with those in $ADC_0$ (control), $ADC_6$ and $ADC_9$, where these parameters deteriorated at start-up, or even throughout the trial. So, 3% remains the adequate rate of baobab seed cake incorporation in a starter diet to optimize production performance and profit margin in broiler chickens. Baobab seed cake therefore remains an alternative resource that can make a significant contribution to improve poultry and animal feed in Senegal and sub-Saharan Africa. Further trials should be conducted over a longer period of time to evaluate the optimum level of its incorporation in the diet to determine its impact on digestibility, zootechnical, biochemical and hematological parameters in broilers or laying hens.

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