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Effects of Cocoa Pod Shell Flour on the Zootechnical and Economic Performance of Broiler Chickens Undergoing Finishing Growth in Côte d'Ivoire

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ABSTRACT

Background: A study was conducted to evaluate the impact of incorporating cocoa pod shell flour into the feed of broiler chickens during the growth-finishing phase on their production performance.

Methods: Four feed treatments were formulated with incorporation rates of 0% (CC0); 5% (CC5); 10% (CC10); and 15% (CC15) cocoa pod shell meal and these were then compared with a commercial feed as a control. Three hundred broiler chicks of the 'Cobb 500' strain, aged 21 days and with an average weight of 450±47 g, were divided into 15 experimental units. The assignment of each feeding treatment to three experimental units was completely random.

Result: Following a 28-day rearing period, the statistical analysis revealed that the weights of the chickens fed with the treatments CC0 (2302.14 g) and CC5 (2280.53 g) were significantly different ($p<0.05$) from those of the others, TC (1727.96 g), CC10 (2032.86 g) and CC15 (1653.16 g). In a similar vein, the consumption indices of treatments CC0 (2.02) and CC5 (2.20) were found to be statistically identical and lower than those of the other treatments, TC(2.63), CC10 (2.49) and CC15 (3.02). From an economic perspective, the production cost of the feeds decreased in proportion to the increase in rates of pod shells, from 332 FCFA/kg for the TC feed to 242.96 FCFA/kg for the CC15 feed. Regarding the production costs per kilogram of live weight, those of the CCO and CC5 treatments are statistically identical (613 and 658 FCFA, respectively) but lower than those of the other three treatments TC, CC10 and CC15 (871, 737 and 732 FCFA, respectively).

Key words: Broiler chicken, Carcass, Cobb 500, Cocoa pods, Cote d'Ivoire, Live weight.

INTRODUCTION

Broiler breeding is a short-cycle method of breeding that produces high-quality protein within six weeks. In Côte d'Ivoire, intensifying livestock production is essential to guarantee self-sufficiency in animal protein and ensure food security for the population (Ducroquet *et al.*, 2017). However, the development of the sector is hindered by the high cost of producing chickens, primarily due to the expense of feed, which accounts for 60-70% of total costs in poultry farming. This high cost is linked to the high corn content of rations, with almost 70% being used as the main energy source (Salami and Odunsi, 2003; Teguia *et al.,* 2004; Ukachukwu, 2005). In addition, maize is in high demand for human consumption, creating competition. Price fluctuations are linked to availability, which varies according to location and season.

In order to reduce the cost of food production, an increasing number of farmers are turning to alternative products (Kreman, 2011; Kana *et al.,* 2015). With an average annual production of 1.4 million tonnes of cocoa beans, Côte d'Ivoire is the world's leading cocoa producer (FIRCA, 2018). According this author, the shells represent around 70% of the whole pod, *i.e.* almost 3,200,000 tonnes of dry matter per year and are currently not recycled. Obtained after the bean has been extracted, the husks represent a significant amount of agricultural waste left in the fields after harvesting (Jagoret *et al.,* 2020). Despite their high cellulose and theobromine content (Assiri *et al.*, 2009), they could be economically valorized after drying or ensilage in livestock feed and thus increase the income of cocoa producers in production zones (Kouadio and Kreman, 2016). Valorizing this by-product is necessary to limit competition for food with humans (Kouadio *et al.,* 2022).

It is in this context that this study was carried out. Its aim is to promote the use of cocoa pod shell flour in the feed of chickens raised for meat production.

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MATERIALS AND METHODS

Preparation of cocoa pod shell flour and feed formulation

The trial was carried out at the site of livestock production program of the National Centre for Agricultural Research (CNRA), in Bouaké between July and September 2020. Cocoa pod shells were collected at the Divo research station after shelling process. These were then packaged and transported to Bouaké, where they were dried on a cement surface for ten days. The shells were then ground in a mill. The resulting flour was then incorporated into the various experimental feeds at increasing rates. Feed formulation involved combining several raw materials to meet animal requirements based on the average needs of broilers selected in the growth phase, using the trial-and-error method (Fouquet, 2017). Four iso-protein and iso-energy feeds (CC0, CC5, CC10 and CC15) were therefore formulated with different incorporation rates using the Excel 2017 spreadsheet. A commercial control feed was also added to these feeds (Table 1).

Feed production

After formulation, the various feeds were manufactured. The mixtures were prepared by hand. First, the bulky ingredients (maize, wheat bran, cottonseed meal, soybean meal, fish meal and cocoa pod hull meal) were mixed together. Then, the minor ingredients (salt, shellfish, methionine, lysine, red oil and CMV) were added and the mixture was then blended. Flour was then introduced into the feed at increasing rates: 0%, 5%, 10% and 15%. A commercial control feed was added to these experimental feeds.

Experimental set-up

Three hundred (300) 21-day-old "Cobb 500" broiler chicks, weighing an average of 450±47 g, were divided into 15 batches of 20 homogeneous subjects. In a completely randomised design, three batches of twenty chicks were randomly assigned to each feed treatment. The chicks were reared on rice husk bedding at a density of 10 per m^2 for 28 days. Feed was weighed before distribution and water was provided ad libitum. All animals benefited from the same prophylaxis program.

Data collection and calculation of zootechnical variables

Feed intake was determined by weighing the feed distributed by weekly weighing of leftovers. Animals were weighed individually every 7 days, fasting at the same time,

Table 1: Centesimal composition of foods containing cocoa pod shell flour.

Ingredients	Feeds composition				
	TC	CC0%	CC5%	CC10%	CC15%
Corn	-	60	54	48	42
Cocoa pod shells	-	0	6	12	18
Wheat bran	-	6.75	4.45	2.05	0
Cotton cake	-	8	8	8	8
Soya cake (49)	-	14	15	16.5	17.4
Fish meal (58)	-	7	7.5	7.5	7.85
Shellfish	-	1	1	1	1
Lysine	-	0.12	0.12	0.12	0.12
Methionine	-	0.08	0.08	0.08	0.08
Premix 2%*	-	0.25	0.25	0.25	0.25
Palm oil	-	2.5	3.3	4.2	5
Iodized salt	-	0.3	0.3	0.3	0.3
Total	100	100	100	100	100
		Calculated chemical composition and food production cost			
Protein (%)	19,86	21.19	21.20	21.15	21.07
Metabolisable energy (kcal/kg.MS)	2920	3105.95	3103.12	3104.86	3100.00
ME/CP ratio	153,68	146.60	146.36	146.80	147.13
Fat (%)	7,6	6.05	6.55	7.11	7.61
Calcium (%)	0,6	0.80	1.20	1.56	1.94
Phosphorus (%)	0,35	0.52	0.54	0.54	0.55
Price /kg (FCFA)	332	303.34	299.12	295.93	242.96

TC: Commercial control feed; CC0: Feed containing 0% cocoa pod shells; CC5: Feed containing 5% cocoa pod shells; CC10: Feed containing 10% cocoa pod shells; CC15: Food containing 15% cocoa pod shells; ME: Metabolizable energy; CP: Crude proteins; DM: Dry matter.

*Premix 2%: Vitamine A: 425 000 UI/kg; Vitamine D3:106 300 UI/kg; Vitamine E: 730 UI/kg; Vitamine B1: 70 mg/kg ; Vitamine K3: 90 mg/kg; Cuivre (sulfate): 500 mg/kg; Fer (carbonate): 1300 mg/kg; Manganèse (oxyde): 4000 mg/kg; Zinc (oxyde) 2950 mg/kg; Salinomycine sodium: 3000 mg/kg.

using an electronic scale with a 5 kg capacity and 1 g accuracy. Mortalities were also recorded daily.

These data were used to calculate the various zootechnical variables. Average daily gain (ADG), feed consumption (FC) and consumption index (FC) were calculated using the expressions below:

$$ADG = \frac{\text{Weight gain over a period (g)}}{\text{Period duration}}$$

FC =
Quantity of feed distributed - Quantity of feed not consumed

$$CI = \frac{\text{Quantity of food consumed over a period (g)}}{\text{Weight gain during the period}}$$

After 28 days of rearing, 12 chickens per batch (6 males and 6 females, *i.e.* 36 chickens per treatment) were randomly selected and subjected to a 24-hour diet, then weighed, bled, plucked and eviscerated, as recommended by Jourdain, (1980). The relative weight of each organ (gizzard, liver, heart and pancreas) was calculated in relation to live weight. Gut length was measured from the duodenal loupe to the cloaca using a tape measure and gut density (gut weight/gut length) was calculated (Kana *et al.,* 2015).

Evaluation of economic feed parameters

For economic production calculations, only the cost of the feed was considered, with all other costs remaining unchanged. The price of ingredients on the Bouaké market at the time of the study was used to value the feed. Production costs per kilogram of live chicken weight were calculated by multiplying the feed cost per kilogram by the consumption index.

Statistical analysis of the data

Data from the chicken by-product evaluation were entered into Excel 2017© and analysed using one-factor ANOVA in STATISTICA 7.1. The Student Newman-Keuls test was used to separate means at a threshold of 5% for significant differences.

RESULTS AND DISCUSSION

Zootechnical performance of growing and finishing chickens

At the end of the 28-day trial, the recorded weights were 1,724.96±184.58 g, 2,302.14±228.72 g, 2,280.53±204.01 g, 2,032.86±219.45 g and 1,653.15±192.89 g for treatments TC, CC0, CC5, CC10 and CC15, respectively (Table 2). Statistical analysis shows that the final weights of animals in treatments CC0 and CC5 are identical and higher than those in treatments TC, CC10 and CC15 ($p<0.05$). Conversely, the weights of the TC and CC15 treatments were identical but lower than those of the CC10 treatment. This phenomenon can be attributed to the fact that, following an incorporation rate of 5%, an increase in lignin concentration would exert a detrimental effect on nutrient digestibility. The inclusion of crude cellulose in the diet has been demonstrated to exert a detrimental influence on the digestibility of other nutrients, thereby compromising their bioavailability. Furthermore, the addition of crude cellulose has been shown to expedite the passage of digestate through the digestive tract. This result is analogous to that of Meffeja *et al.* (2006), who, in their study, incorporated cocoa pod shells into pig feed and observed a decline in animal growth exceeding 10% incorporation. Similar observations were also reported by Mahanta *et al.* (2017), who used plant-based growth promoters on the performance of commercial broilers. As shown in Table 3, the highest weight gains were obtained with treatments CC0 and CC5, which were statistically different from the other treatments. The corresponding feed conversion ratios ranged from 2.02 to 3.02. The highest feed conversion ratios were obtained with feed CC15 (3.02 ±0.14). The best indices were obtained with treatments CC0 (2.02±0.02), CC5 (2.20±0.04) and CC10 (2.49±0.16). This result is different from that of Malsawmthangi *et al.* (2015), according to which there were no significant differences ($P>0.05$) among the different treatment groups in regards to feed conversion efficiency and average daily gain on the use of a diet based on sweet potato flour (*Ipomoea batatas*) on the growth performance of growing indigenous pigs.

Carcass characteristics

Summary data on carcass characteristics are presented in Table 4. Carcass yields ranged from 77.79±1.90% (CC0) to 71.63±1.08% (CC15). Statistical analysis revealed no significant difference at the 5% threshold between the carcass yields of animals fed CC0, CC5 and CC10. However, these carcass yields differed significantly from

Table 2: Broiler weights at standard age by treatment (g).

	21 days	28 days	35 days	42 days	49 days
TC	449.76±4.32	644.53±104.38	906.39±146.38	1279.27±172.13	1724.96±184.58[a]
CC0	444.73±3.28	887.88±84.57	1335.82±117.85	1853.37±169.78	2302.14±236.84[c]
CC5	466.22±4.13	844.31±82.76	1290.63±112.82	1838.37±229.02	2280.53±209.87[c]
CC10	448.37±3.96	739.24±73.25	1111.98±94.92	1604.42±149.88	2032.86±218.69[b]
CC15	446.67±3.23	663.04±54.84	984.65±92.69	1345.69±134.98	1653.16±201.34[a]

In the same column, means indexed by the same letter are not statistically different at the 5% threshold according to the Newman-Keuls test.
TC: Commercial Control feed; CC0: Food containing 0% cocoa pod shells; CC5: Food containing 5% cocoa pod shells; CC10: Feed containing 10% cocoa pod shells; CC15: Food containing 15 % cocoa pod shells.

those of the CC15 and TC treatments. These results are different from those of Hou *et al.* (2020) which revealed that carcass characteristics showed no significant difference (p>0.05) on the parameters studied in pigs. Offal yields varied from 14.61±0.83% (CC0) to 17.28±1.38% (CC15). Statistical analysis revealed that the offal yields of the CC0, CC5 and CC10 treatments were homogeneous compared with the TC and CC15 treatments. CC15 feed produced leaner chickens, with a fat index of 0.52±0.05%, whereas the highest fat index was obtained with CC0 feed (2.09±0.60%). The fat index decreased with the inclusion of cocoa pod shells. However, statistical analysis did not reveal any significant differences between treatments TC, CC0, CC5 and CC10 at the 5% threshold, despite these treatments differing from CC15. This property can be attributed to the high crude cellulose content of cocoa pod shells. Extensive research has demonstrated that lignin, a natural component of cassava flour, may exert an effect on intestinal transit without compromising organ size. Those result are similar to those of Muzi *et al.* (2017) who conducted a study on the digestibility and productivity of slow-growing Venda indigenous chickens.

Table 5 shows the relative organ weights and gut density. As can be seen in this table, the inclusion of cocoa pod meal in the feed did not affect the relative weights of the liver and heart or the density of the intestine. However, the relative weight of the gizzard was statistically lower in treatments CC0 and CC5 than in treatments TC, CC10 and CC15, which were statistically identical. This observation appears to contradict the results of the study conducted by Mafouo-Ngandjou *et al.* (2011), which suggested that the relative weight of these same organs increased in the presence of cassava flour in the feed.

The relative weight of the pancreas was lower for the CC0 treatment than for the CC10 and CC15 treatments. Conversely, the weight of the CC5 treatment was comparable to that of the CC0 treatment, as well as the TC, CC10 and CC15 treatments.

The incorporation of cocoa pod shell flour into the diet has been demonstrated to exert a significant impact on the

Table 3: Weight gain (g) and feed conversion of chickens by treatment.

Treatment	Weight gain(g)	Consumption index
TC	1274.75±15.84[a]	2.63±0.12[b]
CC0	1811.04±84.82[c]	2.02±0.07[a]
CC5	1815.42±50.72[c]	2.20±0.04[a]
CC10	1602.80±25.23[b]	2.49±0.20[b]
CC15	1261.77±66.73[a]	3.02±0.17[c]

In the same column, means indexed by the same letter are not statistically different at the 5% threshold according to the Newman-Keuls test.

TC: Commercial Control feed; CC0: Food containing 0% cocoa pod shells; CC5: Food containing 5% cocoa pod shells; CC10: Feed containing 10% cocoa pod shells; CC15: Food containing 15% cocoa pod shells.

Table 4: Characteristics of chicken carcasses according to feed treatment.

Feed	Bled and plucked weight (g)	Carcass yield (%)	Offal yield (%)	Fat index (%)
TC	1569.08±52.18[a]	72.98±2.13[a]	17.35±0.96[b]	1.69±0.58[b]
CC0	2173.25±20.32[c]	77.79±.57[b]	14.61±0.83[a]	2.09±0.65[b]
CC5	2092.67±26.68[c]	75.67±1.37[b]	15.52±0.54[ab]	2.08±0.58[b]
CC10	1833.92±16.73[b]	74.11±1.48[b]	16.06±1.09[ab]	1.53±0.46[b]
CC15	1504.67±19.71[a]	71.63±1.30[a]	17.28±1.38[b]	0.51±0.49[a]

In the same column, means indexed by the same letter are not statistically different at the 5% threshold according to the Newman-Keuls test.

TC: Commercial Control feed; CC0: Food containing 0% cocoa pod shells; CC5: Food containing 5% cocoa pod shells; CC10: Feed containing 10% cocoa pod shells; CC15: Food containing 15% cocoa pod shells.

Table 5: Relative organ weights and intestinal density of chickens as a function of feed treatments.

Organ	TC	CC0	CC5	CC10	CC15
PW liver (%)	1.73±0.28[a]	1.62±0.36[a]	1.69±0.26[a]	1.74±0.20[a]	1.79±0.18[a]
PW gizzard (%)	2.59±0.39[b]	1.83±0.27[a]	2.06±0.22[a]	2.48±0.27[b]	2.88±0.28[b]
PW heart (%)	0.53±0.16[a]	0.45±0.06[a]	0.44±0.08[a]	0.49±0.10[a]	0.44±0.09[a]
PW pancreas (%)	0.27±0.05[b]	0.21±0.06[a]	0.25±0.05[ab]	0.30±0.06[b]	0.30±0.08[b]
PW intestine (%)	2.36±0.27[b]	1.83±0.27[a]	2.17±0.21[b]	2.42±0.26[b]	2.69±0.24[c]
Intestine density	4.86±0.61[b]	4.08±0.60[a]	4.33±0.63[ab]	4.42±0.53[ab]	4.62±0.43[ab]

On the same line, means indexed by the same letter are not statistically different at the 5% threshold according to the Newman-Keuls test.

PW: Relative weight; TC: Commercial Control feed; CC0: Feed containing 0% cocoa pod shells; CC5: Food containing 5% cocoa pod shells; CC10: Feed containing 10% cocoa pod shells; CC15 : Food containing 15% cocoa pod shells.

Table 6: Economic parameters of production by treatment.

Treatments	Production cost per kg of feed (FCFA)	Feed consumption (g)	Production cost per kg live weight (FCFA)
TC	332	3348.47±184.01[a]	871.86±39.54[c]
CC0	303.34	3657.61±124.36[b]	613.11±22.06[a]
CC5	299.12	3997.18±73.15[c]	658.78±12.92[a]
CC10	295.93	3992.54±288.81[c]	737.42±57.80[b]
CC15	242.96	3798.20±65.44[b]	732.77±41.61[b]

In the same column, means indexed by the same letter are not statistically different at the 5% threshold according to the Newman-Keuls test.

TC: Commercial control feed; CC0: Food containing 0% cocoa pod shells; CC5: Food containing 5% cocoa pod shells; CC10: Feed containing 10% cocoa pod shells; CC15: Food containing 15% cocoa pod shells.

relative dimensions of the intestine, resulting in an augmentation of its weight and length. This property can be attributed to the high crude cellulose content of cocoa pod shells. As posited by Aderemi and Nworgu, (2007), elevated levels of cellulose in monogastric animals have been demonstrated to stimulate the growth and thickening of the walls of the digestive tract.

Economic performance

The economic data from this study are presented in Table 6. For the commercial control feed, the purchase price of a 50 kg bag of feed was taken into account. The respective costs were 332 FCFA, 303.34 FCFA, 299.12 FCFA, 295.93 FCFA and 242.96 FCFA for TC, CC0, CC5, CC10 and CC15 feeds. TC feed is the most expensive, followed by formulated feeds. This downward trend can be attributed to the relatively low cost of cocoa pod shell flour in comparison to other ingredients The results obtained in this study are consistent with those of the research team led by Abasse *et al.* (2017). The latter conducted an experiment involving the introduction of Moringa leaves into the feed of broiler chickens. Formulated feeds show a downward trend with increasing levels of pod shells in the feed. Feed consumption was 3,348.47±184.01 g, 3,657.61±124.36 g, 3,997.18±73.15 g, 3,992.54±288.81 g and 3,798.20±65.44 g, respectively, for the TC, CC0, CC5, CC10 and CC15 treatments. Statistical analysis shows that the CC5 and CC10 treatments are identical. Feed consumption for these treatments was statistically higher than for the other treatments (TC, CC0 and CC15). In terms of production costs per kg of live weight, the lowest costs were found with CC0 (613.11±22.06 FCFA) and CC5 (658.78 ±12.92 FCFA). The highest production cost per kg of live weight was obtained with the TC feed (871.86±39.54 FCFA). The present findings are consistent with those reported by Ghaffari *et al.* (2007) and Anyanwu *et al.* (2008). These earlier studies documented an enhancement in feed conversion as the proportion of cassava meal in broiler feed increased.

CONCLUSION

The evaluation of the impact of incorporating cocoa pod shell meal into poultry feed on zootechnical performance and economic indicators has shown promise. The findings of the study demonstrate that at an inclusion rate of 5% in the growth-finishing phase, chicken production exhibits zootechnical performances that are comparable to those attained with a ration devoid of cocoa pod shell meal.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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