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Effects of Replacing Maize with *Dioscarea bulbifera* Flour on Growth Performance of Broiler Chickens

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Abstract

The present study was designed to evaluate *Dioscarea bulbifera* flour as potential feed ingredient in broilers diets. For this purpose, 256-day-old Cobb 500 broiler chicks, were divided into 4 groups replicated 4 times in a completely randomized design. A control ration (R0) containing maize as the main energy source was compared to three other rations in which 50%, 75% and 100% maize were substituted with *Dioscarea bulbifera* flour. The main results showed that, the increasing rate of *Dioscarea bulbifera* flour had no significant ($p > 0.05$) effect on the digestibility of feed components. Feed intake was higher with 50% and 75% *Dioscarea bulbifera* flour inclusion levels. As compared to the control ration, a significant ($p < 0.05$) drop in live weight and weight gain was recorded with 50% substitution while feed conversion ratio increased significantly with increasing level of *Dioscarea bulbifera* flour in the ration. *Dioscarea bulbifera* flour induced a linear and significant ($p < 0.05$) increase in the relative weight of the gizzard, liver and production cost. It was concluded that, substituting 50% maize with *Dioscarea bulbifera* flour could be a sustainable solution to palliate the growing inflation of maize as animal feed ingredient. However, the incorporation level of *Dioscarea bulbifera* as feed ingredient in substitution of maize must not exceed 50% at the risk of depreciating growth performance of broilers.

Keywords

Diocorea bulbifera, Growth Performance, Cost of Production, Broilers, Maize Substitute

1. Introduction

Poultry farming in tropical countries faces several constraints, the major one being the high cost of feed ingredients like maize [1]. Maize is a staple food for human and largely used in animal feed and in agri-food industry as well as for the production of biofuel in some countries leads to strong fluctuations in prices and availability [1] [2]. This situation has led to the intensive search for the alternative to cover the energy needs of animals, without affecting their production performance. Hence, the interest and possibilities of including *Dioscorea bulbifera* flour in the diet of broiler chickens.

Dioscorea bulbifera or black hoffe, also called "bulbiferous yam, or apple in the air", is nutritious [3] [4] and is useful for human health [5]. According to Bolaniran *et al.* [6], *Dioscorea bulbifera* is an important source of starch, protein, lipids, fiber and minerals (potassium, sodium, magnesium, copper, manganese, zinc and sulphur). Sanful and Engmann [7] qualified these tubers as raw materials used for the formulation of different food products. Olatoye and Arueya [8] reported that *Dioscorea bulbifera* has high agronomic yield, a condition that can boost the growth and socio-economic development of producers. According to Han *et al.* [9], *D. bulbifera* flour has satisfactory organoleptic characteristics.

However, this resource is not yet economically exploited and documents reporting its technological use for the development of food products are not available. *Dioscorea bulbifera* has not yet been studied as feed resources for animal. In the present study, maize was partially and totally replaced by *Dioscorea bulbifera* flour in broilers diets on the digestibility of feed components as well as broiler growth performance.

2. Materials and Methods

2.1. Study Site

The study was carried out at the Teaching and Research Farm (TRF) of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon. This farm is located at 05˚26' North latitude, 10˚26' East longitude and culminates at an average altitude of 1420 m. The prevailing climate is the Equatorial altitude type with an average annual rainfall varying between 1500 and 2000 mm and the average temperatures of 20˚C between July and August, and a maximum of 25˚C in February. The average relative humidity is 76.8%. The dry season lasts from mid-November to mid-March and the rainy season the rest of the year corresponding to the cultivation period.

2.2. *Dioscorea bulbifera* (Air Yam)

D. bulbifera was bought in local markets in the Western region of Cameroon. The tubers were cut, dried, crushed and incorporated in feed without any other particular treatment. Samples of *Dioscorea bulbifera* (**Photo 1**) were collected for proximate analysis as described by [10]. The result revealed that *Dioscorea*

Photo 1. *Dioscorea bulbifera*.

bulbifera tuber contain 70% water, 3.55% ash, 88.82% dry matter, 96.45% organic matter, 5.91% Crude Protein, 1.15% Fat and 8.17% Crude cellulose.

2.3. Birds and Prophylaxis

2.3.1. Birds

A total of 256-day-old Cobb 500 broiler chicks with average weight 39.74 ± 2.35 g were randomly assigned to 16 experimental units of 16 birds each (8 males and 8 females) and reared under the same conditions on litter made of white wood shavings at a density of 20 chicks/m^2 at the starter phase (1 - 21 days) and 10 chickens/m^2 at the finisher phase (22 - 49 days).

2.3.2. Prophylaxis

Birds were vaccinated against Newcastle disease (Hitchner B1®) and infectious bronchitis (H120®) on the 4th day with a booster dose on the 18th day. The vaccine against Gumboro disease (IBA Gumboro®) was administered on the 11th day. From the second week, the anticoccidial (Vetacox®) was administered three days a week in the drinking water. An anti-stress was administered to birds via drinking water for the first three days upon entry into the brooder and each time before and after vaccination, weighing and transfer of birds to the finisher house.

2.4. Experimental Rations and Experimental Design

At starter and finisher phases, a basal ration was formulated with maize as the main source of energy. From the latter, 3 other rations were respectively made by substituting maize with *Dioscorea bulbifera* flour at the level of 50%, 75% and 100%. Each of the 4 experimental rations was randomly assigned to 64 chicks divided in 4 replicates in a completely randomized design. Throughout the trial, birds were fed *ad libitum*. The composition of the experimental rations is summarized in **Table 1**.

2.5. Data Collecting and Studied Parameters

The previously weighed feed was served to the animals and at the end of each week the refusals from each experimental unit were weighed. The weekly feed

Table 1. Characteristics of the experimental diets.

Ingredients (%)	Starter phase				Finisher phase			
	0	50	75	100	0	50	75	100
Maize	57.0	28.5	14.25	0.00	66.0	33.0	16.5	00.0
Dioscorea bulbifera	0.00	28.5	42.75	57.0	0.00	33.0	49.5	66.0
Wheat bran	2.00	0.25	1.25	0.5	0.00	0.00	0.00	0.00
Cotton seed meal	5.00	6.75	4.5	5.25	5.00	3.25	2.25	2.00
Soybean meal 49	25.0	25.0	24.5	24.5	18.0	18.0	18.0	17
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	6.00
blood meal	0.00	0.00	1.75	1.75	0.00	1.75	2.75	3.00
Oyster shell	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Premix 5%*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total (kg)	100	100	100	100	100	100	100	100
Analyzed chemical characteristics								
Crude protein (%)	22.27	21.88	21.98	21.75	19.93	19.72	19.67	19.50
Calcium (%)	1.17	1.17	1.17	1.17	1.16	1.16	1.16	1.12
Phosphorous (%)	0.48	0.44	0.42	0.40	0.45	0.40	0.38	0.39
Lipids (%)	2.68	1.82	1.63	1.26	2.89	2.11	1.73	1.35
Calculated chemical characteristics								
ME (kcal/kg)	2938.8	2881.2	2888.3	2860.5	3000.6	2971.8	2958.9	2938.9
Energy/Protein	131.9	131.7	131.4	131.5	150.6	150.7	150.4	150.7
Calcium/Phosphorous	2.42	2.66	2.78	2.92	2.56	2.85	3.03	3.12
Lysine	1.48	1.42	1.47	1.44	1.27	1.28	1.30	1.29
Methionine	0.50	0.46	0.44	0.43	0.46	0.42	0.40	0.38
Lysine/Methionine	2.96	3.08	3.31	3.39	2.76	3.07	3.27	3.35

Premix 5%*: Crude protein = 40%, Lysine = 3.3%, Methionine = 2.40%, Calcium = 8%, Phosphorous = 2.05%, Metabolisable energy = 2078 Kcal/Kg.

intake of each experimental unit was calculated by doing the difference between the feed distributed during the week and the refusal collected at the end of the week. At the start of the trial and every 7 days thereafter, birds from each experimental unit were weighed individually. The weekly weight gain was obtained by doing the difference between two consecutive weekly live weight and the weekly feed conversion ratio was calculated by dividing the quantity of feed intake during the week by the weight gain of the same week. At 49 days old, 8 chickens per treatment (4 males and 4 females) were randomly selected and submitted to a 24-hour fasting, then weighed, sacrificed, plucked and eviscerated as proceeded by [2]. The relative weight of each organ (gizzard, liver, heart) in relation to the live weight was calculated. The length of the intestine was measured from the duodenal loop to the cloaca using a measuring tape and the density of the intestine (weight of the intestine/length of the intestine) was calculated.

2.6. Feed Digestibility

Each bird was housed in an individual cage and the experimental rations were assigned to each cage following a completely randomised design replicated 4 times. Feed was weighed before being served to the animals and after 3 days of adaptation, feed refusals and faeces were collected and weighed every day at 8:00 a.m. for 3 days. The faecal samples and feed were analysed for dry matter, organic matter, crude protein and crude cellulose contents according to the procedure described by [10]. The apparent digestive utilization coefficient (aDUC) of feed components was calculated using the following formula.

$$aDUC = (ingested - excreted)/ingested \times 100$$

2.7. Statistical Analysis

Data on feed intake, live weight, feed conversion ratio, digestibility of feed components and carcass characteristics were submitted to one-way analysis of variance (ANOVA). When there was a significant difference between treatments, Duncan's multiple range test at a 5% threshold was used to separate means [2]. SPSS 20.0 (Statistical Package of Social Sciences) software was used for the analyses.

3. Results

3.1. Effects of *D. bulbifera* Flour on Feed Components Digestibility

Table 2 summarizes the effects of *D. bulbifera* flour incorporation level on feed components digestibility. It showed that the increasing substitution of maize by *D. bulbifera* flour had no significant ($p > 0.05$) effect on the digestibility of feed components. However, a downward trend ($p > 0.05$) in dry matter and organic matter digestibility was noticed with increasing levels of *D. bulbifera* flour compared to the control ration.

3.2. Effects of Increasing Levels of *Dioscorea bulbifera* Flour on Growth Performance

Table 3 summarizes the effects of *Dioscorea bulbifera* flour on feed intake, live weight, weight gain and feed conversion ratio of broiler chickens. All the growth parameters were significantly ($p < 0.05$) affected by the increasing levels of *D. bulbifera* flour regardless of the study phase considered. Feed intake increase with 50% and 75% *D. bulbifera* in the ration giving a regression percentage of 82.9% ($R^2 = 0.829$) (Figure 1). A significant ($p < 0.05$) decrease in live weight and weight gain was recorded with 75 and 100% *D. bulbifera* flour at the finisher phase and throughout the entire trial period. Replacing 50% of maize with *D.*

Table 2. Effects of *D. bulbifera* flour incorporation levels as maize substitute on feed digestibility.

Parameters	Substitution rate%				P
	0	50	75	100	
Ingested DM	186.00 ± 22.65	188.33 ± 25.11	178.00 ± 12.72	168.33 ± 16.91	0.550
Excreted DM	89.67 ± 18.45	88.67 ± 10.21	98.67 ± 5.69	103.67 ± 22.29	0.696
aDUC DM	49.76 ± 1.47	50.16 ± 1.80	48.00 ± 1.63	47.99 ± 2.96	0.636
Ingested OM	167.55 ± 20.38	172.36 ± 22.52	163.33 ± 8.06	150.3 ± 08.18	0.433
Excreted OM	68.84 ± 15.05	69.21 ± 12.01	79.79 ± 10.54	83.44 ± 24.82	0.565
aDUC OM	58.24 ± 5.77	58.15 ± 3.63	54.03 ± 0.88	53.51 ± 1.63	0.680
Ingested CC	5.29 ± 0.64	5.43 ± 0.43	4.97 ± 0.34	5.19 ± 0.87	0.827
Excreted CC	4.28 ± 0.20	4.54 ± 0.76	4.50 ± 0.45	4.80 ± 0.63	0.724
aDUC CC	24.80 ± 0.25	23.02 ± 1.78	21.30 ± 0.21	21.90 ± 0.71	0.109
Ingested CP	31.38 ± 3.82	32.22 ± 4.21	30.08 ± 1.48	26.6 ± 01.45	0.196
Excreted CP	6.73 ± 1.56	6.54 ± 0.61	6.73 ± 0.61	6.03 ± 1.53	0.864
aDUC CP	77.99 ± 7.80	79.34 ± 4.28	77.51 ± 2.78	77.43 ± 5.43	0.969

DM = dry matter, OM = organic matter; CC = Crude cellulose; CP = Crude Protein; aDUC = apparent digestive utilization coefficient, P = Probability.

Table 3. Variation in growth performance of broiler chickens as affected by the rate of substitution of maize by *D. bulbifera* flour in the feed.

Period (Days)	Substitution rate %				P
	0	50	75	100	
	Feed intake (g)				
01 - 21	1064.44 ± 13.89	1109.91 ± 49.38	1121.16 ± 17.72	1089.32 ± 4.87	0.062
22 - 49	4336.13 ± 163.12[b]	4595.18 ± 107.64[a]	4712.50 ± 50.20[a]	4299.00 ± 54.74[b]	0.000
01 - 49	5400.57 ± 156.96[b]	5704.10 ± 63.57[a]	5833.65 ± 61.79[a]	5397.80 ± 51.29[b]	0.000
	Live weight (g)				
01 - 21	684.00 ± 44.59[a]	641.45 ± 24.64[a]	638.70 ± 22.90[a]	395.50 ± 73.28[b]	0.000
22 - 49	2603.18 ± 142.68[a]	2650.78 ± 50.01[a]	2427.08 ± 77.38[b]	1710.90 ± 16.62[c]	0.000
	Weight gain (g)				
01 - 21	646.58 ± 44.61[a]	603.98 ± 24,63[a]	601.28 ± 22.94[b]	358.05 ± 3.27[c]	0.000
22 - 49	1919.18 ± 165.18[a]	2009.35 ± 61.52[a]	1788.35 ± 86.45[a]	1315.40 ± 68.83[b]	0.000
01 - 49	2565.73 ± 142.63[a]	2613.35 ± 49.96[a]	2389.68 ± 77.38[b]	1673.48 ± 16.62[c]	0.000
	Feed conversion ratio				
01 - 21	1.65 ± 0.13[c]	1.85 ± 0.06[b]	1.85 ± 0.06[b]	3.17 ± 0.62[a]	0.000
22 - 49	2.28 ± 0.22[c]	2.30 ± 0.14[c]	2.65 ± 0.13[b]	3.25 ± 0.17[a]	0.000
01 - 49	2.13 ± 0.10[c]	2.18 ± 0.05[c]	2.45 ± 0.06[b]	3.25 ± 0.06[a]	0.000

a, b, c: means with the same letters on the same line are not significantly different (p > 0.05), P = Probability.

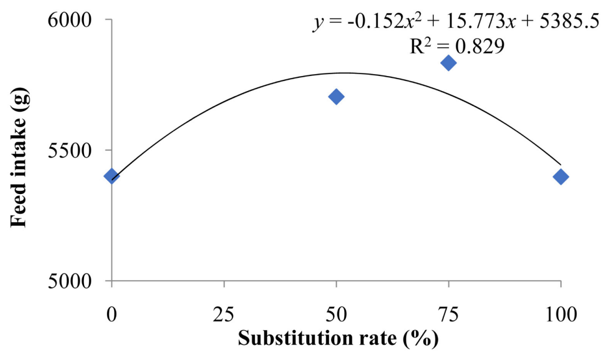

Figure 1. Regression curve of feed intake of broilers as affected by *D. bulbifera* flour inclusion level.

bulbifera induced the highest weight and weight gain meanwhile the drop in the weight of chickens was 98% ($R^2 = 0.984$) linked to the increasing level of *D. bulbifera* flour in the ration (**Figure 2**).

Rations containing 75% and 100% black *D. bulbifera* flour induced a significant ($p < 0.05$) increase in feed conversion ratio compared to all the other rations irrespective of the trial phase. It is observed in **Figure 3** that the increase in feed conversion ratio was strongly linked (98.5%) to the level of *D. bulbifera* flour in feed.

3.3. Effects of Inclusion Levels of *D. bulbifera* on Broiler's Carcass Characteristics

Table 4 summarizes the effects of increasing levels of *D. bulbifera* on carcass yield and relative organ's weight of broiler chickens. Analysis of variance revealed no significant ($p > 0.05$) difference between treatments means for the relative weight of head, legs and heart. Birds fed on ration without maize (100% substitution) recorded the lowest ($p < 0.05$) carcass yield and the highest ($p < 0.05$) relative liver weight compared to all the other rations. Meanwhile, abdominal fat decreased with increasing levels of *D. bulbifera* and was completely absent in birds fed on ration without maize. The variation in the inclusion level of *D. bulbifera* flour explains the increase in the relative weight of the liver by 99.7% ($R^2 = 0.997$) (**Figure 4**) unlike the drop in the abdominal fat by 97% ($R^2 = 0.977$) (**Figure 5**).

3.4. Effects of Incorporation Levels of *D. bulbifera* on Broiler's Digestive Organs

As summarized in **Table 5**, substituting maize with *D. bulbifera* flour had no significant ($p > 0.05$) effect on the intestine length, intestine weight, intestine density and relative weight of the pancreas. *D. bulbifera* induced a linear and significant ($p < 0.05$) increase in the relative weight of the gizzard compared to birds fed on the control ration. This increase in the relative weight of the gizzard was explained at 99.4% ($R^2 = 0.994$) by the increase in the level of substitution of maize with *D. bulbifera* flour (**Figure 6**).

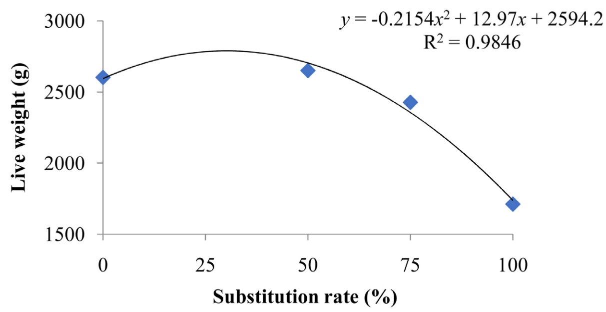

Figure 2. Live weight regression curve of broilers as affected by *D. bulbifera* flour inclusion level.

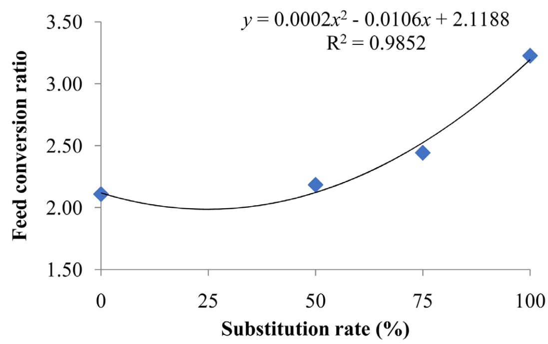

Figure 3. Regression curve of feed conversion ratio of broilers with respect to the incorporation level of *D. bulbifera* flour.

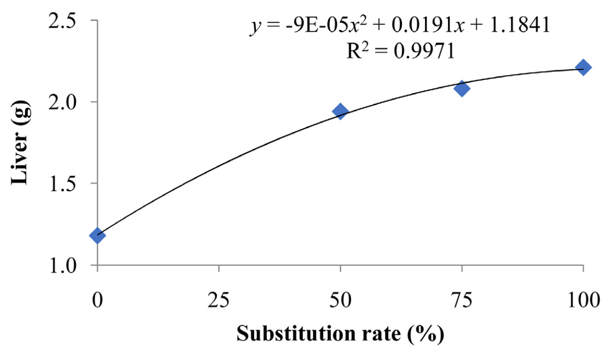

Figure 4. Regression curve of the relative liver weight of broilers on the substitution rate of maize by *D. bulbifera* flour.

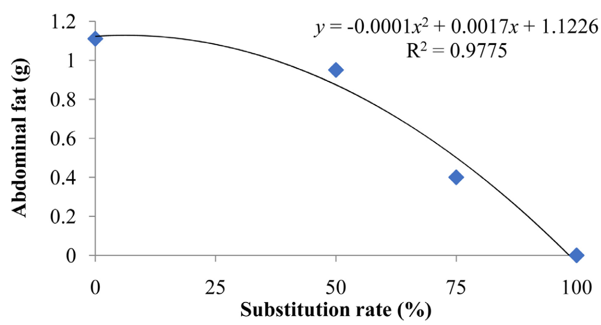

Figure 5. Regression curve of abdominal fat with respect to maize substitution rate by *D. bulbifera* flour.

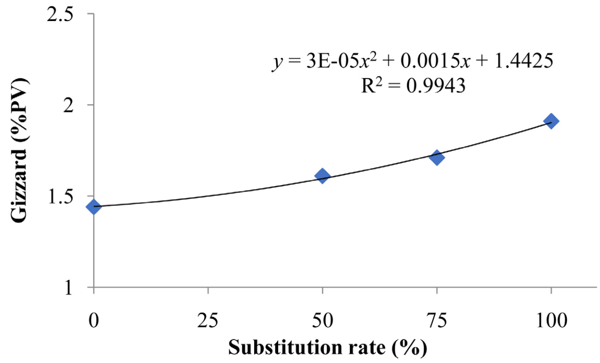

Figure 6. Regression curve of the relative weight of the gizzard with respect to the substitution rate of maize by *D. bulbifera* flour.

Table 4. Effects of substituting rate of maize by *D. bulbifera* flour on carcass characteristics of broiler chickens.

Parameters (% LW)	Substitution rate %				P
	0	50	75	100	
Carcass yield	73.66 ± 1.37[a]	74.43 ± 1.06[ab]	73.55 ± 0.83[b]	71.04 ± 1.50[c]	0.000
Head	2.20 ± 0.23	2.23 ± 0.22	2.38 ± 0.25	2.34 ± 0.22	0.371
Legs	3.59 ± 0.59	3.62 ± 0.36	3.84 ± 0.53	4.06 ± 0.43	0.193
Liver	1.88 ± 0.13[c]	1.94 ± 0.13[bc]	2.08 ± 0.12[ab]	2.21 ± 0.22[a]	0.001
Heart	0.48 ± 0.12	0.54 ± 0.09	0.53 ± 0.09	0.53 ± 0.09	0.588
Abdominal fat	1.11 ± 0.36[a]	0.95 ± 0.21[a]	0.40 ± 0.14[b]	0.00 ± 0.00[c]	0.000

a, b, c: means with the same letters on the same line are not significantly different (p > 0.05), P = Probability.

Table 5. Effects of increasing levels of *Dioscorea bulbifera* flour as maize substitute in feed on broiler's digestive organs.

Parameters	Substitution rate %				P
	0	50	75	100	
Pancreas (%LW)	0.34 ± 0.03	0.35 ± 0.05	0.35 ± 0.03	0.38 ± 0.02	0.299
Gizzard (%LW)	1.44 ± 0.23[b]	1.61 ± 0.16[ab]	1.71 ± 0.17[a]	1.91 ± 0.19[a]	0.000
Intestine length (cm)	220.00 ± 23.40	223.25 ± 19.15	219.13 ± 43.65	213.63 ± 26.73	0.932
Intestine weight (g)	103.00 ± 14.99	94.37 ± 11.26	106.50 ± 11.94	97.88 ± 18.57	0.437
Intestine density (g/cm)	0.48 ± 0.07	0.43 ± 0.05	0.50 ± 0.09	0.45 ± 0.09	0.272

a, b, c: means with the same letters on the same line are not significantly different (p > 0.05), P = Probability.

3.5. Effects of Increasing Levels of *Dioscorea bulbifera* on the Production Cost of Broilers

Whatever the study phase, the cost of production increased with the increasing level of *D. bulbifera* in the ration (Table 6). The highest costs were induced by the ration without maize regardless of the study phase, while the lowest costs were recorded with birds fed on control ration. The cost of feed intake and production of kilogram of live weight are closely linked ($R^2 = 0.9905$ and $R^2 = 0.993$) to the incorporation level of *D. bulbifera* in feed (Figure 7).

4. Discussion

This study revealed no significant ($p > 0.05$) effect on feed components digestibility although a downward trend was observed in dry and organic matter digestibility with increasing levels of *D. bulbifera* flour in feed compared to the control ration. This downward trend is suggested to be as a result of the increasing

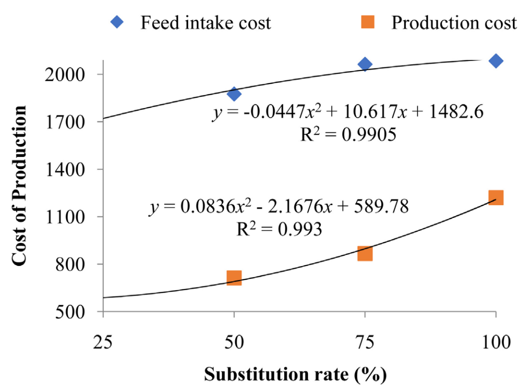

Figure 7. Regression curves of feed intake cost and production cost per kg of broiler with respect to inclusion level of *D. bulbifera* flour as maize substitute.

Table 6. Variation in broiler's production cost with respect to the period and inclusion level of *D. bulbifera* flour in feed.

Period (Days)	Substitution rate %				P
	0	50	75	100	
	Feed intake cost (Fcfa)				
01 - 21	300.68 ± 3.93[d]	358.17 ± 15.92[c]	393.48 ± 6.64[b]	408.08 ± 1.77[a]	0.000
22 - 49	1185.93 ± 44.60[c]	1516.43 ± 35.51[b]	1655.13 ± 21.10[a]	1690.60 ± 18.01[a]	0.000
01 - 49	1486.65 ± 42.84[c]	1874.60 ± 21.25[b]	2063.15 ± 19.79[a]	2084.08 ± 22.06[a]	0.000
	Production cost of Kg of body weight (Fcfa)				
01 - 21	466.93 ± 35.78[b]	593.40 ± 26.06[b]	654.95 ± 20.82[b]	1175.00 ± 231.80[a]	0.000
22 - 49	620.93 ± 50.95[d]	755.43 ± 35.08[c]	946.65 ± 36.92[b]	1260.78 ± 66.20[a]	0.000
01 - 49	586.15 ± 28.27[d]	712.98 ± 20.67[c]	866.75 ± 20.10[b]	1219.95 ± 16.56[a]	0.000

a, b, c: means with the same letters on the same line are not significantly different ($p > 0.05$, P = Probability.

level of cellulose in the ration. This assertion corroborates those of Yaakugh *et al.* [11] and Ndindana *et al.* [12] who reported that feed digestibility is inversely related to the crude fibber content. Feed intake increased with ration contain 50% and 75% *D. bulbifera* flour at the finisher phase and over the entire period of the trial compared to those fed on the control ration and ration without maize. This increase in feed intake could be explained by the low energy level of these rations which leads to the intake of a large quantity of feed to compensate the lack of energy. These results are similar to those obtained by Ukachukwu [13], where the increase in the level of cassava flour (root, stem and leaves) led to an increase in broilers feed intake. In the same line, Mebanga *et al.* [14] reported a significant increase in feed intake in broilers fed 30% and 45% dried artisanal brewer's grain compared to those in the control group. However, these results are different from those obtained by Mafouo *et al.* [15] who reported a decrease in feed intake with increasing levels of cassava flour in broiler's diet.

Above 50% substitution, live weight and weight gain decreased significantly with increasing levels of *D. bulbifera* in the ration. Birds fed on ration containing 50% maize and 50% *D. bulbifera* induced the highest live weight and weight gain. These results differ from the findings of Kouadio *et al.* [16] who recorded a decrease in broiler's weight when 30% cassava peelings were included in their ration. In present study, broilers fed 100% *D. bulbifera* flour recorded a significant decrease in live weight and weight gain compared to all other rations. This result corroborates those of Kana *et al.* [2], who obtained a decrease in live weight and weight gain with increasing levels of row potato in feed. This suggests that *D. bulbifera* flour, since it is richer in cellulose than maize, was less digested by birds. According to Esonu and Udedibie [17] and Chauynarong *et al.* [18], high crude fibre levels in the diet negatively affect digestibility and nutrient utilization by broilers.

Whatever the study phase, feed conversion ratio increased significantly and linearly with increasing levels of *D. bulbifera* in the ration compared to the control ration. This may be related to the viscosity of the feed which might be increases with high levels of *D. bulbifera* flour, which led to a decrease in feed digestibility. This result is in accordance with the work of Kouadio *et al.* [16] who reported an increase in feed conversion ratio with increasing levels of cassava peelings in the ration of broilers. In the same line, Kana *et al.* [19] reported a significant increase in feed conversion ratio with increasing levels of cassava fibber supplemented or not with spirulina in the ration. These results agree with those of Mafouo *et al.* [15] who reported an increase in feed conversion ratio with increasing levels of cassava flour in broiler's diet. Meanwhile, Mebanga *et al.* [14] recorded no significant effect on feed conversion ratio when broilers were fed on dried artisanal brewer's grains.

No significant difference was observed on the relative weights of the head, legs and heart of chickens with the increasing levels of *D. bulbifera* in feed. However, birds fed on diet without maize recorded the lowest carcass yield compared to the other rations. This result concords the findings of Awah-Ndukum *et al.* [20]

who, after substituting maize with cassava peel flour at increasing levels, recorded a linear decrease in carcass yield. The low carcass yield recorded in this study could be due to the low digestibility of carbohydrates present in *D. bulbifera*. Moreover, birds fed on the ration with *D. bulbifera* as the main and only source of energy recorded the highest relative weight of the liver. This result corroborates the findings of Mafouo *et al.* [15]) who showed that increasing the level of cassava flour in ration tends to increase the relative liver weight in broilers. This increase in the relative liver weight could be due to the presence of diosbulbin B which can causes liver damage [21] and also fractions of saponins and flavonoids which have effects on liver function by significant changes in liver ratio and liver weight [22]. Abdominal fat decreased with increasing levels of maize substitution and was absent in birds fed only with *D. bulbifera* (100%). This suggest that dioscin present in *D. bulbifera* prevents non-alcoholic fatty liver diseases (NAFLD) induced by a highly energised (fat) diet [22]. Dioscin has been reported to reduce symptoms of lipid accumulation in the liver, and increase energy and oxygen intake in mice [23]. This result corroborates the results of Awah-Ndukum *et al.* [19] who, after substituting maize with cassava peel at increasing levels, recorded a drop-in broilers abdominal fat.

Dioscorea bulbifera flour in feed had no significant effect on intestine length, weight, density and relative weight of the pancreas. The relative weight of the gizzard increased significantly with increasing levels of *D. bulbufera* in the ration. This result is in accordance with the findings of Kana *et al.* [2] which revealed that potato inclusion in feed tends to increase the relative weight of the gizzard. Indeed, *D. bulbufera* flour has a relatively higher crude cellulose level than maize, thus confirming the explanations given by Aderemi and Nworgu [24] who stipulated that, in monogastric, a high level of cellulose stimulate growth and thickening of the digestive tract walls. In the same line, Teguia *et al.* [25] hypothesized that the ingestion of high cellulose content increases the weight of the digestive tract. This result is also in line with those of Viveros *et al.* [26] who reported that the increase in the weight of the digestive organs of birds can be attributed, to some extent, to the presence of a high concentration of indigestible matter in the intestine of these birds.

Irrespective of the study phase, the cost of production of broiler increases with increasing levels of *D. bulbifera* in the ration. This could be explained by the high cost of *D. bulbifera* on the market compared to that of maize. These results are contrary to those obtained by Kouadio *et al.* [16] who reported a decrease in the cost of production of feed when the inclusion level of cassava peelings in broilers feed increased.

5. Conclusion

Irrespective of the study phase, substituting 50% maize with *D. bulbifera* flour in broiler's feed induced growth performances comparable to broilers fed on the control containing maize as the main source of energy. *D. bulbifera* flour can be a sustainable solution to palliate the growing scarcity of maize in poultry feed.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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