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Use of *Dioscorea dumetorum Pax* as feed ingredient and natural antioxidant on growth, carcass characteristics and blood metabolites of broiler chickens

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Additional keywords

Uric acid.
Cholesterol.
Dioscorea dumetorum.
Feed conversion ratio.
Broiler chickens.

SUMMARY

This experiment was conducted to evaluate the effects of *Dioscorea dumetorum* chips (DDC) as a feed ingredient and natural antioxidant on growth performance, carcass characteristics, and blood metabolites in broiler chickens. A total of 240 seven-day-old male broiler chickens were randomly assigned to 5 diets: maize and soya bean meal as the basal diet without antioxidant or negative control diet (D0-A), basal diet with synthetic antioxidant or positive control diet (D0+A) and the basal diet containing 4, 8 or 12% of DDC without synthetic antioxidant corresponding to diets D4-A, D8-A and D12-A. Each experimental unit contains 12 birds reared on litter. The results indicated that feed intake was higher (P<0.05) for diet D8-A. Dietary inclusion of DDC had no effect on live weight gain during starting period. Average feed conversion ratio varied from 2.07 to 2.36. This was better for D12-A, over all rearing period. At day 56 of age, the higher carcass yield and most of others part (P<0.05) were obtained on the diets D12-A and D8-A. The abdominal fat weight percentage has reduced with increasing the level of DDC in the diet. Haematological indices of broiler finishers were not affected by the diets (P>0.05). However, the concentration of haematocrit increased significantly with inclusion levels of DDC in the diet compare to the control diets. Also, high uric acid concentration was recorded (P<0.05) in broiler chickens fed diet D12-A. So, 12% and 8% of DDC in diets improved feed efficiency and can replace synthetic antioxidant and part of maize as a feed ingredient to enhance broiler chicken's growth and overall health.

Utilisation de *Dioscorea dumetorum Pax* comme ingrédient alimentaire et antioxydant naturel sur les performances de croissance, les caractéristiques de carcasse et les métabolites sanguins des poulets de chair

Mots-clés supplémentaires

Acide urique.
Cholestérol.
Dioscorea dumetorum.
Indice de consommation.
Poulets de chair.

RÉSUMÉ

Le but de l'étude était d'évaluer l'effet de l'incorporation des cossettes de *Dioscorea dumetorum* (DDC) comme ingrédient alimentaire et antioxydant naturel sur les performances de croissance, les caractéristiques de la carcasse et les métabolites sanguins des poulets chair. Au total, 240 poulets chair mâle âgés de 7 jours étaient répartis au hasard en 5 rations : la ration de base ou témoin négatif (D0-A) composé de maïs et de soja sans antioxydant de synthèse, ration de base avec antioxydant de synthèse ou témoin positif (D0+A) et la ration de base contenant 4, 8 ou 12% de DDC sans antioxydant de synthèse correspondant aux rations D4-A, D8-A et D12-A. Chaque unité expérimentale contient 12 poulets élevés sur litière. Les résultats ont montré que l'ingestion alimentaire était plus élevé (P<0,05) pour la ration D8-A. L'inclusion de DDC dans la ration n'a eu aucun effet sur le gain de poids vif en phase démarrage. L'indice de consommation a varié de 2.07 à 2.36. Il était meilleur pour la ration D12-A, sur toute la période d'élevage. Au 56ème jour, le rendement carcasse et des abats les plus élevés (P<0,05) sont obtenus avec les rations D12-A et D8-A. La proportion de la graisse abdominale a diminué avec l'augmentation du niveau d'inclusion de DDC dans les rations. Les paramètres hématologiques des poulets n'étaient pas affectés (P>0,05) par la ration alimentaire. Cependant, l'hématocrite a augmenté significativement avec le niveau d'inclusion de DDC dans la ration comparée aux témoins. De même, une concentration élevée d'acide urique a été enregistrée (P<0,05) chez les poulets de chair nourris à la ration D12-A. Ainsi, 12% et 8% de la DDC dans la ration ont amélioré l'efficacité alimentaire et peuvent remplacer l'antioxydant de synthèse et une partie du maïs comme ingrédient alimentaire pour améliorer la croissance et la santé globale des poulets de chair.

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INTRODUCTION

Intensification of agricultural production into a profitable and competitive livestock enterprise is one of the options to increase food production and reduce urban and rural poverty in Africa (Otte et al. 2012, p. 1-161). The improvement of feed efficiency and the industrialization of animal husbandry require the use

of feed additives to ''increase production'' without damaging the health of the animals (Alloui 2011). The poultry industry is one of the fastest growing agribusinesses in sub-Saharan Africa providing income and employment opportunities for the population (Otte et al. 2012, p. 1-161).

The increasing demand for chicken meat has implied the industrialization of chicken husbandry. Feed plays an important role in maintaining health and zootechnical performance of chickens (Surai 2007, p. 669). Feed is, therefore, improved in breeding activities by covering the nutritional needs of a chicken via the distribution of quality industrial feed that is inexpensive. This implies better profitability of the farmers, since perfect feed ensures rapid growth of the animal and which helps in preventing some diseases.

Among many dietary factors, synthetic antioxidant is the most specially used in the maintaining of high growth level, reproductive and immune-competence in poultry production. The presence of synthetic antioxidant residues in poultry meat and eggs can have deleterious effects on human consumers. Therefore, consumers prefer day by day a natural substance as an antioxidant in animal feed.

Many local plants and species have also been used as feed additives for poultry all over the world (Alloui et al. 2012, p. 25-27; Kumar et al. 2014, p. 1-8). These spices and their extracts represent a new class of growth activators in livestock, but knowledge is still limited concerning their mode of action and their application (Windisch et al. 2007, p. 140). In addition, Alloui (2011) reported that spices contain active substances which have a positive impact on the production performances of domestic animals. The stimulation of feed intake, the improvement of digestive enzyme secretion, activation of immune responses and antibacterial, antiviral and antioxidant actions were reported that positive impact of bioactive substances in animal nutrition (Toghyani et al. 2011, p. 167).

The cultivated *Dioscorea dumetorum* is the most nutritious among of the six yam species mostly consumed in West Africa (Sefa-Dedeh & Afoakwa 2002, p.27). It contains high protein content (9.6%) compared with 8.2% for the *D. alata* and 7% for *D. rotundata* (Lape & Treche 1994, p. 447). According to Alozie et al. (2009, p. 103), the edible *D. dumetorum* is rich source of the essential amino acids (tryptophan, threonine, valine, methionine, phenylalaline, lysine, etc.). As a medicinal food, *D. dumetorum* has been shown to possess hypoglycemic, hypocholesterolemic properties (Ogbunugafor et al. 2014, p. 88; Oluwatosin & Olubunmi 2015, p. 285), anti-microbial, antioxidant and anti-nociceptive properties (Sonibare & Abegunde 2012, p. 3583; Ukwueze et al. 2015, p.132). The radical scavenging capacity of tubers of this dioscorea species studies indicated that boiling did not change significantly the antioxidant activity of *D. dumetorum* tubers although a significant decrease in total phenolic (60%) and vitamin C contents (56.7%) was observed (Doka et al. 2016, p. 262). The contents of total polyphenols, flavonoids and tannins are higher in the *D. dumetorum* boiled for 30 minutes compared to these boiled for 60 or 90 minutes (Ezeocha et al. 2012, p.28). Based on the worth mentioning values, *D. dumetorum* variety with yellow flesh is suggested to be used as alternatives to cereals in human and animal nutrition or in livestock industries. However, the effects of *D. dumetorum* chips on broilers performance are still less known. This research was, therefore undertaken to investigate effects of dietary inclusion of *D. dumetorum* meal as a feed ingredient and antioxidant on the growth performance of broilers chickens, carcass yield and quality, and blood parameters. The hypothesis is that the use of the high proportion of inclusion of *D. dumetorum* in the diet of broilers as an energy source and antioxidant, improves the growth, the characteristics of the carcass, without modifying the blood parameters, as compared to those of broilers that receive conventional feed with synthetic antioxidant.

MATERIAL AND METHODS

Bird, feed, experimental design and husbandry

A total of 240, seven day-old broiler chicks (“Cobb 500” Strain), were grown over 49-day period. The experiment was laid out as a completely randomized design with 5 experimental diets and 4 replicates making a total of 20 experimental units. Each experimental unit contains 12 birds reared on litter in 2.5 m² pen. It is worth to mention that no antibiotic was supplemented to or injected in the broilers from the first day until the end of the experiment. The birds were beforehand vaccinated against Newcastle disease by AVI ND HB1; Infectious Bronchitis disease by AVI IB H120; Gumboro disease by CEVAC GUMBO L and dewormed by FINIWORM (Piperazine Citrate®) through drinking water in accordance with the instructions of the manufacturer.

The five experimental diets were formulated with different levels of 0; 4; 8 or 12% of *D. dumetorum* chips (DDC) used as a feed ingredient and natural antioxidant. That corresponds to five experimental diets such basal diet containing 0% of DDC, without synthetic antioxidant or negative control (D0-A); basal diet containing 0% of DDC, plus synthetic antioxidant or positive control (D0+A); diet containing 4% of DDC without synthetic antioxidant (D4-A); diet containing 8% of DDC without synthetic antioxidant (D8-A); diet containing 12% of DDC without synthetic antioxidant (D12-A).Vitamin C was the synthetic antioxidant and supplemented at the rate of 200 mg/kg in feed according to Njoku (1986, p. 17).

Yellow flesh *D. dumetorum* tubers used were washed, peeled, boiled in water at 100°C for 30 minutes, cut into small pieces and then sun dried on a tarpaulin up to constant weight to obtain chips. Diets were formulated to provide the recommended requirements for broiler (without added antibiotics or growth promoters). The composition of starter diet (**Table I**) was replaced by the finisher diet (**Table II**).

The chicks were weighed individually. Water was provided *ad libitum*. The 12 birds in each pen, was considered an experimental unit and the pooled data for the 12 birds was used in the statistical analysis. Feed

Table I. Dietary compositions and nutrient of experimental starter diets (7-28 days old) of the broilers chicks.
(Composition alimentaire et nutritif des rations expérimentales démarrage (7-28 jours d'âge) des poulets de chair).

Ingredient (g kg-1)	Experimental diets with or without synthetic antioxidant				
	D0-A	D0+A	D4-A	D8-A	D12-A
Maize	58	58	55	54	50
Wheat bran	3	3	3	0	0
Roasted soybeans	14	14	14	14	14
Soybean meal	19	19	18	18	18
DDC	0	0	4	8	12
Bicalcium phosphate	1.7	1.7	1.7	1.7	1.7
Concentrated broilers	1.6	1.6	1.6	1.6	1.6
Lysine	0.2	0.2	0.2	0.2	0.2
Methionine	0.2	0.2	0.2	0.2	0.2
Oyster shell	2	2	2	2	2
Salt	0.3	0.3	0.3	0.3	0.3
Total	100	100	100	100	100
Calculated chemical analysis					
Dry matter (%)	90.68	90.92	91.24	91.17	90.65
Crude fiber (%)	2.8	2.8	2.93	2.85	3
ME (Kcal/kg.MS)	3009	3009	3032	3096	3113
Fat (%)	5.37	5.37	5.23	5.06	4.89
Crude protein (%)	23	23	22	22	22
Lysine (%)	1.22	1.22	1.38	1.57	1.77
Methionine (%)	0.5	0.5	0.49	0.48	0.48
Calcium (%)	1.24	1.24	1.23	1.23	1.23
Total phosphorus (%)	0.49	0.49	0.49	0.49	0.5

DDC= *D. dumetorum* chips; D0-A= Diet containing 0% of DDC without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant. Concentrated broilers: Crude Protein = 40%, Fat = 2%, Calcium = 7%, Phosphorus = 4.1%, Sodium = 2.7%, Chlorine = 3.1%, Lysine = 3.85%, Methionine = 4.45 %, Methionine + Cystine = 4.9%, EM = 2200Kcal / Kg; Vitamins: A=220000 IU, D3=80000 IU, E=600 mg, K=40 mg, B1=35 mg, B2=100 mg, pantoth. acid=200 mg, B6=60 mg, B12= 0,4 mg, nic. acid=600 mg, folic acid=20 mg, Biotin=2 mg, Choline chl.=5000 mg, Minerals: Fe=900 mg, Cu=300 mg, Mn=1200 mg, Zn=1400 mg, Iodate=40 mg, Se=8 mg.

intake was recorded daily for each pen and pooled for a week (7 days). Any feed left over at the beginning of the next day was weighed and subtracted from that which had been fed the previous day to determine feed intake. Feed allowance was adjusted at the end of each week after the chicks had been weighed. Feed consumption and live weight measurements were taken weekly and used to compute feed conversion ratio (FCR). Broilers mortality was recorded each day.

Haematological and biochemical analyses

Haematological and serum biochemical parameters were examined at 56 days of age from 2 chickens of different experiment unit. Fresh blood samples were taken in three tubes containing EDTA (Ethylene-Diamine-Tetra acetic-Acid), the second containing sodium fluoride and the third without anticoagulant for haematological, glycemic and biochemical analyses, respectively. The haematological parameters were analysed using a 5-population haematology machine (Mindray BC-5000, Medsinglong Co., Ltd/Guangdong, China). The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were computed according to Campbell (1988). For biochemical tests (including blood sugar), the samples from the tubes were centrifuged for 5 minutes at 3000 rpm to obtain the plasma. The assay of the various parameters was carried out using a biochemistry analyzer (Mindray BS-220, Medsinglong Co., Ltd/Guangdong, China). The LDL content was calculated by the formula of Friedewald et al. (1972, p. 500).

Evaluation of carcass traits

At the end of 56 days of age, two chickens per experimental unit were chosen at random and slaughtered by bleeding after 12 hours of fasting. Then, the birds were scalded in hot water and then plucked manually. The organs of the abdominal and thoracic cavities, legs, head and neck were then removed and weighted. The carcasses were cut according to the method described by Ricard et al. (1967, p. 23-39).

Statistical Analysis

All analysis were performed under R (Team, 2019) and the level of significance of the statistical tests was

Table II. Dietary compositions and nutrient of experimental finisher diets (28-56 days old) of the broilers chicks (Composition alimentaire et nutritif des rations expérimentales finition (28-56 jours d'âge) des poulets de chair).

Feed ingredient (%)	Experimental diets with or without synthetic antioxidant				
	D0-A	D0+A	D4-A	D8-A	D12-A
Maize	63	63	60	56	50
Wheat bran	5	5	4	3	3
Roasted soybeans	11	11	11	12	14
Soybean meal	15	15	15	15	15
DDC	0	0	4	8	12
Bicalcium phosphate	1.7	1.7	1.7	1.7	1.7
Concentrated broilers	1.6	1.6	1.6	1.6	1.6
Lysine	0.2	0.2	0.2	0.2	0.2
Methionine	0.2	0.2	0.2	0.2	0.2
Oyster shell	2	2	2	2	2
Salt	0.3	0.3	0.3	0.3	0.3
Total	100	100	100	100	100
Calculated chemical analysis					
Dry matter (%)	93.68	93.88	93.95	92.55	93.05
Crude fiber (%)	2.79	2.79	2.86	2.96	3.17
ME (Kcal/kg.MS)	3014	3014	3046	3079	3096
Fat (%)	5.06	5.06	4.89	4.86	4.97
Crude protein (%)	21	21	21	21	21
Lysine (%)	1.05	1.05	1.24	1.46	1.69
Methionine (%)	0.47	0.47	0.47	0.46	0.46
AAS (%)	0.83	0.83	0.93	1.03	1.15
Calcium (%)	1.22	1.22	1.22	1.22	1.22
Total phosphorus (%)	0.47	0.47	0.47	0.48	0.49

DDC= *D. dumetorum* chips; D0-A= Diet containing 0% of DDC without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant. Concentrated broilers: Crude Protein = 40%, Fat = 2%, Calcium = 7%, Phosphorus = 4.1%, Sodium = 2.7%, Chlorine = 3.1%, Lysine = 3.85%, Methionine = 4.45 %, Methionine + Cystine = 4.9%, EM = 2200Kcal / Kg; Vitamins: A=220000 IU, D3=80000 IU, E=600 mg, K=40 mg, B1=35 mg, B2=100 mg, pantoth. acid=200 mg, B6=60 mg, B12= 0,4 mg, nic. acid=600 mg, folic acid=20 mg, Biotin=2 mg, Choline chl.=5000 mg; Minerals: Fe=900 mg, Cu=300 mg, Mn=1200 mg, Zn=1400 mg, Iodate=40 mg, Se=8 mg.

set at 5%. Analyse of variance (ANOVA) were performed on each parameters of growth performance, carcass characteristics and of biochemical and haematological parameters. Multi-normality has been checked with the mvnormtest package (Jarek, 2012) for the different parameter groups. To stabilize the variances in carcass characteristics and biochemical and haematological parameters that exhibited non-normal distributions (P<0.05), the natural log transformation was applied to the data. Student-Newman-Keuls (SNK) tests were carried out with the agricolae package (De Mendiburu, 2019) to compare the levels of treatment. The adjusted means were calculated with the emmeans package (Lenth, 2019). All results were expressed as mean ± standard error.

RESULTS

Feed intake and growth performance of broiler

The performance of the broilers on varying levels inclusion of DDC as a substitute for maize is presented in **Table III**. The initial and final live weight of chickens were similar for all diets (P>0.05). The result indicated that daily feed intake was also similar during starter period. But, during the finisher period and across all experimental periods, the feed intake and the average daily feed intake, were higher (P<0.05) for diet D8-A. During the starter period, the daily live weight gain (LWG) was similar (P>0.05) between diets. But, during the finisher period, 12% and 8% inclusion levels of DDC have shown the highest (P<0.05) values of LWG compared to D4-A and control diets. While, during the all experimental period, 12% inclusion level of DDC has shown the highest (P<0.05) value of LWG as compared with other DDC diets and the controls. The feed conversion rate (FCR) at finisher period was higher (P<0.05) for negative control diet. But the average FCR was significantly lower (P<0.001) for 12% inclusion level of DDC as compared with other DDC diets and the control diets. All animals fed various diets had linear growth (**Figure 1**), and no mortality was recorded in any experimental diets.

Table III. Feed intake and growth performance of broilers chickens fed on diets containing different level of *D. dumetorum* chips as a feed ingredient and natural antioxidant (Ingestion alimentaire, performances de croissance des poulets de chair alimentés avec des rations contenant différent taux des cossettes de *D. dumetorum* comme ingrédient alimentaire et antioxydant naturel).

Variable	Experimental diets with or without synthetic antioxidant					
	D0-A	D0+A	D4-A	D8-A	D12-A	P
Feed intake starter (g/d)	54.87±1.97^{a}	55.48±1.43^{a}	55.63±1.01^{a}	56.97±1.33^{a}	55.02±1.63^{a}	0.348
Feed intake finisher (g/d)	119.47±1.52^{b}	119.93±1.61^{b}	120.01±0.73^{b}	123.37±0.87^{a}	121.70±1.11^{ab}	0.002
Average feed intake (g/d)	91.79±1.64^{b}	92.31±1.52^{b}	92.42±0.81^{b}	94.91±0.99^{a}	93.12±1.26^{ab}	0.03
Initial body weight (g)	114.29±0.92^{a}	116.48±5^{a}	113.60±5.31^{a}	114.37±5.27^{a}	109.64±5.26^{a}	0.376
Final body weight (g)	2016±104^{a}	2108±89^{a}	2093±87^{a}	2162±105^{a}	2217±107^{a}	0.104
LWG starter (g/d)	26.54±2.06^{a}	26.39±1.72^{a}	26.68±2.34^{a}	27.50±2.28^{a}	28.13±2.32^{a}	0.757
LWG finisher (g/d)	48.01±2.22^{b}	51.34±2.08^{ab}	50.69±1.33^{ab}	52.49±2.07^{a}	54.17±2.07^{a}	0.007
Average LWG(g/d)	38.80±2.13^{c}	40.64±1.76^{b}	40.40±1.70^{b}	41.78±2.06^{b}	44.81±0.47^{a}	0.002
FCR starter	2.07±0.11^{a}	2.10±0.10^{a}	2.09±0.14^{a}	2.08±0.13^{a}	1.96±0.12^{a}	0.51
FCR finisher	2.49±0.08^{a}	2.33±0.06^{b}	2.36±0.05^{b}	2.35±0.08^{b}	2.24±0.08^{b}	0.007
Average FCR	2.36±0.08^{a}	2.27±0.06^{a}	2.29±0.07^{a}	2.27±0.09^{a}	2.07±0.01^{b}	< 0.001

D0-A= Diet containing 0% of DDC, without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant; LWG= Live weight gain; FCR= feed conversion rate ; a,b: indicate that the means followed by different letters (on the same line) are significantly different (P < 0.05); P= probability.

Carcass traits

The result based on DDC diets, indicated that the average carcass yields and some parts of broiler chickens were significantly different (P<0.05) between experimental diets (**Table IV**). But, 12% and 8% inclusion levels of DDC have the highest values compared to D4-A and the control diets for carcass, wings, feet, head + neck, thigh and breast. The values of carcass yields increased with increase of DDC inclusion level across the experimental diets. In contrast, abdominal fat decrease with increase level in DDC inclusion across the experimental diets and positive control diet.

Haematological and biochemical parameters

The haematological indices of broiler finishers fed on diets containing different levels of DDC are presen-

Table IV. Carcass traits of broilers fed on diets containing different levels of *D. Dumetorum* chips as a feed ingredient and natural antioxidant at 49 days (Caractéristiques de carcasse des poulets de chair alimentés pendant 49 jours avec des rations contenant différent taux des cossettes de *D. dumetorum* comme ingrédient alimentaire et antioxydant naturel).

Parameters (%)	Experimental diets with or without synthetic antioxidant					P
	D0-A	D0+A	D4-A	D8-A	D12-A	
Carcass yield	70.21±1.01^{c}	72.32±0.30^{b}	69.44±1.03^{d}	74.04±0.46^{a}	74.59±0.53^{a}	< 0.001
Wings	5.66±0.71^{b}	6.86±0.49^{a}	5.50±0.57^{b}	6.80±0.40^{a}	6.85±0.47^{a}	< 0.001
Feet	3.72±0.34^{a}	3.73±0.21^{a}	3.53±0.25^{ab}	3.81±0.33^{a}	3.42±0.20^{ab}	0.042
Head + neck	5.18±0.55^{c}	6.75±0.42^{a}	5.95±0.61^{b}	7.03±0.39^{a}	6.63±0.36^{a}	< 0.001
Thigh	32.37±4.46^{b}	33.38±4.00^{b}	31.08±4.85^{b}	34.01±2.22^{a}	34.16±2.92^{a}	< 0.001
Breast	13.79±3.73^{b}	15.90±2.28^{b}	14.82±1.96^{b}	20.15±1.23^{a}	20.17±1.39^{a}	< 0.001
Gizzard	1.26±0.31^{a}	1.37±0.07^{a}	1.44±0.20^{a}	1.51±0.14^{a}	1.43±0.18^{a}	0.136
Heart	0.43±0.07^{a}	0.43±0.03^{a}	0.43±0.03^{a}	0.42±0.05^{a}	0.40±0.03^{a}	0.528
Lung	0.30±0.08^{a}	0.32±0.07^{a}	0.35±0.04^{a}	0.33±0.04^{a}	0.34±0.04^{a}	0.357
Kidney	0.49±0.11^{a}	0.45±0.05^{a}	0.39±0.08^{a}	0.46±0.07^{a}	0.46±0.07^{a}	0.139
Liver	1.39±0.18^{a}	1.34±0.07^{a}	1.46±0.18^{a}	1.43±0.18^{a}	1.39±0.23^{a}	0.718
Spleen	0.19±0.04^{a}	0.16±0.02^{ab}	0.14±0.03^{b}	0.14±0.02^{b}	0.13±0.02^{b}	< 0.001
Abdominal fat	1.27±0.28^{a}	0.83±0.09^{c}	1.06±0.16^{b}	0.89±0.13^{bc}	0.84±0.13^{c}	< 0.001

D0-A= diet containing 0% of DDC, without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant; a, b, c, d: means on the same row with different superscripts are significantly different (P < 0.05); P= probability,.

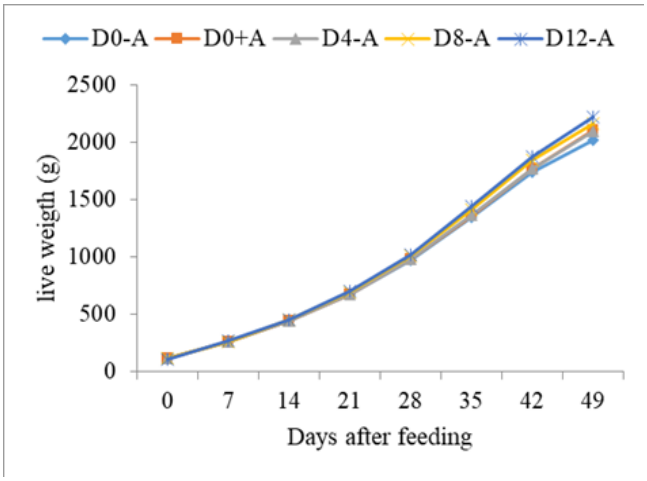

Figure 1. Evolution of live weight changes of broilers subjected to different diets during starter and finisher periods (Evolution du poids vif moyen des poulets de chair alimentés avec différents rations durant les phases démarrage et finition). D0-A= Diet containing 0% of DDC, without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant.

ted in **Table V**. There were no significant differences (P>0.05) among diets for parameters tested including white blood cell (WBC), MCV, haemoglobin, red blood cell (RBC), and MCHC. However, the concentration of haematocrit increased significantly (P<0.05) with inclusion levels of DDC in the diets compared to the control diets (positive and negative).

The creatinine concentration was similar (P>0.05) for all diets (**Table VI**). In contrast, the others biochemical concentrations were significantly affected by DDC inclusion levels in the diets. Uric acid concentration increased significantly (P<0.05) with increasing of DDC level in the diet. On the other hand, the broilers chickens fed diets D12-A and positive control (D0+A) recorded the higher (P<0.05) uric acid concentration. In contrast, compared to control diets, the concentration values of low density lipoprotein (LDL) cholesterol, high density lipoprotein (HDL) cholesterol, total cholesterol, triglyceride and glycaemia levels decreased significantly (P<0.05) with increasing of DDC inclusion levels in the diets. The least concentration values (P<0.05) were noticed with chickens fed on diet D12-A followed by D8-A.

DISCUSSION

Zootechnical performance and carcass traits

Feed intake of diet containing 8% of DDC fed to broiler chickens has increased compared to the control (negative and positive) diets. This may indicate that DDC enhances the flavor and palatability of feed. This excellent palatability of concentrate diet containing DDC, may be attributed to the processing used manly boiling and drying that could reduce *D. Dumetorum* bitterness. Indeed, previous studies shown *D. dumetorum* has a bitter taste (Cemaluk et al. 2014, p. 1; Alamu et al. 2016, p. 640). Our result shown, that the average FCR of diet with supplemented vitamin C was similar to negative control diet. While, the literature reported that the optimum response in terms of feed conversion ratio, feed efficiency in broilers under heat stress appeared to occur with average supplements of 250 mg/kg vitamin C. (Shakeri et al. 2020, p 3). This imply that the difference could be the type of strain of broiler, the dose of vitamin C used or the environment conditions.

At the starter phase, the similarity of LWG and FCR values recorded across the experimental diets, indicate that synthetic and natural antioxidant effects are not noticeable on FCR. This result implies that the broiler feed could, on one hand, be formulated without synthetic antioxidants, and on other hand, DDC could be used as feed ingredient at most at low level, to replace part of maize as energy source. However, in the finisher phase, the difference in performance improvement in terms of LWG and FCR in broilers supplemented with vitamin C and those on diets containing

Table V. Haematological parameters in broilers chickens fed on diets containing different level of *D. dumetorum* chips as a feed ingredient and natural antioxidant (Paramètres hématologiques des poulets de chair alimentés avec des rations contenant différent taux des cossettes de D. dumetorum comme ingrédient alimentaire et antioxydant naturel).

	Experimental diets with or without synthetic antioxidant					
Parameters	D0-A	D0+A	D4-A	D8-A	D12-A	P
WBC (/ml)	139.54±0.77^{a}	138.50±2.34^{a}	140.33±1.34^{a}	139.73±2.15^{a}	140.88±1.51^{a}	0.095
MCHC (g/dl)	35.63±0.22^{a}	34.11±0.34^{a}	34.52±0.42^{a}	34.41±0.23^{a}	34.95±0.27^{a}	0.689
MCH (pg)	39.39±0.43^{a}	38.06±0.37^{a}	39.82±0.34^{a}	40.65±0.82^{a}	39.40±0.35^{a}	0.347
MCV (fl)	110.67±0.74^{a}	111.59±1.88^{a}	115.6±1.16^{a}	118.39±1.34^{a}	112.75±1.39^{a}	0.093
Haematocrit (%)	31.11±0.42^{b}	31.20±0.37^{b}	32.46±0.61^{ab}	33.58±0.81^{a}	32.33±0.44^{ab}	0.021
Haemoglobin (g/dl)	11.08±0.21^{a}	10.64±0.24^{a}	11.18±0.22^{a}	11.53±0.26^{a}	11.29±17^{a}	0.067
RBC (/ml)	2811±16^{a}	2798±31^{a}	2808±24^{a}	2839±26^{a}	2868±34^{a}	0.369

D0-A= diet containing 0% of DDC, without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant; MCV= Mean corpuscular volume; MCHC =Mean corpuscular haemoglobin concentration; MCH = Mean corpuscular Haemoglobin; WBC= White blood cell; RBC =Red blood cell; a, b, c, d: means on the same row with different superscripts are significantly different (P < 0.05); P= probability.

DDC compared to negative control recorded would be attributed to the effect of the synthetic antioxidant (vitamin C) and natural antioxidant (DDC). More interesting, the inclusion of high levels of DDC as a natural antioxidant brings better effects on feeding efficiency compared to supplemented diet with the synthetic antioxidant. Our result proves that the total polyphenols and flavonoids contained in *D. Dumetorum* seem to act as antioxidant, as reported by previous studies (Sonibare & Abegunde 2012, p. 3583; Ukwueze et al. 2015, p.132; Doka et al. 2016, p. 262). The better effects on broiler growth obtained in this experiment with high inclusion (12%) level of DDC, is in close agreement with the findings reported, that a high dosage of natural antioxidant brings better effects (Fotina et al. 2013, p. 889). Such performance may derive from the nutritional quality of DDC and its antioxidant capacity through the efficient effect of the functioning of the digestive system and the absorption of these nutrients by broilers. As a result, DDC thus help the broilers to grow better within the framework of their genetic potential through immune defense situations and increased availability of essential nutrients.

However, the feed intakes of broiler finisher of the current study were less than 150.48 to 168.81 g/day reported by Abdulrashid and Agwunobi (2009, p. 670), when testing 25 and 50% inclusion level of taro cocoyam (*Colocasia esculenta*), boiled for 30 minutes as a energy feed ingredient source in broiler chickens' diets. In contrast, the FCR (3.19 to 3.7) recorded by Abdulrashid and Agwunobi (2009, p. 670) in using 25 and 50% inclusion level of taro cocoyam was worse compared to that obtained for this research. The best performance difference using *D. dumetorum* as broiler feed ingredient may be due to its nutritional quality and its antioxidant capacity, even if taro cocoyam has also antioxidative capacity (Wu & Lin 2017, p. 852). Since no mortality was recorded during this study, it seems to indicate that the use of DDC as a feed ingredient does not cause any apparent intoxication disorder in broilers. This could also be explained by the fact that the incorporation of the DDC strengthens the immune system of the chickens, which prevents them from external infections.

The result demonstrated also that vitamin C used as synthetic antioxidant improves broiler carcass yield and quality by diminution of fat proportion in carcass. But, the use of DDC as feed ingredient and natural antioxidant has noticeably improved carcass yield and quality than synthetic antioxidant mainly with high levels 8 and 12% of DDC in the diets. This fat diminution may be due to poor fat contained in the DDC and its low absorption by broiler chickens. Indeed, the fat content of *D. dumetorum* boiled for 30 to 90 minutes ranged from 0.54 to 0.65% (Ezeocha et al. 2012, p. 28) versus 3.81 to 3.99% for maize (Atchade et al. 2019, p. 30). So, this result suggests that DDC can be used in the diet to produce less fat broilers. Therefore, meat quality may be improved with the use of DDC in broiler diet.

Haematological parameters and serum biochemistry

About haematological parameters, the higher count of haematocrit observed in chicks fed DDC diets could indicate that *D. dumetorum* may possess constituents that would trigger the erythropoietic system to produce red cells. The MCHC recorded were higher than 33.58 to 36.3 mg/dl reported by Ayuk and Essien (2009, p. 487) when replacing sweet potato (*Ipomoea batata*) by maize in broiler diets. Likewise, the proportions of haematocrit and MCV observed in this study were higher than respectively the ranges of 25 to 30.5% and 11.3 to 11.42 fl, obtained by Adegoke et al. (2018, p. 100), when testing the supplementation of *Curcuma longa* and *Capsicum frutescens* powder (as natural antioxidants) in the diets.

There was a decreasing trend in total serum cholesterol in response to increasing level of DDC up to 12%. The present study showed that increasing DDC in diets resulted in decreased serum total cholesterol, serum LDL cholesterol and triglyceride. This indicated that as the level of serum LDL decreased, the total serum cholesterol decreased. In the present study, diets containing 8 % and 12% of DDC reduced total serum cholesterol respectively by 5.9 % and 24.6% compared

Table VI. Biochemical parameters in broilers chickens fed on diets containing different level of *D. dumetorum* chips as a feed ingredient and natural antioxidant (Paramètres biochimiques des poulets de chair alimentés avec des rations contenant différent taux des cossettes de *D. dumetorum* comme ingrédient alimentaire et antioxydant naturel).

	Experimental diets with or without synthetic antioxidant					
Parameters	D0-A	D0+A	D4-A	D8-A	D12-A	P
Uric acid (mg/l)	11.36±2.25^{e}	40.15±1.47^{a}	15.07±1.07^{d}	31.89±3.49^{c}	42±1.84^{a}	< 0.001
Creatinine (mg/l)	3.09±0.21 ^{a}	3.85±0.34 ^{a}	2.9±0.36 ^{a}	3.36±0.25 ^{a}	3.36±0.24 ^{a}	0.208
LDL- cholesterol(g/l)	0.44±0.02^{a}	0.38±0.05^{ab}	0.44±0.04^{a}	0.38±0.03^{ab}	0.30±0.02^{b}	0.044
HDL-cholesterol (g/l)	0.67±0.02^{a}	0.74±0.05^{a}	0.68±0.02^{a}	0.67±0.03^{a}	0.53±0.03^{b}	< 0.001
T_Cho (g/l)	1.21±0.03^{a}	1.18±0.02^{a}	1.2±0.05^{a}	1.11±0.03^{b}	0.89±0.02^{c}	< 0.001
Triglyceride (g/l)	0.51±0.06^{a}	0.32±0.02^{c}	0.42±0.05^{b}	0.27±0.02^{c}	0.29±0.02^{c}	0.001
Glycaemia (g/l)	1.68±0.02^{a}	1.69±0.02^{a}	1.65±0.03^{ab}	1.50±0.02^{c}	1.45±0.02^{c}	< 0.001

D0-A= Diet containing 0% of DDC, without synthetic antioxidant (negative control); D0+A= diet containing 0% of DDC, plus 200 mg of synthetic antioxidant per kg of diet (positive control); D4-A= Diet containing 4% of DDC without synthetic antioxidant; D8-A= Diet containing 8% of DDC without synthetic antioxidant; D12-A= Diet containing 12% of DDC without synthetic antioxidant; T_Cho= Total cholesterol, LDL= Low density lipoproteins; HDL= High density lipoproteins; a, b, c, d: means on the same row with different superscripts are significantly different (P < 0.05); P= probability;.

to positive control. Also, the reduction of HDL cholesterol was about 9.5 and 28.4% for diets containing respectively 8 % and 12% of DDC compared to positive control. This result is in agreement with the findings of Oluwatosin & Olubunmi (2015, p. 292) who reported hypocholesterolemic effect of *D. dumetorum*. The decrease in cholesterol levels may be due to the inhibition of the hepatic 3-hydroxy-3-methylglutaryl coenzyme A (HMGCoA) reductase activity, which is a key regulatory enzyme in cholesterol synthesis (Qureshi et al. 1988, p. 1222; Goldstein & Brown 1990, p. 426).

High triglycerides levels in blood of bird fed D0-A have led to high body fat deposition in bird confirm the finding which states that triglycerides are the most important sources of fatty acids for fat accumulation (Kersten 2001, p. 282). Likewise, its decrease in the blood, lead to the reduction of fat deposit in birds body. This result is in concordance with that of Nahavandinejad et al. (2014, p. 4312), who reported that triglycerides levels in blood were correlated well with body fat. It appears evident that feed, but mainly its antioxidant content is the major source for triglycerides variations. Indeed, the current study also found that low body fat deposition in birds correlates with the proportion of antioxidant in the feed (DDC or synthetic anti-oxidant). This could be explained by the antioxidant effect of the feed for the good health of the consuming bird. Thus DDC has demonstrated its ability to eliminate fat for better bird health.The current study also revealed that, increasing DDC in diets decreased glycaemia level. This finding is in agreement with the report of Ogbunugafor et al. (2014, p. 95), who concluded the hypoglycemic property of *D. dumetorum* in rats. The decrease in glycaemia level may be due to an inhibition of the α-amylase and α-glucosidase, which are key enzymes involved in the post-prandial release of glucose into the systemic circulation (Ghosh et al. 2012, p. 8).

Bird uric acid is the major end product of nitrogen metabolism (Machin et al. 2004, p. 384). In previous studies, *D. dumetorum* contained phenolic compounds that presented high antioxidant activities (Sonibare & Abegunde 2012, p. 3588). In the current study, all diets were formulated to meet nutrient requirements with equal calculated crude protein content. The high uric acid level recorded ($P<0.05$) in broiler chickens fed diet containing high rate of DDC and for diet containing synthetic antioxidant (positive control), may be due to the effect of antioxidant activities that gave ability to organism of these chickens to react positively to oxidative stress. For the present study, its appears clearly that uric acid has functioned as an antioxidant in broiler chickens as observed for humans as well, where its effect is greater than vitamin C used in this experiment (Waring, Webb & Maxwell 2001, pp. 369-368). According to Machin et al. (2004, p. 383), uric acid is an important antioxidant and methods to elevate its plasma concentration may be important in animal health. Indeed, previous studies in birds have shown a negative relationship between plasma uric acid concentrations and oxidative stress (Klandorf et al. 2001, p. 93 ; Simoyi, Van Dyke & Klandorf 2002, p. 795 ; Machin et al. 2004, p. 388; Seaman et al. 2008, p. 674). The ability of an antioxidant to scavenge reactive oxygen species is important in genome maintenance as originally put forth by Harman (1956, pp. 298-300). However, the uric acid recorded in this study was lower than 63.9 to 65.8 mg/l reported by Donsbough et al. (2010, p. 290) with a supplemental amino acids diet. From this result, these data demonstrate that uric acid is sensitive to dietary antioxidant content for broiler chickens. Oxidative processes are the most important factors responsible for deterioration of meat quality (Kanner 1994, p. 169; Nissen et al. 2004, p. 494). So, the application of the natural antioxidants such as DDC could be used to improve poultry meat quality, mainly with low body fat deposit.

CONCLUSION

Results in this research have shown evidence that the broilers tolerate inclusion levels of DDC in the diet as energy source feed ingredient to replace partially maize and also act as natural antioxidant for broiler. Furthermore, dietary DDC inclusion improves growth performance, FCR, carcass yield and meat quality of broilers. The DDC used as feed ingredient did not induce any adverse effects on chicks' health and blood profiles. The results suggested that DDC can be used in the diet of broilers up to 12% inclusion level without being detrimental to their performance. Also, it can be applied as alternatives to in-feed antioxidant for broiler diets.

Further investigations in different situations should be conducted to achieve more comprehensive results, mainly layer performance, egg qualities and economic aspects.

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