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Effect of Maize (*Zea mays*) Substitution by Sprouted Off-season Sorghum (*Sorghum bicolor* L. Moench) on the Growth and Physiological Response of Broiler Chickens (*Gallus gallus*) in Maroua, Far North, Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

With a view to finding an alternative to maize in the composition of poultry feed, a study was carried out to assess the effect of replacing maize with sprouted off-season sorghum on the growth performance and physiological response of broiler chickens at start-up. To achieve this, 180, one

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day-old chicks of the "Cobb 500" strain with a live weight of 34±3.26 g were randomly divided into 09 batches corresponding to 03 treatments with 3 replicates of 20 subjects. The batches were fed one of 03 rations : 100 % maize (R0), 50 % maize and 50 % sprouted off-season sorghum (R1) and 100 % sprouted off-season sorghum (R2). Every week, feed intake, weight gain and feed conversion ratio were evaluated. At 21 and 42 days of age, carcass characteristics and some haematological and biochemical parameters were assessed. Results showed that feed intake, feed conversion ratio and carcass yield were not significantly affected by the substitution of 50% and 100 % corn by sprouted off-season sorghum. Average daily gain was significantly affected by the substitution of 50 % maize by sprouted off-season sorghum. However, compared with the control ration (100 % maize), the ration containing 100 % germinated off-season sorghum significantly increased the relative weights of the pancreas and proventriculus. Serum levels of transaminase, glucose, total protein, albumin and globulin were not statistically modified when 50 % and 100 % corn were replaced by germinated off-season sorghum. Analysis of haematological parameters showed that the ration containing 50 % maize and 50 % germinated off-season sorghum significantly reduced ($p<0.05$) red blood cell concentration and significantly increased ($p<0.01$) mean corpuscular volume (MCV) and mean corpuscular haemoglobin content (MCHC). It can therefore be concluded that corn can be 100 % substituted by sprouted off-season sorghum, without any deterioration in broiler growth performance.

Keywords: Broilers; off-season sorghum; zootechnical performance; germination; haematological and biological parameters.

1. INTRODUCTION

The worldwide shortage of animal protein is a real problem that many countries face in the fight against food deficit. In Africa, around 20 % of the population is undernourished [1]. The poultry industry is more specifically modern poultry farming which has emerged in recent years as an attractive solution to offset the ever-increasing demand for animal protein [2]. This sector occupies a prime position in Cameroon's livestock sector due to the short rearing cycle of the species that make it up its low price, ease of production, and appreciable nutritional qualities [3]. The development of the poultry sector has an important role to play in the fight against food insecurity in Africa in general, and in Cameroon in particular where protein requirements are increasing all the time [4]. One of the major constraints limiting the development of poultry farming is the high cost of broiler feed, which represents 60 to 70 % of the total cost of feed production [5]. The high cost of maize on the market (around 250 to 300 FCFA/kg) is the problem that links the quality and cost of feed which is currently increasingly expensive (around 15500 to 17000 FCFA for a 50kg bag). The high demand for maize for human and animal consumption in Cameroon in general, and in the northern part of the country in particular, has led to inflation in market prices, which is increasingly slowing down the development of the poultry sector [6,7]. In addition, the import of inputs at very high prices is leading to broiler production at prices beyond the reach of the population [8,9]. To reduce production costs, one sustainable solution seems to be the use of alternative raw materials to the main ingredients, such as maize, soya meal, fish meal, etc. [10,11]. Sorghum seems to be one of the sustainable solutions for the substitution of maize, as it is widely used in the Sudan-Sahelian zone for traditional chicken rearing Numerous studies have been carried out on substituting corn with low-tannin white and red rainfed sorghum at rates of 25, 40, 50, 75 and 100 % in poultry. The results of these sorghum-based rations showed that total substitution of maize by low-tannin white and red rainfed sorghum did not affect the growth performance of broilers in the growth-finishing phase [12,13]. In Cameroonand especially in the Sahelian zone, rainfed sorghum production remains very low due to climatic constraints and low adoption by farmers [14]. One of the most widely available cereals on the market in Cameroon's Sahelian zone is off-season sorghum, which production in the 2014-2015 season was around 1.099 million tonnes. It increased by just over 200,000 tonnes each year [15], eventually reaching 2 million tonnes in 2020 [16] The Agricutural Research institute for Development estimates off season sorghum production at over 2300000 tonnes in 2023 [17]. Work on the use of this variety in broiler feed remains scarce. The aim of the present work is therefore to assess the effects of substituting sprouted off-season sorghum for maize on the zootechnical, haematological and biochemical performance of broilers in the start-up phase.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was carried out from June to August 2022 in the town of Maroua, located at 10°35' N latitude, 14°19' E longitude and 384 m altitude in the Far North region of Cameroon. In the cool season, 30 °C in the rainy season and peak at 45 °C during periods of extreme heat [18].

2.2 Animal Material

A total sample of 180, day-old chicks with an average weight of 35 g, of Cobb 500 strain, obtained from the AGROCAM hatchery in Ngaoundéré was used. On arrival, the chicks were subjected to routine checks, including leg and beak condition and vivacity. They were each given lemon-enriched glucose water, followed by an anti-stress treatment to prevent any effects of transport stress. The animals were reared in the same building on wood shavings on the floor ; in 8/m^2 density boxes under the same environmental conditions. Water and food were provided ad libitum, in accordance with the recommendations of the ethics committee.

2.3 Experimental Setup

The chicks were randomly assigned, without sexing, to three batches of 60 chickens each. Each batch was randomized into three replicates of 20 birds each. Batch 1 or treatment R0 consisted of birds fed only a ration with 100 % maize without sprouted sorghum ; batch 2 or treatment R1 consisted of birds fed only a ration with 50 % maize, 50 % sprouted sorghum; and finally batch 3 or treatment R2 consisted of birds fed only a ration with 100 % sprouted sorghum.

2.4 Experimental Rations

The rations were formulated from various ingredients purchased at harvest time in the town of Maroua. Ingredients, such as concentrate, lysine and methionine were used on the basis of the nutritional characteristics indicated on the labels. Other ingredients such as off-season sorghum, corn, peanut meal and corn bran were analyzed. A 100 g packet of each of these ingredients was sent for bromatological analysis (Table 1) to the Animal Nutrition and Feeding Laboratory of the Faculty of Agronomy and Agricultural Sciences at the University of Dschang (FASA).

Three isoenergetic and isoproteinic starter rations were formulated. The centesimal values of the ration ingredients are given in Table 2 and Table 3.

2.5 Data Collection

2.5.1 Growth parameters

To determine live weight, the animals were weighed on the first day, then weekly. The quantity of food to be distributed was weighed daily, and rejected food was removed from the food troughs the following day and weighed using a precision digital balance with 1g sensitivity.

Individual food intake (IFA) [19]: Expressed in g/subject/d, it was obtained using the formula:

IFA= quantity of feed distributed -quantity of feed refused/ number of animals

Table 1. Chemical composition of off-season sorghum, maize, groundnut cake and maize bran

Samples	Dry matter (%)	Organic matter (% MS)	Crude protein (% MS)	Raw cellulose (% MS)	Fat (% MS)	Gross energy (Kcal/kg MS)	Metabolizable energy (Kcal/kg MS)
Corn bran	90.90	92.38	1.20	7.80	4.30	4220	2460
Groundnut cake	95.62	93.52	37.68	11.15	13.32	5201.18	3422.45
Corn	95.05	98.49	7.98	3.41	3.68	4400.15	3787.72
Sprouted sorghum	95.67	98.49	6.99	3.22	3.06	4359.94	3770.41

DM: Dry matter; Kcal/kg DM: Kilocalorie per kilogram of dry matter

Table 2. Centesimal and nutritional composition of experimental diets in the start-up phase

Ingredients	Corn-based feed Ration R_0 (%)	Corn and sorghum sprout feed Ration R_1 (%)	Sprouted sorghum feed Ration R_2 (%)
Corn	40	20	00
Sound	15	15	14.50
Sprouted sorghum	00	20	40.50
Groundnut cake	37.50	37.50	37.50
5 % concentrate	5	5	5
Bone powder	1	1	1
Shell	1	1	1
Kitchen salt	0.20	0.20	0.20
Lysine	0.15	0.15	0.15
Methionine	0.15	0.15	0.15
Total	**100**	**100**	**100**
Calculated nutritional values			
Crude protein	**20.77**	**20.87**	**20.87**
Metabolizable energy (Kcal/kg DM)	**3253.74**	**3250.38**	**3254.54**
Energy / Protein	**156.28**	**155.76**	**155.92**

%: percent; Kcal/kg DM: Kilocalorie per kilogram of dry matter

Table 3. Centesimal and nutritional composition of experimental diets in the growing/finishing phase

Ingredients	Corn-based feed Ration R_0 (%)	Corn and sorghum sprout feed Ration R_1 (%)	Sprouted sorghum feed Ration R_2 (%)
Corn	42.5	21.25	00
Sound	15	14.75	14.50
Sprouted sorghum	00	21.25	43
Groundnut cake	35	35	35
5 % concentrate	5	5	5
Bone powder	1	1	1
Shell	1	1	1
Kitchen salt	0.20	0.2	0.20
Lysine	0.15	0.15	0.15
Methionine	0.15	0.15	0.15
Total	**100**	**100**	**100**
Corn	**Calculated nutritional values**		
Sound	18.85	19.05	18.95
Sprouted sorghum	3150.4565	3180.3301	3158.65
Groundnut cake	167.13	166.94	166.68

%: percent

Energy intake (EI): The energy intake (EI) is obtained by multiplying the metabolizable energy of the feed by the average daily consumption. (ADC)

EI = EM x ADC

Protein intake (PI): Protein intake (PI) is obtained by multiplying the crude protein content of the ration by the average daily intake.

PI = PB x ADC

Consumption index (CI): This was determined by dividing individual weekly feed intake by total weight gain in the same week [19]:

Individual weekly food consumption/ weekly weight gain

Average daily gain (ADG): This was obtained by dividing the weight gain (live weight (n+1) - live weight (n)) recorded during a week by seven (number of days in the week) [19].

ADG= (live weight (n+1) - live weight (n)) / (period length)

Carcass yield (CR): Expressed as a percentage (%), carcass yield (CR) is calculated from data on live weight at slaughter and carcass weight [19].

RC= (Carcass weight) / (live weight)

2.5.2 Carcass characteristics

On the eve of the 21st and 42nd days of age, the animals were subjected to fasting. Three animals per batch were sacrificed, as recommended by animal welfare ethics. The plucked bled weight was taken and they were eviscerated. Carcass weight and organ weights, including empty gizzard, liver, small intestine, legs, head, heart, spleen, pancreas, abdominal fat and intestine length were taken using 5 kg precision, 0.1g sensitivity scales.

2.5.3 Hematological parameters

At the end of each phase, 2 to 4 ml of blood was collected from the wing vein using a syringe-mounted epicranium from dry tubes (without anticoagulant) and EDTA tubes [20]. Hematological parameters such as red blood cell (RBC) count were determined by light microscope counting as described by the method of Natt and Herrick [21]. Hemoglobin, hematocrit and erythrocyte indices were determined in the laboratory using an SNFSBC30S automatic analyzer.

2.5.4 Biochemical parameters

Blood collected in dry tubes (without anticoagulant) was left to rest, and serum collected the following morning was used to determine biochemical parameters. Serum levels of glucose, total protide, albumin, GTP and GOT were determined by colorimetric methods following the protocols described by commercial Human assay kits. The URIT 810 spectrophotometer was used to read optical densities.

2.6 Statistical Analysis of Data

Growth, haematological and biochemical parameters were presented as mean±standard deviation. Analysis of variance using Graphpad Sprint 5 software was used to test the effect of different rations on growth performance, haematological and biochemical parameters. Means were compared using the Turkey test at the 5 % threshold.

3. RESULTS

3.1 Start-Up Phase

3.1.1 Growth performance

3.1.1.1 Growth parameters

Table 4 presents the growth parameters of broilers fed diets containing different rates of intake of sprouted off-season sorghum. It appears that the average daily consumption, energy intake, protein intake and food efficiency were not significantly affected at the 5 % threshold by the different experimental rations. The average daily gain was significantly decreased with diets where corn was 50 % substituted by sprouted off-season sorghum, compared to the control diet containing only corn ($p < 0.05$).

Table 4. Broiler growth parameters based on experimental diets

Parameters	Treatments			P
	R0	R1	R2	
ADC (g)	34.64±1.96^{a}	35.81±1.77^{a}	34.27±3.28^{a}	0.3925
IE	136137±6.91^{b}	138639±5.67^{b}	140089±5.81^{b}	0.7800
IP	888.10±4.56^{b}	896.80±3.96^{b}	895.9±3,61^{b}	0.9997
ADG (g)	21.94±5.21^{a}	19.62±4.60^{b}	20.14±4.61^{ab}	0.0246
FE	1.79±0.61^{a}	1.89±0.59^{a}	1.844±0.50^{a}	0.9401
Cost of 1kg of feed (FCFA)	253.50±0.31^{a}	245.75±0.46^{ab}	240.75±0.38^{b}	0.001
Feed cost per 100g body weight (FCFA)	562.06±0.46^{a}	549.78±0.52^{ab}	539.18±0.41^{b}	0.001

Values with the same letter on the same line are not significantly different at the 5 % level. ADC : Average Daily Consumption ; IE : Ingested Energy ; IP : Ingested Protein ; ADG : Average Daily Gain ; FE : Feed Efficiency ; IP : Ingested Protein ; FCFA= CFA francs

Table 5. Carcass characteristics of broilers fed diets containing different levels of incorporation of sprouted off-season sorghum

Parameters	Treatments			P
	R0	R1	R2	
Carcass yield %	0.55±1.96[a]	0.55±5.94[a]	0.58±5.54[a]	0.4409
Gut %	0.09±0.01[a]	0.09±0.00[a]	0.09±0.014[a]	0.4985
Gizzard %	0.02±0.00[a]	0.02±0.00[a]	0.02±0.00[a]	0.9506
Legs %	0.03±0.00[a]	0.04±0.00[a]	0.04±0.00[a]	0.3827
Liver %	0.02±0.00[a]	0.02±0.00[a]	0.02±0.00[a]	0.3868
Length of intestine %	0.37±0.06[a]	0.36±0.02[a]	0.39±0.05[a]	0.5980
Diameter of the intestine %	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.3896
Proventricule %	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[b]	0.0193
Heart %	0.00±0.00[b]	0.00±0.00[b]	0.00±0.00[b]	0.6311
Rate %	0.00±0.00[b]	0.00±0.00[b]	0.01±0.00[b]	0.6203
Abdominal fat %	0.00±0.00[b]	0.00±0.00[b]	0.00±0.00[b]	0.0940
Pancreas %	0.00±0.00[a]	0.00±0.00[ab]	0.00±0.00[b]	0.0435

Values with the same letter on the same line are not significantly different at the 5% level

Table 6. Biochemical parameters of broiler chickens fed diets at different levels of incorporation of sprouted off-season sorghum

Parameters	Treatments			P
	R0	R1	R2	
GOT U/L	34.78±2.10[a]	36.11±2.93[a]	36.33±8.97[a]	0.8166
GPT U/L	49.22±1.09[b]	49.11±0.78[b]	46.44±4.27[b]	0.0531
Albumin	56.44±3.28[a]	58.22±4.11[a]	57.67±3.77[a]	0.5941
Glucose	0.80±0.04[a]	0.83±0.10[a]	0.83±0.14[a]	0.7269
Total Protein	92.00±4.84[b]	91.22±3.11[b]	93.56±4.55[b]	0.5035
Globulin	37.89±5.02[b]	33.44±4.50[b]	35.89±6.03[b]	0.4390

Values with the same letter on the same line are not significantly different at the 5 % level ; GOT : Aminotransferase ; GPT : aspartate aminotransferase

Table 7. Haematological parameters of broiler chickens fed diets at different levels of incorporation of sprouted off-season sorghum

	Treatment			
Parameter	R0	R1	R2	P
RBCs	2.55±0.37[ab]	1.92±0.21[a]	2.63±0.95[b]	0.0380
H	139.60±16.12[b]	129.40±10.10[b]	143.00±52.46[b]	0.6551
HCT	36.70±5.19[a]	32.81±4,84[a]	34.58±5.20[a]	0.2862
MCV	144.30±7.49[ab]	173.40±19.44[b]	137.60±3,62[ab]	<0.0001
MCHC	55.00±2.58[ab]	67.39±7.50[b]	54.11±1.03[ab]	<0.0001
MCHL	381.90±16.96[b]	393.20±12.62[b]	393.70±15.32[b]	0.7582

Values with the same letter on the same line are not significantly different at the 5 % level. RBCs: Red blood cells; H: Hemoglobins; HCT: Hematocrit; MCV: Mean blood cell volume; MCHC: Mean corpuscular haemoglobin concentration; MCHL: Mean corpuscular haemoglobin

3.1.1.2 Characteristics of the carcass

Carcass characteristics of broilers fed diets containing different levels of incorporation of sprouted off-season sorghum are presented in Table 5. As a result, the carcass yield and the relative weight of most organs between treatments were not significantly affected at the 5 % threshold by the different experimental rations. In contrast, the relative weight of the pancreas and proventricle was significantly higher (p <0.05) for the diet containing 100 % sprouted off-season sorghum compared to the R0 control diet (100 % corn).

3.1.1.3 Biochemical and haematological parameters

The values and concentrations of the different biochemical and haematological parameters of the blood samples taken from the broiler chickens used generally showed non-significant differences at the 5 % level.

Biochemical parameters: The effect of the incorporation of sprouted off-season sorghum on the biochemical parameters of early-stage broilers is summarized in Table 6. The effect of the incorporation of sprouted off-season sorghum on the biochemical parameters of early-stage broilers is summarized in Table 6. It was found that serum levels of aminotransferase (AST or GOT), aspartate aminotransferase (ALT or GPT), albumin, glucose, total protein and globulin were not significantly influenced by the experimental diets used.

Hematological parameters: The effect of the incorporation of sprouted off-season sorghum on haematological parameters in early-stage broilers is summarized in Table 7. It can be seen that the mean corpuscular concentration of haemoglobin, haematocrit and haemoglobin content were not significantly influenced by the experimental diets used. However, the red blood cell count of chickens fed the R1 diet (50 % sprouted sorghum) was significantly reduced ($p < 0.05$), while their mean blood cell volume and mean corpuscular haemoglobin count were significantly higher ($p < 0.01$) compared to other treatments. Compared to the control, blood platelet levels were significantly decreased ($p < 0.01$) in chickens fed a diet containing sprouted off-season sorghum.

3.2 Growth-Finishing Phase

3.2.1 Growth performance

3.2.1.1 Growth parameters

Table 8 presents the growth parameters of broilers fed diets containing different rates of intake of sprouted off-season sorghum. It can be seen that the average daily consumption, the energy intake, the protein intake and the feed index, the average daily gain were not significantly affected at the 5 % threshold by the different experimental rations.

Table 8. Broiler Growth Parameters Based on Experimental Diets

Parameter	Treatment			P
	R0	R1	R2	
ADC (g)	97.33±5.85^{a}	98.99±4.64^{a}	97.83±3.77^{a}	0.884
ADG (g)	53.41±17.54^{a}	54.05±16.68^{a}	54.25±15.56^{a}	0.997
FE	1.99±0.65^{a}	1.97±0.63^{a}	1.91±0.52^{a}	0.981
IE	314419.60±6.91^{a}	321750.10±5.67^{a}	316837.10±5.81^{a}	0.78
IP	1834.67±4.56^{a}	1885.75±3.96^{a}	1853.87±3.61^{a}	0.9997
Cost of 1kg of feed (FCFA)	253.50±0.31^{a}	245.75±0.46^{ab}	240.75±0.38^{b}	0.001
Feed cost per 100g body weight (FCFA)	562.06±0.46^{a}	549.78±0.52^{ab}	539.18±0.41^{b}	0.001

Values with the same letter on the same line are not significantly different at the 5 % level. ADC: Average Daily Consumption; ADG: Average Daily Gain; FE: Feed Efficiency; IE: Ingested Energy; IP: Ingested Protein; FCFA=CFA francs

Table 9. Carcass characteristics of broilers fed diets containing different levels of incorporation of sprouted off-season sorghum

Parameter	Treatment			P
	R0	R1	R2	
Carcass yield (%)	0.61±0.01^{a}	0.62±0.01^{a}	0.63±0,02^{a}	0.3010
Intestine (%)	0.07±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	0.3630
Gizzard (%)	0.02±0.00^{a}	0.02±0.00^{a}	0.02±0.00^{a}	0.8210
Liver (%)	0.02±0.00^{a}	0.02±0,00^{a}	0,02±0,002^{a}	0,730
Length of the intestine (%)	0.19±0.02^{a}	0.19±0.01^{a}	0.19±0.01^{a}	0.6970
Diameter of the intestine (%)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.0620
Proventricule (%)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.2150
Heart (%)	0.00±0.00^{a}	0.00±0,00^{a}	0.00±0.00^{a}	0.2760
Spleen (%)	0.00±0.00^{a}	0.000±0.00^{a}	0.00±0.00^{a}	0.0970
Pancreas (%)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.5380
Abdominal fat (%)	0.00±0.00^{a}	0,009±0,005^{a}	0.00±0.00^{a}	0.0740

Values with the same letter on the same line are not significantly different at the 5 % level; %: percent

Table 10. Biochemical parameters of broiler chickens fed diets at different levels of incorporation of sprouted off-season sorghum

Parameter	Treatments			P
	R0	R1	R2	
GOT (U/L)	42,33±6,67[a]	41,11±2,97[a]	39,78±1,92[a]	0,473
GPT (U/L)	52,44±4,36[a]	51,67±4,21[a]	50,78±1,30[a]	0,620
Total Protein (g/l)	113,44±65,90[a]	91,67±3,87[a]	91,56±3,90[a]	0,390
Albumin (g/l)	49,22±4,81[a]	46,78±4,65[a]	44,67±4,03[a]	0,112
Glucose	0,80±0,11[a]	0 ,79±0,18[a]	0,80±0,15[b]	0,0692
α Amylase	46,01±12,79[a]	53,88±13,53[a]	59,11±10,09[a]	0,094
Globulin	42,75 ± 7,302[a]	41,44 ±6,313[a]	43,9 ± 5,830[a]	0,0790

Values with the same letter on the same line are not significantly different at the 5 % level. GOT : Aminotransferase; GPT: Aspartate aminotransferase

Table 11. Haematological parameters of broilers fed diets at different levels of incorporation of sprouted off-season sorghum

Parameter	Treatments			P
	R0	R1	R2	
WBCs	107.38±4.64[a]	106.62±5.85[a]	99.60±4.74[a]	0.610
RBCs	4.72±4.35[a]	3.88±5.55[a]	5.03±6.25[a]	0.869
MBCV	132.33±3.77[a]	130.67±4.84[a]	130.89±4.88[a]	0.773
MCHC	63.14±4.73[a]	63.54±4.19[a]	65.62±5.38[a]	0.426
MCHT	49.20±2.00[a]	48.64±2.88[a]	50.04±2.11[a]	0.366
CLDR	11.82±0.62[a]	12.21±0.68[a]	11.84±0.60[a]	0.365
PL	173.44±30.79[a]	161.56±29.68[a]	153.89±31.13[a]	0.459
VPM	6.60±0.30[a]	6.55±0.25[a]	6.76±0.29[a]	0.264
CLDP	35.97±1.04[a]	35.75±1.07[a]	36.04±0.99[a]	0.850

Values with the same letter on the same line are not significantly different at the 5 % level. WBCs: White blood cells; RBCs: Red Blood Cells; MBCV: Mean Blood Cell Volume (MCV); MCHC: Mean Corpuscular Hemoglobin Concentration; MCHT: Mean Corpuscular Hemoglobin Concentration; CLDR; PL; VPM; CLDP

3.2.1.2 Characteristics of the carcass

The carcass characteristics of broilers fed diets containing different levels of incorporation of sprouted off-season sorghum are presented in Table 9. As a result, carcass yield and the relative weight of organs between treatments were not significantly affected at the 5 % threshold by the different experimental rations.

3.2.2 Biochemical and haematological parameters

The values and concentrations of the different biochemical and haematological parameters of the broiler blood samples used generally showed non-significant differences at the 5 % level ($p < 0.05$).

3.2.2.1 Biochemical parameters

The effect of the incorporation of sprouted off-season sorghum on the biochemical parameters of early-stage broilers is summarized in Table 10. It was found that serum levels of aminotransferase (AST or GOT), aspartate aminotransferase (ALT or GPT), albumin, glucose, total protein and globulin were not significantly influenced by the experimental diets used.

3.2.2.2 Haematological parameters

The effect of the incorporation of sprouted off-season sorghum on haematological parameters in early-stage broilers is summarized in Table 11. It appears that the mean corpuscular concentration of haemoglobin, haematocrit and haemoglobin content were not significantly influenced by the experimental rations used.

4. DISCUSSION

4.1 Growth Parameters

Food consumption was not affected by the partial or total substitution of sprouted off-season sorghum for maize. This could be explained at least in part by the fact that the different rations were isoenergetic and isoproteinic. Energy intake was not statistically modified by the different treatments. The results obtained are similar to those observed by [22], who showed that substituting whole sorghum for coarsely ground maize in broiler food did not affect food intake. However, these results differ from those of [13], who reported that substituting sorghum for maize in the broiler ration would reduce feed consumption. This controversy could be attributed to the effect of malting. Sorghum contains tannins, which are anti-nutritional factors that can reduce feed palatability and feed efficiency [23]. Consequently, malting sorghum would reduce anti-nutritional factors and thus improve its palatability for broilers. Indeed, germination enables the enzymes present to predigest the various proteins, fats and carbohydrates in the seed [24]. [25] have demonstrated that germination improves the digestibility of cereal proteins by breaking down some of the gluten they contain. Average daily weight gain (ADG) was significantly reduced ($p <0.05$) with the 50 % corn 50 % sprouted off-season sorghum ration, compared with the corn-only control ration in the start-up phase ; however, in the finishing growth phase, average daily weight gain (ADG) was not significantly affected with the 50 % and 100 % sprouted off-season sorghum rations, compared with the corn-only control ration. This result corroborates those of [26] and [27], in whom daily weight gains were higher ($p <0.001$) for corn-fed chickens than for sorghum-fed chickens.

4.2 Carcass Characteristics

Carcass yield and the relative weight of most organs between treatments were not significantly affected at the 5 % level by the different experimental rations. The lack of significance for relative organ weights indicates good food quality, as inadequate feed usually leads to significant pathological changes in most organs [28].

A lack of significance in relative organ weight indicates good digestive enzyme activity [29]. On the other hand, the relative weights of the pancreas and proventriculus were significantly increased ($p <0.05$) for the ration containing 100 % sprouted off-season sorghum, compared with the control R0 ration (100 % maize) at start-up. The increase in the relative weight of these two organs is thought to be due to an increase in enzymatic activity : the pancreas secretes pancreatic juice, which plays a role in solubilizing nutrients along the small intestine, and the proventriculus secretes pepsin, which is involved in protein hydrolysis [29].

4.3 Hematological and Biochemical Parameters

With regard to biochemical parameters, the study showed that serum levels of aminotransferase, aspartate aminotransferase, albumin, glucose, α-amylase, total protein and globulin n as well as serum levels of aminotransferase, aspartate aminotransferase, albumin, glucose, total protein and globulin were not significantly influenced by experimental rations. In fact, a decrease or increase in biochemical parameters indicates fasting, poor nutrition or inadequate feeding. These results show that the different rations had no negative impact on the health of the subjects, as shown by [30]. On biochemical and haematological parameters in sorghum-fed ostriches. Results for haematological parameters show that mean corpuscular haemoglobin concentration, haematocrit and haemoglobin content were not significantly influenced by the experimental rations used. However, the number of red blood cells in chickens fed ration R1 (50 % sorghum sprout) was significantly reduced ($p <0.05$), while their mean blood volume and mean corpuscular hemoglobin concentration were significantly increased ($p <0.01$). These results may be due to the corn/sorghum sprout combination in the R1 ration (50 % sorghum sprout), which is thought to have an impact on hematopoiesis. These results are in line with those of [31], who demonstrated that the administration of a reconstituted sorghum-based diet to broilers exerted no appreciable influence on nutrient utilization, blood biochemicals, enzymes and normal hematological values in hens. [32,33] showed that diet has an impact on haematological parameter values in broilers.

5. CONCLUSION

The aim of this study was to evaluate the effects of replacing maize with sprouted off-season sorghum on the zootechnical, haematological and biochemical performance of broilers in the start-up and finishing growth phases. Broilers fed the 100 % sprouted off-season sorghum ration showed comparable characteristics to those fed the control ration. However, the average daily gain of broilers fed a ration containing 50 % corn and 50 % sprouted off-season sorghum in the start-up phase was significantly lower ($p<0.05$)

than that of broilers fed the control ration. Sprouted off-season sorghum can be incorporated as a total replacement for maize in broiler diets without any deterioration in zootechnical, haematological or biochemical performance.

ETHICAL APPROVAL

Animal Ethic committee approval has been collected and preserved by the author(s)

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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