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THE GROWTH PERFORMANCE, CARCASS CHARACTERISTICS AND BLOOD PROFILE OF BROILERS FED ON YELLOW MAIZE STORED IN POLYPROPYLENE AND ZEROFLY® HERMETIC BAGS

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ABSTRACT

This experiment was conducted to determine the growth performance, blood profile and carcass characteristics of broilers fed yellow maize stored in Polypropylene (PP) and ZeroFly® Hermetic (ZFH) storage bags for six months. Two hundred unsexed day-old Cobb-500 broiler chicks were randomly allocated to 2 treatments (2 storage bags) with 100 chicks per treatment in a Completely Randomized Design experiment. Each treatment had four replications with 25 birds per replicate. The experimental diets were formulated using the same quantities of maize stored in the PP and ZFH bags. The study was in three phases, that is, starter, grower and finisher phases and each had 22%, 20% and 18% crude protein (CP), respectively. The experiment lasted for six weeks. Feed and water were offered *ad libitum*. Statistical analyses were performed with SAS Version 9.4. Effects of storage bags were assessed using a one-way analysis of variance (ANOVA). Tukey's Honestly Significant Difference test was used as an option in the Mixed Procedure to determine differences between means ($p < 0.05$). Broilers on the ZFH bag dietary treatment recorded significantly ($p = 0.035$) higher weight gain in grams (2395.11 ± 32.15), than their counterparts on the PP treatment (1980.30 ± 82.19). The feed conversion ratio, measured as feed: gain ratio, was better ($p = 0.041$) for the ZFH birds (1.74 ± 0.03) than the PP birds (2.24 ± 0.19). Birds fed the ZFH diet had higher ($p < 0.05$) dressing percentage (74.05 ± 0.24), percentage whole thigh (14.45 ± 0.10) and percentage drumstick (9.22 ± 0.16) than their PP counterparts. All the blood profile parameters measured were similar except total cholesterol and aspartate aminotransferase in which birds on the ZFH maize recorded higher values ($p < 0.05$). It was concluded that maize stored in ZeroFly® hermetic storage bags could be fed to broilers for better feed efficiency and carcass yield.

Key words: Deltamethrin, grain storage technique, mycotoxin contamination, post-harvest loss

INTRODUCTION

Undoubtedly, the two most indispensable nutrients in the diets of poultry are carbohydrates and proteins because they represent virtually 90% of the total cost of the ingredients in a ration of the bird, and also their influence on voluntary feed intake [1]. Between the two nutrients, the carbohydrates generally constitute at least 50% or more of the poultry diets and basically the main energy source. The primary carbohydrate sources are the cereal grains which include maize (*Zea mays*), rice (*Oryza sativa*), millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*). Maize is by far the most common and important staple cereal food crop in sub-Saharan Africa. It is grown on the vast majority of smallholder farms, not affected by the different agroecological zones and is consumed by people with diverse socio-economic backgrounds in the tropics [2]. In Ghana, maize consumption has culminated into high domestic demand, thus increasing its production from 2 million metric tons to 3.1 million metric tons between 2017 and 2020 [3].

However, it has been reported that, huge post-harvest losses of maize in terms of consumer quality features and value occur recurrently in developing countries as a result of inappropriate post-harvest handling, processing and storage techniques; invasion by insects, rodents, birds and other pests; and contamination by spoilage fungi and bacteria [4]. For instance, according to a report of the FAO [5], post-harvest loss of maize in Ghana in 2012 skyrocketed to 70%. In developing countries, farmers store their maize in bags, baskets, clay structures, on the field, in homes, on raised platforms and in conical structures [6]. Currently, the preferred grain storage technique in most developing countries is bag storage [7]. Studies conducted in the Middle Belt and Northern Region of Ghana have shown that temporary heaping of harvested maize on the ground, in the field, leads to insect infestations and an increase in mycotoxin levels [8, 9]. In the case of Ghana, this means post-harvest losses of bagged maize caused by mycotoxin contamination and insect pest infestation likely commence in the field, and usually get exacerbated during storage in mostly polypropylene (PP) bags. Post-harvest maize loss is still pervasive across Africa, and therefore requires urgent solutions to ensure food safety and security.

It has been reported that ZeroFly® Hermetic (ZFH) Storage bags reduce post-harvest maize losses caused by stored product insect pests in bagged grain [10]. Similarly, a study by Bosomtwe *et al.* [11] demonstrated that the deltamethrin-incorporated polypropylene ZFH bag produced by Vestergaard SA, Lausanne, Switzerland, also offers effective protection to stored maize against insect pests and mycotoxins. Unlike the Purdue Improved Crop Storage (PICS) bag, the ZFH bag comprises a single inner liner with an outer deltamethrin-incorporated

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polypropylene fabric. In ZFH bags, the deltamethrin incorporated in the yarns of the outer layer also serves as a barrier to infestation from outside, giving maize additional protection [10]. A study evaluated hermetic storage bags (that is, ZeroFly® Hermetic and Purdue Improved Crop Storage bags) and the polypropylene (PP) bag for the preservation of yellow maize at three poultry farms in Dormaa, Ghana, and concluded that the hermetic storage bags preserved the maize quality better than the PP bag by maintaining the nutrient content and keeping aflatoxin and fumonisin within safe levels for human and animal use [10].

Nevertheless, there is a dearth of information on the effects of maize stored in hermetic bags in the diets of poultry in the tropics. This study was therefore conducted to determine the growth performance, blood profile and carcass characteristics of broilers fed yellow maize stored in ZeroFly® Hermetic and polypropylene bags.

MATERIALS AND METHODS

Ethics Statement

All experimental procedures were conducted in strict accordance with the guidelines provided by the Institutional Animal Care Committee of the Kwame Nkrumah University of Science and Technology (Ethical Clearance Certificate KNUST-0004).

Source and Processing of the Yellow Maize

Specifically, for the ZFH and PP bags treatments, seventy-two 100-kg capacity ZFH and PP bags, each containing 50 kg of clean, untreated (insecticide-free) yellow maize (Abontem variety) of approximately 13% moisture content were purchased directly from a farmer from Chiraa, in Sunyani, Ghana in 2022, and transported to a single storehouse location provided by the producer. The bags of maize were emptied onto a tarpaulin and thoroughly mixed, and 50 kg was transferred to each of a 100-kg capacity ZFH and PP bags and kept in three different storehouses of three poultry farms; Evans Joes Farms, T. K. Farms, and M. M. Unity Farms, all in Dormaa Ahenkro, Bono Region, Ghana (7°17' N2°53' W), for 6 months. In all, there were twelve 100-kg capacity bags each of ZFH and PP per storehouse making a combined total of 36 bags of each treatment in all the 3 storehouses. The bags were arranged in a horizontal pattern, on two wooden pallets for each of the different storage conditions with 6 bags on each of the pallets. The pallets were placed 2 m apart for the different storage conditions. Prior to using the hermetic bags, the inner and outer liners were checked to ensure that there were no perforations and they were tightly sealed afterward to maintain hermeticity.

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Study Location, Experimental Treatments, Birds and Design

The study was conducted at Gye Nyame Farms in Dormaa Ahenkro (7°17'N 2°53'W). Two types of storage bags (PP and ZFH bags) served as the experimental treatments and the feeding trial lasted for 42 days. The maize stored in the PP and ZFH bags was collected after the 6-month period and used to formulate feed for the experimental birds. Two hundred unsexed day-old Cobb-500 broiler chicks were randomly allotted to the 2 treatments. There were 100-day-old chicks per treatment, and each treatment had four replications with 25 birds per replicate and the study set-up was a Completely Randomized Design (CRD). The two experimental diets were formulated using the same quantities of maize stored in the ZFH and PP bags. The diets were in three phases (starter, grower and finisher phases) which contained 22%, 20% and 18% crude protein (CP), respectively (Table 1), and they were formulated to meet the National Research Council requirements [12]. The quantities of maize at each phase were the same for the 2 treatments as reported earlier. The birds were fed *ad libitum* and each phase lasted for 2 weeks making a six-week feeding period. The chicks were group-housed in units of 25 birds per unit and each bird occupied 0.11 m^2 floor space. There were eight separate units (1.83 m x 1.52 m). Prior to the commencement of the experiment, all the units were thoroughly cleaned and disinfected with a standard disinfectant (Omnicide). Disinfected wood shavings were spread on the floor to about 6-cm depth as litter for the birds. Thirty-watt electric bulbs were used to provide continuous light throughout the experimental period. Charcoal in pots was used as the heat source during the brooding stage and two temperature and relative humidity data loggers were hung in the pen to monitor the room temperature.

Data Collection

Growth Performance

The growth performance parameters measured included initial body weight, feed intake, water consumption, weight gain, final body weight, feed conversion ratio, water conversion ratio and mortality. Feed Conversion Ratio (FCR) and Water Conversion Ratio (WCR) were calculated as feed intake per unit weight gain and water consumption per unit weight gain, respectively, within the experimental period.

Carcass Characteristics

After the feeding trial period, the broilers were deprived of feed for 8 hours and fifteen birds per replicate were randomly selected and slaughtered. The carcasses were scalded in hot water (about 80^{o}C), de-feathered manually and eviscerated to obtain dressed carcass weight. Other carcass components considered were boneless breast, whole thigh, drumstick and wings. The relative weight of the dressed carcass weight, boneless breast, whole thigh, drumstick and wings were calculated by dividing a parameter by the bird's live weight, multiplied by 100.

Haematology and Serum Biochemistry Analysis

Five birds from each replicate were randomly selected for blood analysis. They were restrained and blood samples were drawn from their wing veins with a syringe and needle [13]. Two blood samples were collected from each bird into Ethylenediaminetetraacetate (EDTA)-containing tubes and sterilized micro tubes for haematology and serum biochemistry analysis. For the haematology, the samples were centrifuged at 3000 rpm for 5 minutes in a Thermo-spectronic automated analyzer and the parameters were determined: Red Blood Cells (RBC), Hematocrit (HCT), Haemoglobin (HGB), Mean Cell Haemoglobin (MCH), Mean Cell Volume (MCV), Mean Cell Haemoglobin Concentration (MCHC), White Blood Cells (WBC) and Platelets. For the serum biochemistry analysis, the blood samples were allowed to clot and centrifuged at 3000 rpm for 5 minutes to obtain the serum which was analyzed for total protein, albumin (ALB), total cholesterol, aspartate aminotransferase (AST), alanine aminotransferase (ALT), thyroglobulin (TG) and high-density lipoprotein (HDL).

Data Analysis

The experimental design was a Completely Randomized Design (CRD) of two treatments with four replications per treatment. Statistical analyses were performed with SAS Version 9.4 (SAS Institute, Cary, NC). Effects of storage bag (that is., ZFH and PP) were assessed using a one-way analysis of variance (ANOVA) (PROC MIXED). Tukey's Honestly Significant Difference test was used as an option in the Mixed Procedure to determine differences between means ($p < 0.05$).

RESULTS AND DISCUSSION

Growth Performance

The data for the indices of growth obtained in this study is shown in Table 2. Feed and water intakes were similar ($p > 0.05$) across the 2 treatments (that is., maize stored in PP and ZFH bags). This could imply that the palatability of the treatment diets was similar because all the birds consumed a similar quantity of feed. In an earlier study, it was reported that the moisture content of maize stored for six months in the ZFH bag (12.36-12.55%) recorded lower values than those stored in PP bag (12.47-15.51%) [10]. According to another report by Liu *et al*. [14], the moisture content of the feed to a certain degree has an effect on the consumption of water or water intake by chicken. Therefore, it was expected that broilers on the ZFH-bag-maize diet would consume a substantial quantity of water than boilers on the PP bag maize diet. It is important to note that the broilers fed the ZFH bag maize's water intake in relation to feed intake (that is. 1.7 parts of water to 1.0 part of feed) was within an acceptable range as reported by Fairchild and Ritz [15]. They reported that the quantity of water consumed by broilers was approximately 1.6 - 2.0 times as feed on a weight basis and again revealed that water intake could be used to monitor the performance of a flock because of its direct relationship with feed intake. On the other hand, broilers fed the PP maize recorded 1.4 parts of water to 1 part of feed. Broilers on the ZFH bag dietary treatment recorded significantly ($p < 0.05$) higher final weight and total weight gain compared to their counterparts on the PP bag maize diet. An experiment evaluated the various storage techniques of maize and their effect on nutrients preservation and aflatoxin contamination, and concluded that maize kept under hermetic condition minimized aflatoxin build-up and preserved nutrients [10]. According to another report [16], the decrease in the nutrients content of maize stored in PP bags was mainly as a result of the presence of internal feeding insect pests that feed on the endosperm and the pericarp which contains the highest portion of the nutrients, especially crude protein. It could therefore be inferred that the broilers fed the ZFH bag dietary treatment had access to most of the nutrients hence the substantial weight gain. With the FCR values, the ZFH bag diet was more efficiently utilized ($p=0.041$) in terms of feed: weight gain ratio than the PP bag diet (Table 2). Feed intake and weight gain are common indices in measuring FCR and therefore although similar feed intakes were recorded across the treatments, the significant change in weight gain of the ZFH bag broilers could have accounted for the better FCR. Also, it has been reported that aflatoxin contaminated feed leads to a reduction in feed efficiency in broilers by reducing the activities of specific enzymes involved in digestion and subsequent absorption of essential nutrients such as lipids, carbohydrates, protein and nucleic acids [17]. Again, there was a reduction in FCR of broilers fed with 0.5 ppm aflatoxin for 4 weeks and a meta-analysis of aflatoxin on FCR of broilers indicated that the adverse effect is prominent from 3-6 weeks of age [18, 19]. There is every indication that aflatoxin has a negative effect on FCR and therefore, higher aflatoxin levels in the PP bag could have accounted for the poor FCR ($p= 0.041$) recorded. The water conversion ratio and mortality (%) values recorded were similar ($p=0.779$) across the dietary treatments. According to earlier reports [20], water to weight gain ratio could be used as a tool in the selection of broiler population for water efficiency and recommended 2.6 to 3.6 as the ideal range.

Carcass Characteristics

Table 3 shows the carcass characteristics of the broilers fed the diets made from the maize stored in different bags (PP and ZFH bags). All the carcass parameters measured were significantly different ($p < 0.05$) among the treatments with broilers on the ZFH bag diet recording higher carcass values, except the % boneless breast and % wings which were similar to those of the PP bag diet birds. This conforms to an earlier report [21], which stated that the final liveweight or weight at slaughter of broilers was directly proportional to the carcass yield, and the dressing percentage could be correlated to the profitability of the enterprise. The primal cuts of chicken which include the thigh, drumstick, wing, and breast depict the meatiness of the carcass and ultimately revenue yield [22]. Therefore, heavier primal cuts are crucial, and meat processors and consumers put a premium on these cuts.

Blood Profile Studies of Broilers

Haematological and biochemical parameters are good indicators of the physiological status of animals, and are vital tools in helping in their nutrition, health and management [23]. All the blood profile indices examined were similar ($p > 0.05$) across the dietary treatments except the haemoglobin, aspartate aminotransferase and total cholesterol (Table 4). Haemoglobin is the component of red blood cells that carries oxygen and therefore, high level means an above-normal level of the iron-containing protein in the blood. Nonetheless, the haematological parameters measured were within the range reported for healthy broiler chickens [24]. Aspartate aminotransferase (AST) concentration is sometimes used as a biomarker for hepatic injury, though it is considered as less specific marker compared to Alanine Aminotransferase (ALT) as a result of expression from other tissues such as skeletal muscle cells, myocardial cells and brain [25]. Therefore, increased AST gives a hint to measure serum ALT to determine whether the increased AST is associated with liver malfunction or damage. In this study, the ALT values recorded were similar and this could imply that the different diets did not have any negative effect on the liver. Although broilers on the ZFH bag maize recorded higher ($p < 0.05$) total cholesterol values compared to the other treatment, the values were within the range of broilers kept in the tropics [26].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Broilers fed with maize stored in ZeroFly® Hermetic storage bags performed better in terms of weight gain, feed conversion ratio and carcass characteristics than broilers fed with maize in the polypropylene bags. The ZFH bag maize diet did not have any adverse effect on the blood profile parameters studied. Poultry farmers can therefore feed their birds with maize stored in ZFH storage bags for improved growth performance and carcass characteristics without any detrimental effect on their blood.

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Table 1: Composition (%) of the experimental diets

Ingredients (%)	Starter	Grower	Finisher
Maize*	56.03	61	62.1
Soybean Meal	36.4	30.63	27
Wheat Bran	1	2	3
Oil	3	3	4.5
Oyster shell	1.3	1.25	1.25
Common salt	0.25	0.25	0.25
Vit-min. premix#	0.25	0.25	0.25
Lysine	0.88	0.80	0.82
Methionine	0.89	0.82	0.83
Total	**100**	**100**	**100**
Composition (calculated)			
Metabolizable Energy (MJ/kg)	12.59	12.92	13.26
Crude Protein (%)	22	20	18
Calcium (%)	0.90	0.84	0.76
Available Phosphorus (%)	0.45	0.42	0.38

*Quantities of maize at each phase were the same for the ZeroFly® hermetic and polypropylene treatments

#Vit-min. Premix per 100kg diet: VitaminA ($8x10^5$U.I); VitaminD3 (1. 5x104U.I); VitaminE (250mg); VitaminK (100mg); VitaminB2 ($2x10^2$mg); VitaminB12 (0.5mg); Folic acid (50mg); Nicotinic acid ($8x10^2$mg); Calcium panthotenate (200mg); Choline ($5x10^3$mg). Trace elements: Mg ($5x10^3$mg); Zn ($4x10^3$mg); Cu ($4.5x10^2$mg); Co (10mg); I (100mg); Se (10mg). Antioxidants: Butylated hydroxytoluene ($1x10^3$mg). Carrier: Calcium carbonate q.s.p (0.25kg)

Table 2: Effects of maize stored in Polypropylene (PP) and ZeroFly® Hermetic (ZFH) bags on growth performance of broilers

Parameters	Treatments		F	P
	PP	ZFH		
Initial weight (g)	39.83 ± 0.34^a	40.19 ± 0.28^a	0.68	0.440
Total feed intake (g)	4396.18 ± 242.16^a	4162.33 ± 125.33^a	0.74	0.424
Total water intake (g)	5999.33 ± 144.21^a	7141.71 ± 539.16^a	2.97	0.183
Final weight (g)	1980.25 ± 82.06^b	2395 ± 32.26^a	22.13	0.003
Total weight gain (g)	1980.30 ± 82.19^b	2395.11 ± 32.15^a	13.42	0.035
FCR (feed: gain)	2.24 ± 0.19^a	1.74 ± 0.03^b	6.76	0.041
Water conversion ratio	3.04 ± 0.09^a	2.98 ± 0.19^a	0.09	0.779
Mortality (%)	8.00 ± 1.63^a	5.25 ± 1.25^a	1.79	0.2296

a,b - Means in a row with different superscripts are significantly ($p < 0.05$) different
FCR- Feed Conversion Ratio, PP- Polypropylene, ZFH- ZeroFly® Hermetic

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Table 3: Effects of maize stored in Polypropylene (PP) and ZeroFly® Hermetic (ZFH) bags on carcass characteristics of broilers

Parameters	Treatments		F	P
	PP	ZFH		
Carcass weight (g)	2443.25 ± 95.02^b	2745.88 ± 53.47^a	7.70	0.0322
% Live weight	72.17 ± 0.37^b	74.05 ± 0.24^a	18.09	0.0054
% Boneless breast	23.06 ± 0.55^a	23.37 ± 0.54^a	0.16	0.7001
% Whole thigh	13.79 ± 0.15^b	14.45 ± 0.10^a	13.18	0.0110
% Drumstick	8.36 ± 0.26^b	9.22 ± 0.16^a	7.75	0.0318
% Wings	7.42 ± 0.04^a	7.54 ± 0.05^a	3.83	0.0981

a,b - Means in a row with different superscripts are significantly ($p < 0.05$) different
PP- Polypropylene, ZFH- ZeroFly® Hermetic

Table 4: Effect of maize stored in Polypropylene (PP) and ZeroFly® Hermetic (ZFH) bags on blood profile of broilers

Parameters	PP	ZFH	F	P
Haematology				
WBC (x10^9/l)	189.50 ± 6.01^a	193.13 ± 3.53^a	0.27	0.6218
RBC (x10^{12}/l)	2.47 ± 0.08^a	2.48 ± 0.05^a	0.03	0.8761
HGB (g/dl)	8.91 ± 0.13^a	8.04 ± 0.14^b	20.25	0.0041
HCT (%)	32.74 ± 0.35^a	31.64 ± 0.29^a	5.91	0.0512
MCV (fl)	130.75 ± 1.16^a	132.88 ± 1.60^a	1.15	0.3239
MCH (pg)	36.28 ± 0.40^a	36.35 ± 0.14^a	0.03	0.8635
PLT (x10^9/l)	28.63 ± 3.00^a	30.00 ± 3.06^a	0.10	0.7591
Biochemistry				
PRO (g/L)	35.38 ± 0.55^a	35.63 ± 0.72^a	0.08	0.7921
ALB (g/L)	10.25 ± 0.63^a	11.38 ± 0.43^a	2.19	0.1895
AST (U/L)	152.25 ± 6.33^a	221.13 ± 8.22^b	44.10	0.0006
ALT (U/L)	9.38 ± 0.59^a	12.38 ± 1.14^a	5.43	0.0586
TCHO (mmol/L)	3.19 ± 0.14^a	4.03 ± 0.24^b	9.11	0.0235

a,b - Means in a row with similar or no superscript are not significantly ($p > 0.05$) different
WBC- White Blood Cells, RBC- Red Blood Cells, HGB- Haemoglobin, HCT- Hematocrit, MCV- Mean Cell Volume, Mean Corpuscular Haemoglobin-MCH, Platelets-PLT, PRO- Protein, ALB- Albumen, AST- Aspartate Aminotransferase, ALT- Alanine Aminotransferase, and TCHO- Total Cholesterol

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