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EVALUATION OF ZEROFLY HERMETIC AND POLYPROPYLENE BAGS FOR PRESERVING MAIZE FOR IMPROVED LAYER PRODUCTION IN GHANA

Opoku B[1], Osekre EA[1], Adomako K[2]*, Hagan BA[3], Opit GP[4] and A Bosomtwe[4,5]

Kwaku Adomako

*Corresponding author email: adomakokwaku5@gmail.com

[1]Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Private Mail Bag, Kumasi, Ghana

[2]Department of Animal Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[3]Department of Animal Production and Health, School of Agriculture and Technology, University of Energy and Natural Resources, Sunyani, Ghana

[4]Department of Entomology and Plant Pathology, Oklahoma State University, 127 Noble Research Center, Stillwater, OK, 74078-3033

[5]CSIR-Plant Genetic Resources Research Institute, P.O. Box 7, Bunso, Ghana

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ABSTRACT

Storage methods for grains is an important determinant in the preservation of quality of grains used for the preparation of poultry feed. A study was undertaken to assess the performance of layer chickens fed maize stored in polypropylene (PP) and ZeroFly® Hermetic (ZFH) bags. Maize was stored in 100-kg PP and ZFH bags for 6 months. There was 9,600 kg for each type of bag. The stored maize was then used to formulate feed using Koudjis 50%-layer concentrate, and the feed was used as diet for 1080 day-old Lohmann Brown Classic chicks (Lohmann Tierzucht Germany) for a period of 32 weeks. The two dietary treatments for this study were feed from white maize stored in ZFH and PP bags with storage method being the only source of variation. The average body weight, average daily feed intake (ADFI), feed intake, average daily weight gain, feed conversion ratio (FCR), mortality, egg production, egg weight and average daily egg mass were measured or computed for birds in the two treatments. Birds fed ZFH maize treatment had significantly ($p<0.05$) heavier body weights at the ends of the starter, grower, developer, pre-lay and layer 1 stages which were 4, 12, 17, 19 and 32 weeks of age (188.00 ± 1.03, 962.50 ± 6.01, 1382.00 ± 3.90, 1509.33 ± 6.30, and 1923.50 ± 12.32 g, respectively) than birds fed PP maize treatment. There were no significant differences in ADFI of birds fed treatments PP and ZFH at pre-starter (ADFI-1), starter (ADFI-4), grower (ADFI-12), developer (ADFI-17) and pre-lay (ADFI-19) phases of development. Birds on PP treatment (120.40 ± 1.32 g/day) however, had significantly ($p<0.05$) higher ADFI at the layer 1 period than those on treatment ZFH (115.64 ± 1.23 g/day). Egg production parameters (hen-day egg production, average egg weight, average daily egg mass) and FCR were better and favourable for birds on treatment ZFH bags compared to those on PP bags at 20, 24, 28, and 32 weeks of age. There was no significant difference in the percentage mortality of birds fed PP and ZFH maize. The favourable values of most of the layer production indicators of birds fed ZFH maize compared to PP maize is an indication that ZFH bags preserve maize quality better than PP bags. Hence, the nutrient qualities of maize stored in ZFH bags are better retained for utilization by layer birds.

Key words: Maize, storage, polypropylene, ZeroFly-Hermetic, bag, poultry, growth, egg-production

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INTRODUCTION

Maize is one of the most important cereal crops in Ghana; however, post-harvest loss is a major constraint to its supply. Practices by farmers, transporters, and warehouse managers along the handling chain result in major losses. In recent times, maize has become first among other grains and cereals in terms of annual area planted in Ghana [1]. Unfortunately, the crop suffers several losses due to insect pest and aflatoxin contamination along the maize post-harvest value chain which affect both quality and quantity before reaching the final consumer.

In developing countries, smallholder farmers typically sell or use their produce immediately after harvest due to inadequate storage and/or lack of effective storage technologies [2, 3]. The lack of appropriate storage structures and/or technologies results in grains being stored under humid and warm conditions which facilitate grain spoilage [4]. Storage of grains in jute and polypropylene bags is popular in many developing countries [5, 6]. However, jute and polypropylene (PP) bags do not adequately preserve the commodities stored in them.

Dormaa Ahenkro is among the hubs of the poultry industry in Ghana which produces substantial proportion of eggs consumed in the country [7]. Poultry farmers in Dormaa Ahenkro typically store their maize in PP bags, which offers relatively minimal protection against insect pest infestation and mycotoxin contamination. The use of PP bags in maize storage could reduce the quality of poultry feed and hence chicken performance. However, increasingly more farmers are now switching to storage of grains using ZeroFly Hermetic (ZFH) bags due to their ability to preserve maize quality better than PP bags [8]. Grain storage parameters such as the number of insects, insect damage, and weight loss were favourable for yellow maize stored in ZFH bags compared to those of this commodity stored in PP bags [8]. In a recent study [9], which produced the maize used in the present study, authors reported aflatoxin and fumonisin levels below recommended safe levels for maize stored in both PP and ZFH bags. However, favourable levels of number of insects per 500 g sample, percentage of insect damage kernels and grain weight loss were reported from maize stored in ZFH bags compared to those for storage in PP bags [9].

In addition, the use of different brands of hermetic bags for grain storage produced similar results of no significant grain damage and weight loss [10]. Similarly, no weight loss or insect damage were recorded for maize stored in different hermetic storage bags (SuperGrainbag™, AgroZ® bag, EVAL™, and Purdue Improved Crop Storage-PICS™ bags) after 7 months of storage; however, in the same study which also included an insecticide-treated woven bag (ZeroFly®) (this is not the ZeroFly® Hermetic bag), and a polypropylene (PP) woven bag, maize stored in the

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ZeroFly® and PP bags lost between 6.3% and 10.3% of its weight, respectively [11]. The ZeroFly® bag does not have the hermetic inner liner that is found in the 2-layer ZeroFly® Hermetic bag. The description and definitions of the different hermetic storage bags have been provided by various authors [12 - 15].

Undoubtedly, an understanding of the reasons poultry farmers store maize, and the systems within which maize storage occurs, are necessary to estimate how the benefits and costs of innovations are likely to be assessed by the intended users of the technologies. In layer chicken production, the quality of feed has important effects on several egg quality characteristics [16], hence the need to preserve the quality of maize used in poultry feed formulation. Over the years, the need for economic analysis in the planning and designing of storage interventions has become more widely recognized. The use of ZFH bags might become attractive to farmers, traders, or governments if the perceived benefits are shown to substantially outweigh the costs. The use of ZFH bags has been reported to preserve maize from insect damage and mycotoxin contamination [8, 17]. However, there is currently limited information on the performance of layer chickens fed maize-based diets preserved with ZFH bags. Thus, the objective of this study was to assess the performance of layer chickens fed maize stored using ZFH 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-0018).

Experimental Sites

The study on storage methods or bags was undertaken at storehouses in three poultry farms in Dormaa Ahenkro, Ghana. The study on the growth and productive performance of layer birds was undertaken at a poultry farm in Dormaa Ahenkro, Ghana.

Storage Experiment and Experiment Design

One hundred and ninety-two 100-kg bags of clean untreated (insecticide-free) white maize (Omankwa variety) of 13% moisture content, was purchased and transported to a single storehouse location in PP bags provided by the maize producer. The maize was emptied onto a tarpaulin and thoroughly mixed and cleaned of debris. One hundred (100) kg quantities of maize were then transferred to 100-kg capacity ZFH and PP bags. Ninety-six bags of each type (ZFH and PP), of 100-kg capacity, were filled with 100 kg of maize. Storage was conducted in storehouses of three poultry farms: Evans Joes Farms, M.M Unity Farms, and T. K.

Takyi Farms, all in Dormaa Ahenkro, Ghana (7°17'N 2°53'W). The mean annual rainfall was between 1250 to 1750 mm with relative humidity ranging from 70 to 80%. The temperature range during the experiment was between 26 and 30 ºC. In each storehouse, 32 bags for each treatment were arranged on two wooden pallets, that is; 16 bags on each of the pallets. The pallets for each treatment were separated by two meters of free space. There were 64 bags of 100-kg capacity in each storehouse. The experimental design used for the maize storage was a Randomized Complete Block Design (RCBD) with two treatments (ZFH and PP bags) and poultry farm as block. Each treatment was replicated three times with each poultry farm storehouse being a block. Refer to Opoku *et al.* [9] for details of the storage study that produced maize used in the present study.

Storage methods or treatments

ZeroFly Hermetic Bag

Thirty-two ZFH bags of 100-kg capacity containing 100 kg of maize were stored in each of the three storehouses used [9]. These 32 ZFH bags were arranged on two wooden pallets, that is, 16 bags on each of the pallets. A total of 96 ZFH bags were used in the three storehouses [9]. In each storehouse, the two pallets with ZFH bags were placed next to each other as closely as possible to minimize spatial temperature variation. The bags were arranged in horizontal patterns on the pallets placed close to each other. The integrity of the inner and outer liners of the ZFH bags was checked to ensure there were no punctures before use. Each bag was properly sealed to maintain its hermetic property.

Polypropylene Bags (Control)

Thirty-two PP bags of 100-kg capacity containing 100 kg of maize were stored in each of the three storehouses used [9]. These 32 PP bags were arranged on two wooden pallets, that is, 16 bags on each of the pallets. A total of 96 PP bags were used in the three storehouses. In each storehouse, the two pallets with PP bags were placed next to each other as closely as possible to minimize spatial temperature variation. The bags were arranged in horizontal patterns on the wooden pallets placed close to each other. The protocol used for this storage method was the same as that of ZFH bags. However, in each storehouse, the pallets for PP bags were two metres apart from the pallets for the ZFH treatment. The maize in the storage bags was stored for six months after which maize was used for feed formulation for layer hens [9].

Layer Experiment

The layer experiment was conducted at Gye Nyame Farms, Dormaa Ahenkro. The stored white maize from each storage method (PP and ZFH bags) was used to formulate layer feed. The feeds were formulated using Koudjis 50%-layer concentrate. This concentrate was selected because it contains all the ingredients (vitamins, minerals, amino acids, phosphates, additives and proteins) needed by layer hens except 50% energy source ingredient. In addition, the use of Koudjis 50%-layer concentrate will keep all other feed ingredients in the complete layer feed constant. The maize stored in ZFH bags and PP bags for six months was used to formulate feed for 1080 day-old Lohmann Brown Classic chicks for 32 weeks. The two dietary treatments for this study were feed from maize stored in ZFH bags and feed from maize stored in PP bags with the storage method being the main source of variation [9]. The proximate analysis of different diets at pre-starter (zero to seven days), starter (one to four weeks), grower (five to twelve weeks), developer (13-17 weeks), pre-layer (18-19 weeks), and layer 1 (20-32 weeks) using maize from ZFH bags and PP bags are presented in Table 1. A completely randomized design (CRD) experiment was used for this study on the effects of the two dietary treatments on the growth and productive performance of the layer chickens.

The Lohmann Brown Classic breed of layer chicken was selected for this experiment because of its quick response to nutrition and its being one of the popular layer chicken breeds raised by poultry farmers in Dormaa Ahenkro. Lohmann Brown Classic breed has shown good performance in terms of feed intake, feed conversion, and liveweight gain [18].

Chickens were housed in one experimental pen divided into 12 separate experimental units of 3.05 m x 3.05 m floor area each. Wood and wire mesh were used for partitioning experimental units. Each experimental unit contained 90 birds with each bird occupying a floor area of 0.11 m^2. The units were thoroughly cleaned and disinfected with Omnicide before the start of the study. The floor of each unit was spread with disinfected wood shavings to a depth of about 8 cm to provide litter for the birds. Thirty-watt electric bulbs were used to provide continuous light in the pens. Day-old chicks (DOCs) were brooded in their respective units with charcoal in pots as the main heat source. Two temperature and relative humidity data loggers were hung in the pen to monitor the room temperature and relative humidity during the brooding stage.

Management practices including maintenance and cleanliness within and outside the poultry pens were carried out. The drug administration and vaccination schedule from the Dormaa Central Veterinary Department was followed as the medication schedule [19].

One thousand and eighty (1080) day-old-chicks of Lohmann Brown Classic layer breed that were purchased from the Netherlands were grouped into 90 birds per replicate with six replicates per treatment (ZFH and PP bags).

Bird handling and management

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Pens were cleaned of old litter, washed, disinfected, and aerosol-treated before the arrival of DOCs. Vitamins and glucose were provided to the DOCs through their water after weighing them with a digital weighing scale. Formulated feed was placed in feeding troughs and placed for easy access by all birds. Feeders were not over-filled with feed to prevent wastage. Feeders were constantly checked and litter and droppings found in them were removed daily. Feeding was done twice daily, in the morning and evening. Fresh water was provided ad libitum. The feeders and drinkers were adjusted to the height of the birds as the birds grew to avoid feed and water wastage. Wet litter around drinkers was regularly removed and replaced.

To prevent the build-up of ammonia in the litter, regular turning of compacted litter was done and wet litter was changed periodically. A 17:7-hour light-dark photoperiod was kept throughout the study period. Feed was weighed and recorded daily before it was given to birds in each experimental unit. The leftover feed was weighed the next morning. Any feed that spilled onto the litter was also gathered and weighed. Actual feed consumed per animal per unit was then computed as: (Total feed supplied – feed leftover and spilled) ÷ number of birds per unit.

DATA COLLECTION

Body weight, feed intake, average daily gain, mortality

The initial body weight of each of the birds was taken with an electronic weighing scale and recorded. At the end of each week, the average body weight of birds in each experimental unit was taken and recorded. The average daily weight gain for each different stage of production (pre-starter, starter, grower, developer, pre-lay, and layer 1) was computed as the difference between the body weights at the start and end of the stage divided by the number of days between the start and end dates. This was computed for birds in each experimental unit pen. The weekly feed intake of birds in a given experimental unit was also recorded by measuring the feed supplied per week and the feed weighed back. This was used to compute the average feed intake for each stage per treatment. The number of birds that died in each unit pen each week was recorded to compute the average percentage mortality for each stage in each treatment.

Egg production, egg weight, egg mass

The start of lay for each treatment was recorded and the number of eggs produced per unit pen per week was recorded. The total weight of eggs for each experimental unit per week was measured with an electronic weighing scale. Average egg mass was computed as hen-day egg production x average egg weight.

Data analysis for the layer experiment

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Data were analysed using the generalized linear model procedure of SAS version 9.4 (SAS Institute, CARY, NC). A one-way analysis of variance (ANOVA) was used where the storage bag or method was the only source of variation. The model used for the analysis of the data is as presented in Model 1:

$Y_{ij} = \mu + SB_i + e_{ij}$ Model 1

where Y_{ij} = the observation of the j^{th} response variable of the i^{th} treatment (storage method);
μ = overall mean;
SB_i = the fixed effect of the i^{th} storage bag;
e_{ij} = random residual error.
Significant differences between treatments were separated using Tukey's Test of Significance at $p<0.05$.

RESULTS AND DISCUSSION

Body weight and average daily gain

The mean body weight of DOCs, in weeks 1, 4, 12, 17, 19, and 32 as influenced by the maize storage bag method is presented in Table 2. The initial mean body weight of DOCs (36.83 vs 37.00 g) was similar for the two treatments (PP vs ZFH). Mean body weights at weeks 1, 4, 12, 17, 19, and 32 for birds fed maize stored in ZFH bags were significantly heavier ($p<0.05$) than the mean body weights of respective ages of birds fed maize in PP bags. The growth of the birds on the two treatments (PP and ZFH) moved or progressed steadily from week 0 to week 28 after which it stabilized (Figure 1). Although the pattern of growth of the two groups of birds (PP and ZFH) was similar, birds of ZFH treatment showed significantly higher growth ($p<0.05$) than those on PP treatment (Figure1).

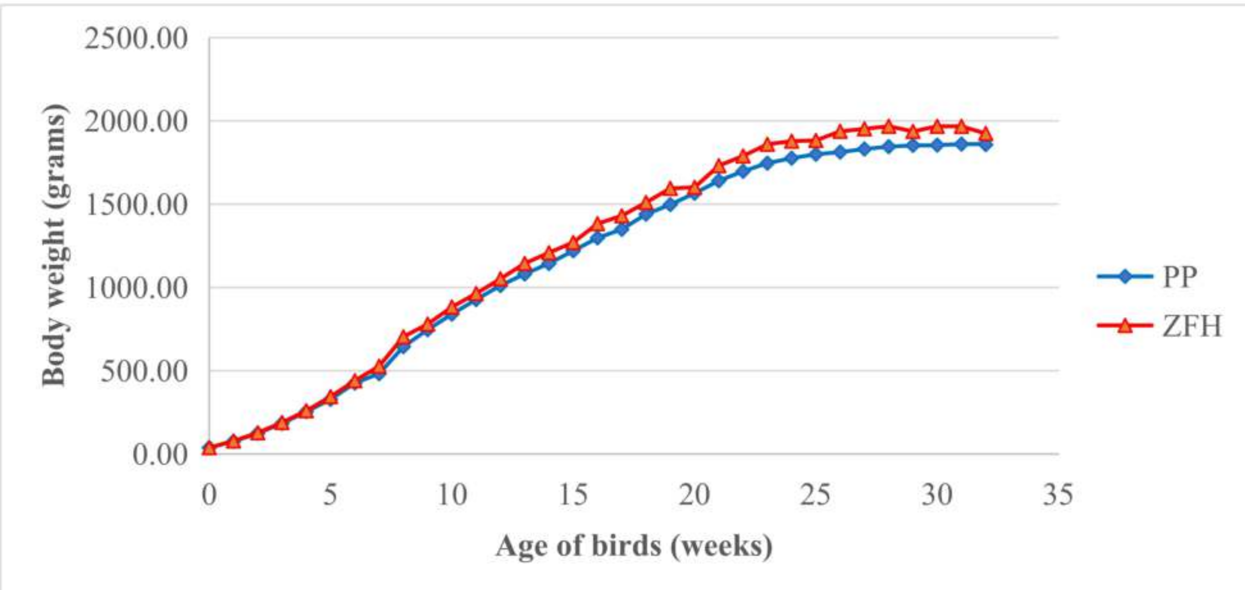

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Figure 1: Average weekly body weight of layers under Polypropylene (PP) and ZeroFly Hermetic (ZFH) storage bag treatments

The average daily gain of birds for the various layer phases as influenced by maize storage methods is presented in Table 3. The mean daily gains of birds during pre-starter (ADG1), grower (ADG12), and developer (ADG17) phases of birds on ZFH bags were significantly ($p<0.05$) higher than those for birds fed maize stored in PP bags. There were no significant differences ($p>0.05$) between mean daily gains during the starter, pre-lay and layer 1 phases of birds on PP and ZFH bags.

The body weights of birds in this study rapidly increased as birds grew. The significant differentials in body weights of birds fed maize stored by the two storage methods started immediately after day-old till the end of the study at 32 weeks of age. The significantly ($p<0.05$) heavier body weights of birds on ZFH treatment compared to those on PP treatment could probably be due to the fact that ZFH bags stored maize is better than that in PP bags and enabled maize to retain most of its nutrients; hence birds fed with ZFH bags maize obtained more nutrients for growth and development. The results in this study agree with several studies on differentials in layer body weights after being fed on different planes of nutrition [20, 21].

At the onset of egg production and throughout the production period, body weight of birds influences the efficiency of egg production. Research over the years shows that the onset of egg production can be an indicator of sexual maturity, which is closely associated with body weight [22, 23]. It is stipulated that different breeds of layers possess different mature body weights, and there is a specific body weight threshold for the onset of egg production in each particular strain of egg-type chicken [24]. In an experiment using Brown Nick Pullets, it was observed that the body weight necessary for egg production to be initiated and maintained is at least 1.4 kg [25]. In a study on South African White Leghorn, Du Plessis and Erasmus [26], reported that a body weight of 1.6 - 2.27 kg showed a positive correlation between egg production and egg weight; however, an inverse relationship was observed when the birds weighed beyond 2.27 kg.

The body weights of the birds in this study prior to the onset of lay were within the minimum required weight for the onset of lay (1.50–1.59 kg). From the onset of lay (19 weeks) to week 32, laying birds on the two maize storage treatments gained an average of 29.1% (PP) and 27.4% (ZFH) in body weights. These should not affect the egg production trajectory of birds as several studies have reported no change in egg production due to changes in body weights [20, 27].

The differences in average daily weight gain in the different phases of layers is an indication that the rate of growth of birds varies for different stages of birds. The

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largest average daily growth rate was observed during the grower phases. The significant (p<0.05) differences in growth rate recorded in the pre-starter, grower, and developer phases of birds fed with maize stored in PP and ZFH could be attributed to the higher levels of crude protein and metabolizable energy in the ZFH feeds compared to the PP feeds (Table 1). The use of the ZFH storage bags maintained the quality of maize for poultry feed formulation better than the PP bags [8,9].

Feed intake

There were no significant differences (p>0.05) in the average daily feed intake at all the phases for birds on PP and ZFH bags except the layer 1 phase where birds on PP bags had significantly (p<0.05) higher average daily feed intake than those on ZFH bags (Table 4).

The non-significant difference in average daily feed intake (ADFI) of birds on PP and ZFH bags for all phases of the birds in this study except the lay 1 period was quite encouraging. This suggests that the cost of production due to feed cost before the onset of lay will not be adversely affected by the storage method (PP or ZFH). However, the significantly (p<0.05) higher ADFI during the layer 1 period for birds on PP treatment compared to the ZFH treatment could be attributed to the fact that PP maize lost some of its nutrient quality [8,9]. Therefore, birds fed with PP maize needed to consume more feed to meet their daily nutrient requirement. This is expected to increase the cost of feeding during the lay 1 period for birds on PP compared to ZFH bags.

Egg production, egg weight, and egg mass

The age at first lay for birds fed maize stored in ZFH bags was earlier (19 weeks) than birds fed on PP stored maize (20 weeks). The mean hen-day egg production and average egg weight for birds on the two treatments (PP and ZFH) for weeks 20, 24, 28, and 32 are presented in Table 5. The mean hen-day egg production at weeks 20, 24, 28, and 32 for birds on treatment ZFH were significantly (p<0.05) higher than those of birds on treatment PP (Table 5; Figure 2). At 32 weeks of age, the difference in mean hen-day egg production between birds on treatment ZFH and PP was 21.76% (Figure 2). This has a lot of financial implications in the layer industry. On the average, in each treatment, for 13 weeks, 90 ZFH-stored grain-fed chickens laid an average of 4,042 eggs, while 90 PP-stored grain-fed chickens laid an average of 2,855 eggs. This is a difference of 1,187 eggs per 90 birds in 13 weeks, or an average of 13 more eggs per chicken in 13 weeks, or an additional egg per week for the ZFH bag-stored maize-fed chickens. Similarly, the average daily egg masses of birds on treatment ZFH were significantly (p<0.05) higher than those on treatment PP at all ages studied (Table 5). For both groups, daily egg mass per bird also increased with increase in age of birds.

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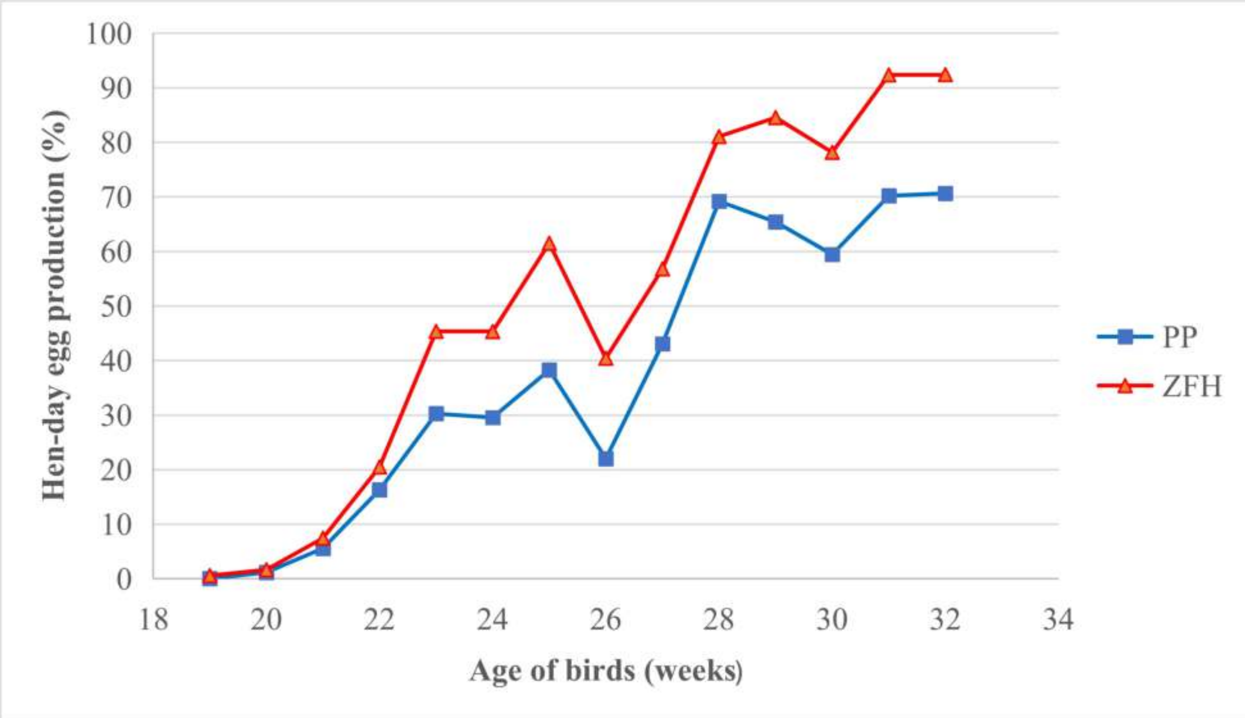

Figure 2: Hen-day egg production (%) for birds on the Polypropylene (PP) and ZeroFly Hermetic (ZFH) storage bag treatments

The significantly ($p<0.05$) higher hen-day egg production for birds on treatment ZFH compared to those on treatment PP at all ages could be attributed to the better nutrition from well-conserved maize. Hen-day egg production was influenced significantly ($p<0.01$) by the levels of dietary protein fed to layer birds during the growing period [28]. They reported higher percentages in hen-day egg production as dietary protein levels increased. Hen-day egg production was higher for layer birds fed higher levels of protein (22% and 24%) compared to those fed 20% crude protein diets during the first eight weeks of lay [29].

The increase in egg weight with advancement in the age of layers irrespective of the treatment the birds received was consistent with reports of several studies [30 - 33]. The significantly ($p<0.05$) heavier average egg weight of birds on treatment ZFH compared to birds on PP at all ages is indicative of the high nutrition density of ZFH-prepared feed compared to PP-prepared feed. An increase in nutrient density improves egg production and egg weight [34].

The significantly ($p<0.05$) higher average daily egg mass of birds on ZFH treatment relative to those on PP treatment is consistent with the report of Khatibi *et al.* [34]. This could be attributed to the relatively higher density of ZFH maize compared to the PP maize. An increase in dietary energy and nutrient density has a positive effect on egg mass in Hy-Line laying hens [35].

Feed conversion ratio and bird mortality

The feed conversion ratio of birds at weeks 20, 24, 28, and 32 were all significantly (p<0.05) lower for birds on ZFH treatment compared to those on PP treatment at the respective ages. In both groups (treatments), layers were more efficient in converting feed consumed to eggs at weeks 28 and 32 than at weeks 20 and 24. There was no significant difference (p>0.05) in bird mortality between birds on treatments PP and ZFH (Table 6).

The significantly (p<0.05) lower FCR of birds on ZFH treatment relative to birds on PP at all ages studied is suggestive of the superior ability of ZFH bags to conserve nutrients in maize giving birds fed with such maize (relatively higher nutrient density compared with PP maize) the ability to effectively utilize feed for egg production. The findings in this study agree with Kazemi *et al.* [35] who also reported improvement in FCR with an increase in nutrient density. The higher FCR at week 32 compared to week 28 in both groups suggests that as birds get older their feed intake increases whilst their egg mass [36] or egg production declines.

The non-significant effect of the maize preservation method on total bird mortality suggests that both storage methods might not be contributing factors to the mortalities recorded in the study.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The use of ZFH bags in the storage of maize preserved the quality of nutrients better than the use of PP bags hence feed prepared from maize stored in ZFH bags gives layer birds superiority in traits such as body weight, average daily weight gain, age at first lay, egg production, egg weight and daily egg mass over birds fed maize stored in PP bags. The superiority of production parameters such as body weight from week 1 to 32, average daily feed intake at week 32, average daily gain at grower and developer stages, hen-day egg production at weeks 20, 24, 28, and 32, average egg weight at weeks 20, 28, and 32 average daily egg mass at weeks 20, 24, 28, and 32 of layers fed layer feed prepared from maize stored in ZFH bags is likely to increase the profitability of layer production. Birds fed maize stored in ZFH bags better utilized feed for egg production than those fed maize from PP bags. It is recommended that poultry farmers feed their egg-type chickens with maize stored in ZFH bags.

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Table 1: Proximate analyses of layer feeds at different stages formulated from maize stored in ZeroFly Hermetic (ZFH) bags and Polypropylene (PP) bags

Nutrients	Pre-starter	Starter	Grower	Developer	Pre-layer	Layer 1
ZFH Bags						
Crude Protein (%)	23.12	20.89	18.72	16.1	16.77	15.27
Crude Fibre (%)	3.11	3.8	4.01	4.51	4.01	3.55
Crude Fat (%)	4.04	4.04	4.13	4.11	3.91	4.39
ME (Kcal)	2944	2900	2901	2922	2712	2802
Calcium (%)	0.8	0.66	0.65	0.66	2.14	3.35
Sodium (%)	0.2	0.17	0.14	0.13	0.14	0.15
PP bags						
Crude Protein (%)	21.21	18.88	17.22	15.11	15.77	14.66
Crude Fibre (%)	5.03	5.08	5.91	5.21	5.99	5.88
Crude Fat (%)	3.01	2.99	3.27	3.39	2.95	3.07
ME (Kcal)	2722	2769	2775	2708	2607	2651
Calcium (%)	0.79	0.77	0.61	0.68	2.01	3.01
Sodium (%)	0.2	0.19	0.13	0.13	0.16	0.15

*ME – Metabolizable Energy

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Table 2: Mean ± SE body weights at 0, 1, 4, 12, 17, 19, and 32 weeks of age (WOA) in grams as influenced by maize storage bags

	Storage Methods	
Body weights (grams)	**Polypropylene (PP)**	**ZeroFly Hermetic (ZFH)**
DOC weight	36.83 ± 0.40	37.00 ± 0.37
BWT at 1 WOA	74.33 ± 0.61^{b}	77.17 ± 0.60^{a}
BWT at 4 WOA	182.50 ± 1.03^{b}	188.00 ± 1.03^{a}
BWT at 12 WOA	926.17 ± 6.03^{b}	962.50 ± 6.01^{a}
BWT at 17 WOA	1296.33 ± 3.94^{b}	1382.00 ± 3.90^{a}
BWT at 19 WOA	1438.83 ± 6.20^{b}	1509.33 ± 6.03^{a}
BWT at 32 WOA	1856.67 ± 13.43^{b}	1923.50 ± 12.32^{a}

$^{a-b}$Means within the same row with different superscripts are significantly different at p<0.05; *BWT – Body weight; DOC – Day-old chick; WOA – Week of age; SE – Standard error

Table 3: Mean ± SE average daily gain for pre-starter (ADG1), starter (ADG4), grower (ADG12), developer (ADG17), pre-lay (ADG19) and layer 1 (ADG32) in g/day as influenced by maize storage bags

	Storage Methods	
Average daily gain (g/day)	**Polypropylene (PP)**	**ZeroFly Hermetic (ZFH)**
ADG1	5.36 ± 0.08^{b}	5.74 ± 0.08^{a}
ADG4	5.15 ± 0.05	5.28 ± 0.05
ADG12	13.28 ± 0.12^{b}	13.83 ± 0.10^{a}
ADG17	10.58 ± 0.14^{b}	11.99 ± 0.11^{a}
ADG19	10.18 ± 0.49	9.10 ± 0.48
ADG32	4.59 ± 0.11	4.55 ± 0.10

$^{a-b}$Means within the same row with different superscripts are significantly different at p<0.05

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Table 4: Mean ± SE average daily feed intake for pre-starter (ADFI-1), starter (ADFI-4), grower (ADFI-12), developer (ADFI-17), pre-lay (ADFI-19) and layer 1 (ADFI-32) in g/day as influenced by maize storage bags

	Storage Methods	
Average daily feed intake (g/day)	**Polypropylene (PP)**	**ZeroFly Hermetic (ZFH)**
ADFI-1	9.00 ± 0.20	9.25 ± 0.20
ADFI-4	25.63 ± 0.34	24.66 ± 0.30
ADFI-12	62.00 ± 0.59	60.54 ± 0.49
ADFI-17	72.13 ± 0.62	70.43 ± 0.54
ADFI-19	77.98 ± 0.93	76.10 ± 0.79
ADFI-32	120.40 ± 1.32[a]	115.64 ± 1.23[b]

[a-b]Means within the same row with different superscripts are significantly different at $p<0.05$

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Table 5: Mean ± SE hen-day egg production (%), average egg weight (grams) and average egg mass (g/bird) at weeks 20, 24, 28, and 32 of layer chickens as influenced by maize storage bags

	Storage Method	
Hen-day egg production (%)	**Polypropylene (PP)**	**ZeroFly Hermetic (ZFH)**
Week 20	1.14 ± 0.15[b]	1.64 ± 0.12[a]
Week 24	29.53 ± 0.94[b]	45.29 ± 0.90[a]
Week 28	69.17 ± 1.58[b]	81.04 ± 1.54[a]
Week 32	70.63 ± 1.85[b]	92.39 ± 1.42[a]
Average egg weight (grams)		
Week 20	44.06 ± 1.00[b]	47.45 ± 0.92[a]
Week 24	55.99 ± 0.44	55.67 ± 0.43
Week 28	58.23 ± 0.29[b]	59.23 ± 0.15[a]
Week 32	59.50 ± 0.24[b]	60.48 ± 0.21[a]
Average Daily Egg mass (g/bird)		
Week 20	0.50 ± 0.07[b]	0.78 ± 0.07[a]
Week 24	16.54 ± 0.51[b]	25.20 ± 0.51[a]
Week 28	40.29 ± 1.04[b]	48.01 ± 1.04[a]
Week 32	42.03 ± 1.23[b]	55.89 ± 1.23[a]

[a-b]Means within the same row with different superscripts are significantly different at $p<0.05$

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Table 6: Mean feed conversion ratio (FCR) at weeks 20, 24, 28 and 32 and percentage total bird mortality as influenced by maize storage bag method

	Storage Method	
FCR	**Polypropylene (PP)**	**ZeroFly Hermetic (ZFH)**
Week 20	8.96 ± 0.25[a]	6.73 ± 0.25[b]
Week 24	5.11 ± 0.08[a]	3.13 ± 0.08[b]
Week 28	1.62 ± 0.03[a]	1.30 ± 0.03[b]
Week 32	2.18 ± 0.03[a]	1.54 ± 0.03[b]
Total mortality (%)	13.33 ± 1.89	10.37 ± 1.87

[a-b]Means within the same row are significantly different at $p<0.05$

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