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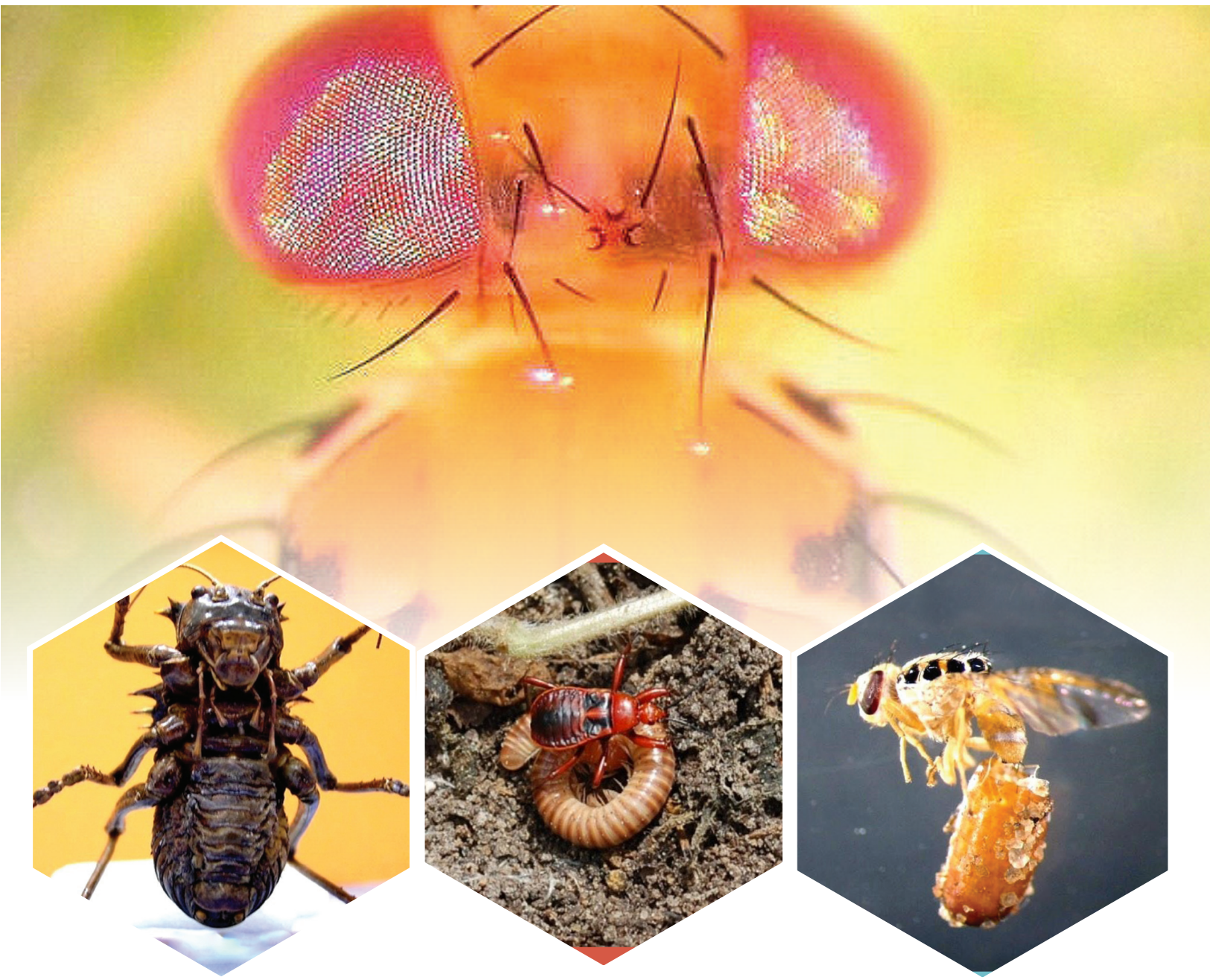

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Cocoa Pod Husk Plus Enzymes is a Potential Feed Ingredient for Hy-Line Silver Brown Laying Hens

Thomas N. Nortey[1*], Dorinda V. Kpogo[1], Augustine Naazie[1] and Emmanuel O. K. Oddoye[2]

[1]Department of Animal Science, College of Basic and Applied Sciences, University of Ghana, Legon, Accra
[2]Cocoa Research Institute of Ghana, New Tafo-Akim
***Corresponding author:** tnortey@ug.edu.gh

ABSTRACT

The aim of the experiment was to determine whether the inclusion of pelleted cocoa pod husks (CPH) in diets for Hyline Silver Brown (HSB) layers would affect egg laying performance and egg characteristics. Two hundred and sixteen (216), 36-week old, HSB layers in battery cages were randomly assigned to twelve experimental diets for 12 weeks in a completely randomized design (CRD). Diets had three levels of CPH inclusion: 0, 10 and 15%. For each inclusion level, the diets were further sub-divided into four treatments. The four treatments either had, i) no enzyme, ii) phytase only, iii) a commercial enzymes cocktail only, or iv) a mixture of both phytase and cocktail. The enzyme cocktail and phytase were added at rates of 250g and 300g per ton of complete feed respectively according to the manufacturer's recommendation. Overall, adding CPH did not affect Average Daily Feed Intake, although a combination of an enzyme cocktail and phytase improved ADFI, especially at the 15% CPH-inclusion level. Hen-day egg production of birds on diets with 0, 10 and 15% CPH, with an enzyme cocktail alone (78.70, 76.23 and 71.96% respectively), or with a combination of enzyme cocktail and phytase (79.5, 71.89 and 72.16% respectively) was better than egg production of hens on the other diets. There were no effects of CPH or enzyme addition on egg quality characteristics. Cocoa pod husk can be used in diets for HSB birds (up to 15%) without adversely affecting production performance or egg quality characteristics when appropriate exogenous enzymes are added.

Keywords: Egg production, Egg quality, Enzymes, Hy-Line Silver Brown Layers

Introduction

Agriculture forms the backbone of many developing countries. In Ghana it contributed 38.8% of the Gross Domestic Product (GDP) in fiscal year 2012, with the livestock sector contributing 7.5% (Ministry of Food and Agriculture [MoFA] 2012). Commercial poultry production, in particular, provides easily accessible and affordable meat and eggs.

Worldwide, a major contributor to the total cost of raising poultry is feed (Teguia & Beynen, 2004), with traditional cereal grains like maize, rice, wheat and millet constituting the major energy providers (Ravindran & Blair, 1993). Such traditional cereal grains are however major food sources for humans as well, and consequently their use in animal feed brings about undesirable competition with man for this resource. It is important therefore to seek local replacements for traditional feed for livestock in order to alleviate the stress imposed on them (Teguia & Beynen, 2004).

Apart from grains, roots and tubers like cassava root meal have been shown to be potential energy sources for poultry, and have been experimented with some degree of success in poultry feed (Adeniji & Balogun, 2003; Nortey *et al.,* 2013). Cocoa pod husk (CPH) is a by-product of cocoa processing. It is readily available, has high levels of protein, energy and other nutrients, and could be used in animal feeding. Compared to maize however, cocoa pod

husk (CPH) is relatively high in fibre. It is also high in lignin (14%) and non-starch polysaccharides (NSP) like hemicellulose (11%), cellulose (35%) and pectin (6%) (Alemawor *et al.*, 2010). The phosphorous in plant based ingredients like CPH also exists as phytate phosphorous (P) (Adeola & Cowieson, 2011; Adeola *et al.*, 2004). Since monogastrics do not by themselves possess the necessary enzymes to hydrolyse both fibre and phytate P (Yu *et al.*, 2004), diets high in these nutrients need to be supplemented with the requisite exogenous phytase and carbohydrase enzymes, if production performance is to be maintained. Undigested NSP can influence intestinal transit time and increase digesta viscosity (White *et al.*, 1981). Both result in inefficient nutrient absorption which ultimately affects the growth and egg laying performance of birds. Although some work has been done on the use of CPH in monogastric diets, little or no literature exists on the use of CPH as a potential feed ingredient in Hy-Line Silver Brown layer hens. The HSB layer hen is a white bird that lays brown eggs, and is a new strain that has recently been introduced to Ghanaian poultry farmers.

The hypothesis of this study was that CPH in the presence of exogenous enzymes could be used in HSB layer hen diets without adversely affecting performance. The objective was to determine the effect that CPH inclusion in diets with appropriate exogenous enzyme supplementation has on egg production and quality characteristics of HSB layers.

Materials and Methods

The trial was carried out at the Livestock and Poultry Research Centre (LIPREC) of the University of Ghana (UG).

Preparation of dried cocoa pod husk

Fresh cocoa (*Theobroma cacao*) pods were harvested from the cocoa plantations of the Cocoa Research Institute of Ghana (CRIG), New-Tafo in the Eastern Region of Ghana. They were cracked open to remove the cocoa beans together with the placenta. The husks were then chopped into slices (average length 2 cm) at the Product Development Unit of CRIG. They were dried in the sun for about 24 hours to reduce the moisture content to about 80%. The pre-dried slices were then passed through a combination mincer and pelleting machine to produce pellets (about10-12 mm). The pellets were again sun-dried for about 48-72 hours to further reduce moisture content to about 10% and then stored until use.

Dietary Treatment, birds and management

Twelve experimental diets consisting of three main diets initially formulated to contain 0, 10 and 15% CPH were used in the trial. Each main diet was further sub-divided into four parts. Part one was not treated any further. Parts two, three and four were treated respectively with phytase alone (300g/ton of complete feed), a commercial enzyme cocktail alone (250g/ton of complete feed), and a combination of both phytase and the enzyme cocktail at the stated inclusion levels. Thus T1, T2, T3 and T4 represented diets with a) 0% CPH with no exogenous enzyme, b) 0% CPH plus phytase alone, c) 0% CPH plus enzyme cocktail alone, and d) 0% CPH plus a combination of phytase and an enzyme cocktail. Treatments five to eight (T5, T6, T7 and T8), and nine to twelve (T9, T10, T11 and T12) represented diets with 10% and 15% CPH respectively, and with the same combination of enzymes as in T1 to T4. The microbial phytase used was ZY Phytase 5000© which is manufactured by Lohmann Animal Health, Germany. The enzyme cocktail contained phytase, amylase, protease, cellulase, xylanase, β-glucanase and pectinase, and was supplied by Zoetis under the brand name Enziver.

The animal protocol was approved by the LIPREC Research Committee on Animal Use and Experimentation and followed principles recommended by the Noguchi Institutional Animal Care and Use Committee of the University of Ghana. Two hundred and sixteen (216) Hy-Line Silver Brown (HSB) layers at 36 weeks of age were randomly assigned in battery cages to twelve experimental diets in a Completely Randomized Design. The layers were fed the respective diets over a period of

twelve weeks. The experiment was set up in a 3 x 4 factorial arrangement with three levels of CPH and four levels of enzymes. There were 18 birds in each treatment, made up of nine replications of two birds per replication/cage. The laying hens were allowed seven (7) days on the experimental diets for conditioning. The experiment consisted of three periods of 28 days each. Birds were fed the same treatment diet during the experimental period. Water was provided *ad libitum*.

Data collection/criteria

A known amount of feed was provided every morning, and feed left over after 24 hours was collected and weighed to determine feed intake. This amount represented the average daily feed intake (ADFI). Feed conversion efficiency (FCE) was calculated as the ratio of weight of eggs to feed intake. Eggs were collected twice a day at 08:00 and 16:00. Records of egg weight, hen-day and hen-housed egg production performance were kept daily and summarized on a weekly basis.

Six eggs that had been laid within a two hour period on days 28, 56 and 84 were selected at random from each treatment and parameters such as shell thickness, egg length and width, and albumen height were determined within 24 hours of collection. For egg width (at the broadest end) and shell thickness measurements, a digital caliper Model AD-5761-150 (A&D Company Ltd. Yamagata, Japan) with a sensitivity of 0.01mm was used. Egg weight was measured with an electronic balance (OHAUS-Pioneer ™, Ohaus Corp., USA; sensitivity of 0.01g). Albumen height was taken at three points between the yolk and edge of the thick albumen and the results averaged. The Haugh Unit was calculated by the method described by Haugh (1937) as follows:

$$\mathbf{HU = 100 * \log \left[H - \frac{\sqrt{G\,(30\,W^{0.37} + 100)}}{100} + 1.9 \right]}$$

Where:
HU = Haugh unit
H= observed height of the albumen in millimeters
W = weight of egg in grams
G = the gravitational constant, 32.2

Chemical Analysis

The proximate chemical composition of all the major ingredients used was analyzed using methods outlined in the Association of Official Analytical Chemists (AOAC, 1995). Calcium and phosphorus were determined according to the methods outlined by James (1996) and AOAC (1995).

Statistical Analyses

All data gathered were subjected to statistical analysis using the Generalised Linear Model procedure of the Statistical Analysis Systems Institute (SAS, 1999). Significant differences among means were separated using the Student Newman-Kuels (SNK) Test. *A priori*, it was decided to compare the following treatments which were of particular interest, using contrasts:

- All diets without enzymes versus all diets with both phytase plus cocktail
- All diets without enzymes versus all diets with only a cocktail
- All diets without enzymes versus all diets with only phytase
- All diets with only phytase versus all diets with only a cocktail
- All diets with phytase alone versus all diets with both phytase plus a cocktail
- All diets with only a cocktail versus all diets with both phytase and a cocktail

Results

The chemical composition of the CPH used for the trial is shown in Table 1A. A profile of the diets used, showing CPH levels and combination of enzymes (T1 – T12), is shown in Table 1B. The composition and calculated values of the layer diets are shown in Table 2. The crude protein (CP) levels represent the recommended level of 15 -16.5% for brown type laying hens that are consuming between 100 and 120g of feed per day (NRC, 1994).

Table 1: A) Chemical composition of cocoa pod husk

Nutrient	Concentration (g/kg)
Dry matter	857.2
Crude protein	70.4
Crude fibre	311.2
Total ash	96.2
Ether extract	59.3
Calcium	8.1
Phosphorous	4.4

Table 1: B) Profile of layer diets showing CPH inclusion levels and combination of enzymes used

DIET	CPH inclusion	Phytase inclusion*	Enzyme cocktail inclusion
T1#	0	-	-
T2	0	+	-
T3	0	-	+
T4	0	+	+
T5	100	-	-
T6	100	+	-
T7	100	-	+
T8	100	+	+
T9	150	-	-
T10	150	+	-
T11	150	-	+
T12	150	+	+

* -: not included in treatment; +, included in treatment ;T#: Treatment

Table 2: Composition of the primary layer diets

Ingredients (%)	0% CPH*	10% CPH	15% CPH
Corn	51.55	51.55	51.55
Soybean meal	18	18	18
Wheat bran	20	10	5
Cocoa pod husk	0	10	15
L-Lysine HCl	0.15	0.15	0.15
DL-Methionine	0.15	0.15	0.15
Limestone	8.0	8.0	8.0
Dicalcium phosphate	0.7	0.7	0.7
Salt	0.5	0.5	0.5
Layer premix	0.25	0.25	0.25
BE3[1]	0.5	0.5	0.5
Toxin binder[2]	0.2	0.2	0.2
Total	100	100	100
Calculated Analysis			
ME, MJ/kg	9.75	9.55	9.45
CP, g/kg	162.4	156.4	153.4
CF, g/kg	35.7	43.8	47.9
Total Lys, g/kg	9.8	9.8	9.8
Total Met, g/kg	4.0	3.8	3.6
Ca, g/kg	31.2	31.4	31.4
P, g/kg	6.5	5.7	5.3

*Cocoa pod husk

[1:] *Lactobacillus sp, Bacillus sp, Saccharomyces sp* and Fermentation products.

[2:] Mycofix® Select 3.0 by Biomin

At the 0 CPH inclusion level (T1 to T4), there were no differences (P >0.05) in ADFI among the treatments (106.4, 106.4, 107.4 and 106.5g respectively) (Table 3). Similarly, when the level of CPH in the diets was 10% (T5 to T8), there were no differences (P >0.05) in ADFI among the different treatments (109.6, 108.7, 110.7 and 111.6 g respectively). ADFI of birds on T5 to T8 were however higher (P <0.05) than ADFI of birds on treatments with 0 CPH.

On average, birds ate more feed when the level of CPH in the diet was 15% (T9 to T12). ADFI of birds on T10 and T11 (111.5 and 111.6 g respectively) were similar to (P >0.05) ADFI of birds on T12 (110.8 g) and higher than ADFI of birds on T9 (108.1 g).

Table 3: Effect of cocoa pod husk on egg laying performance

	Inclusion level of cocoa pod husk													
	0%				10%				15%					
	Enzyme levels				Enzyme levels				Enzyme levels					
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12		
Parameter	None	Phy	Cock	Phy+ Cock	None	Phy	Cock	Phy+ Cock	None	Phy	Cock	Phy+ Cock	SEM	P-Value
ADFI (g)	106.4^{d}	106.4^{d}	107.4^{cd}	106.5^{d}	109.6^{abc}	108.7^{abc}	110.7^{ab}	111.6^{ad}	108.1^{bcd}	111.5^{a}	111.6^{a}	110.8^{ab}	0.74	<0.001
Egg production (%)*	78.77a	78.57^{a}	78.70^{a}	79.50^{a}	70.77^{b}	75.56^{ab}	75.49^{ab}	71.89^{b}	66.00^{c}	70.85^{b}	71.96^{b}	72.16^{b}	1.17	<0.001
Egg weight (g)	53.68^{d}	55.80^{c}	54.27^{d}	55.70^{c}	55.70^{c}	55.35^{c}	55.47^{c}	55.46^{c}	56.26^{bc}	57.18^{a}	56.80^{ab}	56.33^{bc}	0.25	<0.001
FCE	0.51	0.53	0.51	0.53	0.51	0.52	0.55	0.50	0.53	0.52	0.52	0.51	0.01	0.629

None= No enzyme added: Phy = Phytase added; Cock = Enzyme cocktail added; SEM = Standard Error of Means: * = Hen-Day egg production

The birds appeared to increase their daily feed intake when enzymes were added to the diet.

There was no effect (P <0.05) of enzyme supplementation on hen day egg production in diets with 0 and 10% CPH. For birds on T1, T2, T3 and T4, hen day egg production was 78.77, 78.57, 78.70 and 79.50% respectively.

Birds on T9 (15% CPH; no enzymes) had the lowest hen day egg production (66.0%) and this was different (P <0.05) from all the other hen-day production values. Birds on T10, T11 and T12 had egg production values of 70.85, 71.96 and 72.16% respectively, and these values were not different from each other or from values obtained for birds on T5 and T8. The cocktail and the mixture of cocktail plus phytase significantly improved the production at the 15% inclusion rate despite its being the lowest. There were no differences in FCE among the various treatments.

There were no differences (P >0.05) in egg weights at the 10% CPH inclusion level irrespective of the presence of enzymes. Egg weights for birds on T1 and T3 (53.68 and 54.27 g respectively) were lower (P <0.05) than egg weights of birds on T2 and T4 (55.8 and 55.7 g respectively), but similar to egg weights of birds on T5 to T8. The heaviest eggs (57.18 g) were recorded for birds on T10 (15% CPH plus phytase). This was similar to (P >0.05) egg weight of birds on T11 (56.80 g), but heavier (P <0.05) than eggs from birds on all the experimental diets. There were no differences in egg length and width, shell thickness, albumin height and Haugh Unit (Table 4).

A-priori contrasts between some treatments of specific interest for production parameters indicated differences in ADFI, egg weight, and hen day egg production (Table 5). Average daily feed intake when no enzyme was added was 108.0 g irrespective of the level of CPH. This was lower than (P <0.05) ADFI when phytase plus a cocktail enzyme, cocktail alone, or phytase alone (109.6, 109.9 and 108.9 g respectively) was added. Similarly, egg weight when no enzyme was added to the feed was 55.21 g, and this was lower than egg weights of birds fed diets either with only a cocktail enzyme (55.51 g) or with phytase alone (56.11 g). Hen day egg production of hens fed diets without any enzyme was 71.85%. This was lower than egg production of hens fed diets with a mixture of phytase and a cocktail (74.52 g), a cocktail enzyme alone (75.38 g) or phytase alone (74.99 g) (P <0.05).

Table 4: Effect of cocoa pod husk on egg quality characteristics

	Inclusion level of cocoa pod husk													
	0%				10%				15%					
	Enzyme levels				Enzyme levels				Enzyme levels					
Parameter	None	Phy	Cock	Phy + Cock	None	Phy	Cock	Phy+ Cock	None	Phy	Cock	Phy+ Cock	SEM	P-Value
Egg Length (mm)	57.00	57.47	57.07	57.17	57.20	57.60	57.20	57.60	58.90	57.67	57.20	58.10	0.55	0.496
Egg width (mm)	41.33	41.60	42.03	41.53	41.30	41.34	41.87	41.3	42.57	42.07	41.50	42.03	0.36	0.247
Shell thickness (mm)	0.36	0.37	0.36	0.37	0.36	0.37	0.36	0.37	0.36	0.37	0.35	0.38	0.06	0.412
Albumin height (mm)	7.99	7.95	7.29	7.26	7.30	7.59	7.37	7.44	7.50	7.35	7.62	7.78	0.19	0.36
Haugh Unit	74.23	73.79	68.39	67.80	68.47	70.89	69.03	69.52	70.19	75.24	71.13	72.96	1.67	0.05

None= No enzyme added: Phy = Phytase added; Cock = Enzyme cocktail added; SEM = Standard Error of Means

Table 5: P-values of A priori treatment comparisons of interest: Production parameters

	P-Value					
PARAMETER	Non vs Phy +Cock	Non vs Cock	Non vs Phy	Phy vs Cock	Phy vs Phy+Cock	Cock vs Phy+Cock
ADFI	<0.001	<0.001	<0.001	0.951	0.513	0.474
Hen day production	<0.001	<0.001	0.006	0.556	<0.001	<0.001
FCE	0.894	0.790	0.445	0.303	0.369	0.895
Egg weight	<0.001	<0.001	<0.001	<0.085	0.075	0.953

None= No enzyme added: Phy = Phytase added; Cock = Enzyme cocktail added; SEM = Standard Error of Means

Discussion

Average daily feed intakes of the three main diets by the layers were 106.7, 110.2 and 110.5 g (0% CPH, 10% CPH and 15% CPH respectively). With increasing levels of CPH in the diets, ADFI tended to increase. This may be due to the increasing fibre levels leading to slightly reducing energy densities as the dietary levels of CPH increased. The birds were fed *ad-lib*, and monogastrics like birds will eat more of a diet that is low in nutrient density in an attempt to meet their daily nutrient requirements, particularly energy (Leeson & Summers, 1997). This phenomenon has been observed in broilers by Adeyanju *et al*. (1976) and Alemawor *et al*. (2010) and in layers by Umar Faruk *et al*. (2010).

With increasing dietary CPH levels, hen-housed egg production generally decreased. The average drop in production when CPH was first introduced at a level of 100g per kg was 5% (78.89 to 73.43%) and this was greater than the drop in production when the level of CPH was raised by a further 50 g to 150 g per kg (73.43 to 70.24). These averages represent all the values that were observed when the levels of CPH were 100 g per kg and 150 g per kg respectively, irrespective of enzyme addition.

It can be assumed from this observation that any anti-nutritive factor (ANF) present in CPH exerted a greater negative effect on egg production at a level between zero and 100g/kg than between 100 g/kg and 150 g/kg. Osei *et al.* (1991) however saw no adverse effects on egg production when CPH was included at a dietary level of 75 g per kg. It could be argued that the level of CPH inclusion was tolerable and so no adverse effects of the ANF were manifest. On average, egg weights were 54.9, 55.5 and 56.6 g in the 0%, 10% and 15% CPH diets respectively for the three levels of CPH inclusion. Thus egg weights showed an increase with increasing CPH inclusion in the diets. This increased egg weight followed a similar trend as their ADFI. Several factors affect the weight of an egg, including protein content of the diet, water intake, ADFI, atmospheric temperature and age. The HSB layers increased their feed intake as the level of CPH increased in the diet, and this could explain the resultant increase in egg weight.

Feed conversion efficiency (FCE) in egg production is the efficiency of converting feed into eggs. It is calculated as the weight of eggs (g) that a unit of feed (g) will produce over a period. With the observed trend in ADFI and egg weight, the lack of effect of CPH level in the diet on FCE was expected. The lack of an effect of CPH on shell thickness may be due to the fact that the levels of both calcium and phytate (P) in the diet, which are the main minerals needed for egg shell formation, were adequate and not out of balance. Internal egg parameters were not affected by the level of CPH in the diet.

The need to add exogenous enzymes to monogastric feeds becomes necessary when portions of the diet are such that the animal does not have the appropriate enzymes to hydrolyse them (Bedford, 2000; Brufau *et al.*, 2006). The phytate molecule in addition to phosphorous binds to other nutrients like amino acids, minerals and vitamins. The use of exogenous phytase has thus been demonstrated to improve the availability of these nutrients to monogastrics (Mroz, *et al.,* 1994; Liao *et al.*, 2005; Nortey *et al.*, 2007). The total P in the CPH determined in this study was 4 g/kg, of which a certain portion (not determined) was phytate P. Cocoa pod husk replaced wheat bran which has a total P content of 9 g/kg, of which 80% is phytate P (NRC, 1994). If it is assumed that the phytate P content of CPH, as a percentage of total P, was close to 100%, it can be seen that replacing wheat bran with CPH will result in a diet with a phytate content which is not significantly different from a diet based on wheat bran alone. The targeted substrates for the cocktail enzymes in addition to phytates are amyloses, proteins, celluloses, xylans, β-glucans and pectins. This group of enzymes degrade fibre and release energy (Khattak *et al.,* 2006). They improve nutrient utilization by reducing intestinal viscosity and also through demasking, which is the process whereby xylanase breaks down water-insoluble-pentosans found in cell walls of fibrous plant materials. Increased intestinal content viscosity slows transit time and retards nutrient absorption, with a resultant depression in chick growth (Antoniou *et al.,* 1981; Nasi 1988; Marquardt *et al.*,1994). Enzyme

addition increased ADFI at the various levels of CPH inclusion. This trend was contrary to observations by Osei & Oduro (2000) and Dong (1997).

Although addition of phytase or an enzyme cocktail by itself tended to increase ADFI, especially at the 15% CPH inclusion level in this trial (Table 3), a combination of both phytase and a cocktail caused a slightly higher numerical effect. This observation was contrary to the situation where enzyme addition can result in a drop in ADFI (Osei and Oduro, 2000). The theory behind a drop in ADFI upon enzyme supplementation is the phenomenon of nutrient uplift where exogenous enzyme addition causes a release of nutrients, resulting in the daily nutrient requirement of animals being met much more readily and thereby causing a cessation of feeding (Richardson, 1970). However, according to Smith & Bright-Taylor (1974), the glucostatic theory of feed intake regulation, as observed in some mammals, is either not present in poultry or is not well understood. Results from this study showed an absence of this theory. One can therefore speculate that the inclusion of enzymes, in addition to releasing nutrients, may have reduced (or prevented) any possible fibre-inducing intestinal viscosity. This will result in slightly faster intestinal transit times; thus, less feed in the Gastro-Intestinal Tract (GIT) will result in a feeling of emptiness, leading to a need to increase ADFI. The enzymes reduce the water holding capacity of the gut contents, thus increasing the dry matter (Khusheeba & Sajid, 2013). The fact that a combination of both enzymes in the diet resulted in a marginal increase in ADFI compared to either enzyme alone indicates that there is synergy between the two enzymes, and that the phytase content of the cocktail enzyme alone may not be sufficient. Increased ADFI in the presence of added enzymes could be the cause of an increase in average hen-day egg production and egg weights at each level of CPH inclusion. Although the addition of CPH resulted in a dilution effect of the diets, the resultant increase in ADFI in the presence of enzymes may have compensated for this. Internal egg parameters were not affected by enzyme addition in this trial.

A priori contrasts, performed to determine which of the enzymes and/or combination of enzymes resulted in improved production characteristics irrespective of CPH inclusion, showed that birds benefited significantly from enzyme addition when diets with added enzyme cocktails plus phytase were compared with diets with no enzymes added.

This was expected since in addition to phytase, the cocktail contained other enzymes which together would act synergistically to improve nutrient digestibility (Nortey *et al.*, 2008). The absence of any improvement, when the effect of phytase alone or a cocktail alone versus diets without any enzyme, seems to indicate that the suggested level of enzyme application was either not enough, or the type of substrate in the diets presented a unique "lock" that required slightly different enzyme combinations.

The use of phytase in monogastric diets in developing countries like Ghana must be encouraged. Once the di- and tri-valent bonds in phytic acid are broken by phytase, phosphorous and other encapsulated nutrients are released for use by the animal. Fibre degrading enzymes have not been so popular probably because the results have not always been positive (Nortey *et al.*, 2015). This may be because local ingredients, grown under local climatic and soil conditions, may have slightly different Non-Starch-Polysaccharide (NSP) profiles, which may present slightly different substrates to the commercially available enzymes developed in Europe and North America.

Conclusions

Results of this study on the use of CPH in diets for HSB layers suggest that cocoa pod husk can be included in diets up to a level of 100 g/kg in the presence of enzymes without affecting production or egg characteristics. Also, there was little to no overall advantage of phytase plus a cocktail over phytase or a cocktail alone.

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