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REVIEW PAPER

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Waste and by-products of cocoa in breeding: Research synthesis

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Abstract

This review aims to show the potential nutritional waste and by-products of cocoa in animals through scientific studies. Indeed, research indicates that the waste and by-products generally contain cocoa 12-17% protein, major minerals (Ca, P, K, Na) and fibers that predispose them to feed. Tested in ruminants, chickens, snails, pigs and rabbits, they have been beneficial to low levels. Because these foods contain theobromine, antintritionnel factor, witch limits their use in livestock. However, appropriate treatments can help to increase the quantities of waste and by-products of cocoa in animal diets.

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Introduction

The world population is net growth, about seven billion people to date. Food resources available must be used to satisfy their nutritional needs and those of animals. So, it is a tacit competition between these two entities. This creates a speculative cost of food and inadequate. This finding orders in search of other food sources, less expensive to feed animals: waste and agricultural by-products. By-products of the banana (Ogunsipe *et al*., 2010; Ekwe *et al*., 2011) and cashew (Edet *et al*., 2010; Omosulis *et al*., 2011) had already been successfully tested in animal husbandry. What about waste and by-products of cocoa? It is this question that this review interest. Indeed, waste and by-products of cocoa constitute more than half of world production estimated at 3.53 million tons (World cocoa foundation, 2010).

Packaging and storage of waste and by-products of cocoa

The effect of alkali concentration and treatment on the chemical composition of cocoa pod husk was investigated (Sobamiwa and Longe, 1994). This was followed by the incorporation of the alkali treated cocoa pod husk in broiler starter diets to investigate its nutritive value (Sobamiwa and Longe, 1994). The results showed that increasing treated cocoa pod husk level up to 100 g kg−1 did not significantly reduce growth performance and apparent digestibility of nutrients (Sobamiwa and Longe, 1994). Cocoa products can be rendered harmless by being cooked in water for one and a half hours, filtered and dried (Fao, 2002).

The optimum storage conditions of cocoa-cake-with-shell was studied by Wallace et al. (2010).Three oil seed cakes namely copra cake, palm kernel cake and cocoa-cake-with-shell were studied under four different conditions: room temperature (-15±1^{o}C), room temperature (5±1^{o}C), air condition (19±1^{o}C) and room temperature, (25±1^{o}C). Samples were chemically analysed fortnightly over a 6 month period for proximate, gross energy, Ca, P and free fatty acid composition (Wallace *et al*., 2010). The study indicated that cocoa-cake-with-shell should not be stored longer than 2 weeks when kept under room temperature conditions (Wallace *et al*., 2010). Otherwise, hot-water treated cocoa bean shell based diet was evaluated in respect of performance and physiological response of weaned rabbits. The treatment reduced the theobromine content of cocoa bean shell (Adeyina *et al*., 2010).

Chemical compositions of waste and by-products of cocoa

The chemical analysis of cocoa shell meal showed crude protein values of 5.9% and crude fiber of 21.3% (Meffeja *et al*., 2006) comparable to the results obtained by Lyayi *et al*. (2001). However, the concentration of crude fiber obtained in this study (Meffeja et al., 2006) was much lower than the values of 32.5 and 45.9% respectively reported Donkoh et al (1991) and Aregheore (2002). Chemical compositions of some wastes and by-products of cocoa are recorded in tables 1, 2, 3 and 4.

Nutritional value of waste and by-products of cocoa

The results of Alba *et al*. (1954) who reported an improvement of 7.23% in milk production compared to the control diet when 50% of cocoa shells were used in the ration of dairy cows. Defatted cocoa cake, a byproduct of the cocoa fermentation process, was evaluated as a direct feed in the monosex culture of *Tilapia guineensis* (Dumeril). Experimental yield trials were compared with two types of controls: a locally manufactured fish diet and an unmanaged system. Survival of the fish ranged from 90.21 to 93.13%. At harvest, average net yields were 2310.00, 1707.50 and 1133.13 kg/ha from the fish diet treatment, cocoa cake treatment and unmanaged system, respectively. Feed conversion values (based on dry matter inputs) averaged 5.12 and 2.30 for the fish fed the cocoa cake and fish diet, respectively. Analysis of the stomach contents of fish from the experimental pond showed that cocoa cake was utilized directly as feed (Oyedapo, 1988).

Table 1. Dry matter content (%) and proximate chemical composition (% of dry matter) of cocoa shell and cocoa dust.

Nutrients	Cocoa shell	Cocoa dust
Dry matter	97.5	94.5
Crude protein	16.0	13.8
Crude fiber	58.0	61.0
Ether extract	19.0	22.0
ash	7.5	3.5
Organic matter	92.5	96.5
Gross energy (MJ/kg DM)	23.4	22.6

Adapted from Aregheore (2000)

In 1990, use of cocoa pod in animal feed has been reported by Sampath *et al.* (1990) Cocoa pod has high nutrition value in terms of protein content, energy value and other micronutrients. One year later, Abiola and Tewe (1991) revealing beneficial effect of cocoa pod, shell, dust, incorporated in the diet of poultry and lambs. In case of lambs, increase in body weight was observed when they were fed with 12 -30% cocoa pod and an increase in egg weight and percentage egg production was reported when hen were fed with cocoa pod.

Table 2.1. Nutrients content of cocoa hulls.

Nutrients	Value
Dry matter (DM)	88.5± 2.1
Crude protein %DM	17.9±0.9
Crude fiber %DM	20.7±1.4
Ether extract %DM	5.9±1.6
Ash %DM	9.3±0.5
Total sugar %DM	1.0±0.8
Gross energy kcal/kg DM	4497±140

Adapted from Fao (2002)

The nutritive value of cocoa shell was also studied in vitro and nylon bag technique and a feeding trial was also carried out in growing cattle by Mahyuddin (1995). Cocoa shell contains 17.6% crude protein, 4.6% fat, 0.36% Ca, 0.61% P, 0.06% Na, U 61% Mg and 1.6 % theohromine. The dry matter digestibility of cocoa shell was 63.5 %. Approximately 30 % of cocoa shell protein disappeared from the rumen after 12 hours and there was a small increase after that time. Whereas for fat, there was an increasing amount disappeared from the rumen after 12 hours but may reach the maximum value (73 %) at 48 hours. Cocoa shell is a good source of energy and minerals, P and Mg for ruminants (Mahyuddin, 1995).

Table 2.2. Minerals content of cocoa hulls.

Minerals	Value
Calcium %DM	0.37±0.07
Phosphorus %DM	0.44±0.06
Potassium %DM	2.68±0.19
Sodium %DM	0.02±0.01
Magnesium %DM	0.43±0.10
Copper %DM	39
Chlorides (expressed in Nacl) %DM	0.06±0.03

Adapted from Fao (2002)

Five levels of cocoa shell, 7, 17, 27, 37 and 47% were included in the concentrate to study (I) theobromine disappearance in the rumen, (II) its effect on growing cattle. In experiment 1, fistulated Ougole fed elephant grass ad libitum plus 2 kg concentrate (with 7 % cocoa shell) were used to suspend the nylon bag containing different levels of cocoa shell. Almost all of theobromine disappeared from nylon bag at 24 hours incubation, and there was no difference with 48 hours incubation. In experiment II, thirty Ongole were randomly divided into 5 treatment groups receiving elephant grass ad libitum concentrate (1.2% Live Weight) containing different levels of cocoa shell. The experiment lasted for 80 days. There were no differences in intake of dry matter and metabolisable energy between the treatments (Mahyuddin, 1995). Live weight gain was not affected by feeding less than 27% cocoa shell in the concentrate (or 11% in the ration). However, at 37% cocoa shell (or 15 % the ration), live weight gain stated to decline. At this level, the ration contains approximately 0.24 % theobromine which may be responsible for reduced utilization of metabolisable energy (Mahyuddin, 1995).

Fresh pods are sometimes consumed by livestock, but for efficient use they must be dried and ground. Pod meal has been fed without toxic effects to cattle in quantities of up to 7 kg per day. For dairy cows, pod meal seems to be comparable in value to corn-on-cob meal. Rations containing cocoa pod meal have a somewhat lower feed efficiency for beef cattle, but this will be compensated by the larger intake (Fao, 2002). For pigs, cocoa pod meal can replace maize and can constitute up to 35% of the ration without decreasing weight gains. It has been fed to pigs in quantities of up to 2 kg per day. To ensure that the animals consume sufficient quantities, the pods must be sun-dried (to 60% moisture content) and then chopped ground and pelletized (Fao, 2002). Pig rations can include up to 25% of the processed product without reducing weight gains or feed efficiency (Fao, 2002).

The effect of replacement of maize by cocoa husks in a grower-finisher ration was determined in 180 broiler chickens. Cocoa husks were substituted for the maize component in the ration (65 g maize/100 g of diet) at levels of either 0, 10, 20 or 30% of the maize. The birds fed the diet with the 10% substitution level showed significantly faster growth than the control animals whose growth rates were not significantly different from the birds fed the diet with 20% maize replacement. When compared with the control birds, low body weight and poor efficiency of feed utilization were observed for the birds fed the diet with 30% maize replacement (Teguia *et al.*, 2004). It is concluded that cocoa husk might be used as an ingredient for poultry grower finisher diets (Teguia *et al.*, 2004). A series of studies was conducted by Olubamiwa *et al.* (2006) with the aim of finding commercial usage for cocoa bean shell in poultry (layer) diets. The results of this experiment indicated very strongly that the 15-minutes boiling duration is the best for optimal and profitable utilization of cocoa bean shell in layers mash (Olubamiwa *et al.*, 2006).

Sometime after, Hamzat *et al.* (2007) concluded that cocoa bean shell can be included up to 15% in the diet of rabbit. In their work, five experimental diets were formulated such that diet 1(control) was maize based while diets 2, 3, 4 and 5 had 5, 10, 15 and 20% cocoa bean shell respectively. Measurements taken were live weight gain, final live weight, feed intake, feed conversion ratio and cost per kg weight gain. Results showed that cocoa bean shell is useful in feeding weaned rabbits. Rabbit fed 15% cocoa bean shell were significantly ($p>0.05$) than the 20% cocoa bean shell diet in final live weight and daily weight gain, feed conversion ratio and cost per kg gain in weight (Hamzat *et al.*, 2007).

Another study is used to investigate the effect of partial replacement of maize with cocoa bean shell for growing snail for 20 weeks. There were five treatments and the diets contained 0.0, 2.5, 5.0, 7.5 and 10.0% cocoa bean shell in partial replacement of maize (Owosibo, 2008). The parameters taken were weight gain, feed intake from which feed conversion ratio was calculated. There were significant differences ($p>0.05$) in the values obtained for mean weekly weight gain and mean weekly feed intake. Meanwhile, the values for 10.0% cocoa bean shell based diets were comparable to control. The feed conversion ratio was similar across the treatments. Values obtained for mean weekly shell length increment, mean weekly shell width increment and mean weekly shell thickness increment were not affected by inclusion of cocoa bean shell in the diets of snails. The values obtained for carcass characteristics of snail were not significantly different ($p<0.05$) and so not affected by the treatment (Owosibo, 2008). Values obtained for organoleptic properties revealed no difference in flavour, after taste, mouth feel and general acceptability at 10% replacement level in comparison to control except for colour and texture. The inclusion of cocoa bean shell up to 10% in the diets of snail had no detrimental effect on the performance, carcass characteristics and general acceptability of the snails. Based on the present results, cocoa bean shell could replace maize in the diet of snail up to 10% (Owosibo, 2008).

Table 2.3. Amino-acids content of cocoa hulls.

Amino-acids	value
Lysine %protein	5.1
Methionine %protein	1.3
Cystine %protein	1.3

Adapted from Fao (2002)

Table 2.4. Antinutrient factors of cocoa hulls.

Antinutrient factors	Value
Tannin, generic %DM	1.18
Theobromine %DM	0.82

Adapted from Fao (2002)

Table 3.1. Nutrients content of cocoa oil meal, deoiled.

Nutrients	Value
Dry matter (DM)	88.2±1.1
Crude protein %DM	28.6±0.5
Crude fiber %DM	16.9±1.2
Ether extract %DM	0.4±0.2
Ash %DM	10.3±1.4
Total sugar %DM	0.9±0.0

Adapted from Fao (2002)

Table 3.2. Minerals content of cocoa oil meal, deoiled.

Minerals	Value
Calcium %DM	0.25±0.01
Phosphorus %DM	0.75±0.02
Sodium %DM	0.01±0.0
Chlorides (expressed in Nacl) %DM	0.06±0.0

Adapted from Fao (2002)

Besides the nutritional interest, economic analysis of using cocoa bean shell as feed supplement in rabbit production was studied by Oyinde *et al*. (2010). Data used for this study was collected from an experimental study of performance of rabbits fed graded levels of various treatments of cocoa bean shell as feed supplement. Gross margin and dominance analysis were used to analyze the data. The study showed that untreated cocoa bean shell can be used economically at 100g/kg inclusion in rabbit feed while hot-water treated cocoa bean shell can be included up to 200 g/kg in rabbit feed. The study recommends the use of hot water treatment of cocoa bean shell at 200 g/kg inclusion for optimum profitability of rabbit production (Oyinde *et al*., 2010).

Hot-water treated cocoa bean shell based diet was evaluated in respect of performance and physiological response of weaned rabbits (Adeyina *et al*., 2010). The treatment reduced the theobromine content of cocoa bean shell (Adeyina *et al*., 2010). Feed intake and weight gain were significantly ($p<0.05$) high in rabbits fed Hot-water treated cocoa bean shell up to 200g/kg. Water intake was highest in rabbits fed 400g hot-water treated cocoa bean shell /kg. Rectal temperature and pulse rate also increased with increase in hot-water treated cocoa bean shell inclusion (Adeyina *et al*., 2010). In Nigeria, a study was undertaken to evaluate and compare the chemical composition of the cocoa by products- cocoa pod husk, cocoa shell and cocoa dust- and to establish a rational use of cocoa shell and cocoa dust in the diets of growing goats. Cocoa dust had a high crude protein content of 15.9%, while cocoa shell and cocoa pod husk had 13.8% and 6.7%, respectively. The byproducts were high in crude fiber content. Among the byproducts, cocoa dust had the highest ether extract value (22.0%). Fifteen growing goats, 18–20 months of age, with pre-experimental body weights of 20.9±0.33 kg, were randomly allotted to three diets in growth studies. In diet 1, dried brewers' grains served as the control, while the other two diets had cocoa shell or cocoa dust plus dried brewers' grains. The dry matter intake was 570, 530 and 486 g/head per day for the control, cocoa shell + dried brewers' grains and cocoa dust + dried brewers' grains diets, respectively. The growth rate differed significantly among the goats offered the diets ($p<0.05$) (Aregheore, 2011). Dry matter, crude protein, crude fiber, organic matter and gross energy digestibility were significantly higher ($p>0.05$) in the goats on the control diet than in those on cocoa shell + dried brewers' grains or cocoa dust + dried brewers' grains. The dry matter, crude protein and organic matter in the cocoa shell + dried brewers' grains diet were more digestible ($p>0.05$) than those in the cocoa dust + dried brewers' grains diet. The inclusion of dried brewers' grains in the cocoa shell and cocoa dust diets improved their use by the goats (Aregheore, 2011).

Table 3.3. Amino-acids content of cocoa oil meal, deoiled.

Amino-acids	value
Lysine %protein	4.05±0.1
Methionine %protein	1.3±0.0
Cystine %protein	1.55±0.0

Adapted from Fao (2002)

Table 3.4. Anti-nutrient factors cocoa oil meal, deoiled.

Antinutrient factors	Value
Tannin, generic %DM	1.64

Adapted from Fao (2002)

Table 4. Proximate composition of cocoa pod husk.

Components	g/kg DM
Dry matter	889.6±1.5
Crude protein	91.4±0.4
Crude fiber	337.4±1.7
Total ash	90.7±0.4
Total sugar	33.0±0.6
Lignin	211.6±2.6
Hemicelluloses	127.5±9.6
cellulose	261.5±3.0

Adapted from Alemawor *et al.* (2009)

The digestibility of fiber in flour cocoa shell was discussed by many researchers. A digestion study with sheep, using the total collection method was carried out to determine the effect of graded dietary cocoa-pod (pod) levels of 0, 15, 30, 45, 60 and 75% in sheep, on nutrient digestibilities. The apparent digestibility of cocoa-pod by sheep was also estimated by linear regression. Sheep digested only 23% dry matter and 51% crude protein of the pod (Smith and Adegbola, 1985).

The decrease in digestibility of dry matter, energy and crude protein in the diet based on the increasing level of flour cocoa shells, confirming the results of on the negative influence of the fibrous substances nutrient digestibility (Close 1993; Ndindana *et al.*, 2002). Reducing the digestibility could be explained by the reduction in mean retention time of food in the digestive tract. It is also possible that increasing the concentration of cocoa shell meal in the diet increases the concentration of NDF, ADF and ADL that prevent access of digestive enzymes in the small intestine in the cellular content (Kass *et al.*, 1980). It has been shown that the food rations high in fiber concentration lead to increased secretion of mucus in the digestive tract. This seems all the more understandable that the role of this mucus is to protect the lining of the digestive tract (Meffeja *et al.*, 2006). The digestibility of dry matter, gross energy and crude protein flour cocoa shells, obtained by extrapolation were respectively 37.1, 27.5 and 12.4%. In general, it appears that the apparent digestibility of nutrients from food decreases linearly with increasing level of fibrous substances in the diet (Meffeja *et al.*, 2006). It is well known that nutrients excreted in the feces are not only the undigested portion of food, but also enzymes unused desquamated cells of the lining of the digestive tract and amino acids from microbial fermentation in the large intestine . The fraction of fecal nitrogen from outside the dietary nitrogen is called metabolic fecal nitrogen. This nitrogen is closely related to dry matter intake. The diet contains more indigestible substances, more metabolic excretions, the greater the coefficient of apparent digestibility or fecal decreases (Meffeja *et al.*, 2006). This factor may tend towards zero or negative values for foods low in protein (Ranjhan, 1981). This assertion is consistent with the results of this study and those of Noblet *et al.* (2003) who reported apparent digestibility coefficients of energy and protein of cocoa shell of 20.0% and 0.0% respectively. The strong negative correlation between increasing levels of incorporation of cocoa shells and coefficients of apparent digestibility of nutrients is in agreement with the results of Barnes *et al.* (1984) who reported decreasing values of the coefficients of apparent digestibility of dry matter of 83.9, 86.0 and 47.3%, nitrogen of 83.9, 68.2 and 47.4% and energy 82.0; 64.2 and 40.5% with increasing levels of incorporation of cocoa shells, respectively 0, 25 and 50% in diets of growing pigs finish. Extrapolating the results of Barnes et al. (1984) by linear regression to a level of incorporation of up to 100%, the values of the coefficients of digestibility of nutrients designed to get shells respectively 17.5% for the dry matter, 11.7% for nitrogen and almost zero energy. These low digestibility coefficients are substantially lower than those reported in this study and demonstrate the low food value of cocoa shells (Meffeja *et al*., 2006). Because of the low digestibility of its nutrients, cocoa shells seem better suited to animals in the finishing phase or in reproduction (lactating sows) than those in rapid growth phase. That is why the cocoa shells were valued more in small ruminants (Adeyanju *et al*., 1975), in dairy cows (Alba *et al*., 1954) and in the fattening of cattle. In the same vein, our results show a digestible energy value of cocoa shells to 1229.3 kcal / kg comparable to the values of 1499.1 kcal / kg, 1206.9 kcal / kg and 2007.6 kcal / kg, respectively, reported Donkoh *et al*. (1991) and Lyayi *et al*. (2001).

The weak growth performance of animals fed with increasing concentrations of flour cocoa shells could be due to the high content of crude fiber and lower digestibility of its nutrients, including protein and energy (Meffeja *et al*., 2006).

Risks related to the consumption of waste and by-products of cocoa

Theobromine is a key anti nutritional content in cocoa (Alexander *et al*., 2008). Its presence in the waste and by-products of cocoa could be a factor limiting their intake. What does the research on this? Cocoa beans and shells contain theobromine, an alkaloid poisonous to animals, which limits their use for feeding (Fao, 2002). The level of theobromine is very low in the pods.

Jimson weed seed meal, which contains alkaloids toxic to animals, and cocoa shell meal, which contains theobromine, also toxic to animals, were used in two experiments with broilers to determine relative toxicity (Day and Dilworth, 1984). Pure theobromine was added to diets to furnish the same levels as furnished by 1, 2, 4, and 6% dietary cocoa shell meal, which contained, by analysis, 1.3% theobromine. Approximately 1% jimson meal is the upper dietary limit that can be safely incorporated into the diet of young broilers. Dietary levels of 3 and 6% from 1 to 21 days of age drastically depressed performance. Cocoa shell meal that contained 1.3% theobromine was somewhat less toxic to chicks than jimson meal. However, performance tended to be depressed with dietary levels above 1%. Pure theobromine was a little more toxic than that furnished by cocoa shell meal (Day and Dilworth, 1984).

Liquid feces were observed in diets containing 20% of flour cocoa shells. They suggest that high levels of cocoa husks in the diet could disrupt the normal functioning of the digestive tract. These liquid feces were reported by Ottou (1982) as a toxic level of theobromine in cocoa shells while Trease and Evans (1972) reported a rather diuretic effect of theobromine. Liquid feces could also explain the high concentration of potassium cocoa shell product as it is used in soap making because of its high content of potash. These liquid feces could also be a symptom of diarrhea caused by microbial fermentation in the large intestine (Meffeja *et al*., 2006).

Cocoa shells, beans and oil cake all have high nutritive values and could serve as feedstuffs for livestock except for their theobromine content. Untreated cocoa beans and oil cake can be hazardous to poultry and pigs (Fao, 2002).

The effect of theobromine, a cocoa alkaloid, on total serum protein, albumin, iron and transferring were investigated in albino rats of wistar strain (Eleojo *et al*., 2004). Theobromine was administered intraperitoneally to three groups of rats B, C, and D, weighing between 200-250g averagely. Groups B, C and D respectively received 2.5mg/kg body weight, 5.0mg/kg body weight and 7.5mg/kg body weight of theobromine repeatedly for three days and the control group A received physiological saline. Blood obtained from the sacrificed animal 24 hours later was collected in iron-free centrifuge tube, allowed to clot for an hour and serum separated by centrifugation. Results obtained showed that there was a statistically significant ($p>0.05$) dose dependent increase in mean serum iron in the test groups B, C and D. However serum transferrin levels showed a statistically significant ($p> 0.05$) decrease in the test groups B, C and D compared with control. Mean values of total serum protein in group B, C and D showed no significant difference ($p<0.05$) when compared with the control. Also serum albumin showed no significant difference ($p<0.05$) in the test groups from the control. Consequence of elevated serum iron and lowered transferrin levels are discussed in relation to iron transport and erythropoiesis (Eleojo *et al*., 2004). Many workers have reported on the toxic effect of theobromine in various animal species. The effect of theobromine on iron level in the albino rats of wistar as reflected by the serum iron level suggests that the consumption of theobomine be discouraged (Eleojo *et al*., 2004). The consumption of cocoa fiber with a hypercholesterolemic diet improved the lipidemic profile and reduced lipid peroxidation, suggesting that cocoa fiber might contribute to a reduction of cardiovascular risk (Lecumberri *et al*., 2007).

In Indonesia, Marsetyo *et al*. (2008) showed that cocoa-pods, a by-product of the cocoa industry, could potentially be used as a feed resource for ruminants in areas where cocoa plantations exist. It may be a useful feed resource when fed at low levels of inclusion in the diet (Marsetyo *et al*., 2008). Based on the work of Adeyina *et al*. (2010) except for leucocytes count, $Ca2+$ and urea, other haematological indices (hematocrit, erythrocytes, hemoglobin) and serum $Na+$, $K+$, total protein and glucose decreased ($p<0.05$) in rabbits fed hot-water cocoa bean shell based diet compared with the control group. The findings of this work indicate that hot water treated cocoa bean shell can be included in the diet of rabbit at 200g/kg for optimal performance (Adeyina *et al*., 2010).

Conclusion

Several studies have shown the nutritional value of waste and by-products of cocoa in animal feed. In terms of chemical composition, these foods contain nutrients (13-17% crude protein, Ca, P, K, Na, dietary fiber) that make them food resources. According to the nutritional tests:

-by-products of cocoa can be used as ingredients in poultry and fish;

-in ruminants, flour cocoa shell is a good energy source and can be incorporated up to 20-27% in their diet;

-in pigs, flour cocoa pods can be used in place of corn to the amount of 2kg/day;

-in growing snails, the inclusion at 10% of cocoa shell meal in the diet, replacing corn does not affect their performances;

-flour cocoa pod (treated or untreated) can be introduced into the diet at rates of 10 to 20%.

As observed, the beneficial incorporation of waste and by-products of cocoa regimes animals does not exceed 30%. This is due to the presence of theobromine in such matters. This is an anti-nutrient that consumed in large quantities affects the food digestibility and consequently, the zootechnical parameters.

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