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Performance of weaner buck rabbits fed brewery dried grain as partial replacement for soybeans meal

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Abstract

The study was conducted to investigate the influence of brewery dried grain as partial replacement for soyabean meal on performance of weaner rabbits. A total of 32 mixed breed weaner rabbits (6 weeks of age with average weight of 568.70g) were used for the experiment for a period of 12 weeks. The rabbits were assigned to four treatments which composed of a control diet (containing no amount of brewery dried grain); brewery dried grain (BDG) replacing soyabean meal at 10% inclusion level; BDG replacing soyabean meal at 20% inclusion level; and BDG replacing soyabean meal at 30% inclusion level. Eight animals were assigned to each treatment of four replicates (two rabbits per replicate). Data were collected on growth performance indices, gut morphology, histomorphometry, haematological and serum parameters. Results revealed that weaner rabbit fed diet containing 10% BDG had comparative higher final weight (1196.67g/rabbit), total weight gain (646.67 g/rabbit) and daily weight gain (15.40 g/rabbit) relative to other treatments. Similar trends were seen in the villi height and muscle thickness of rabbits fed 10% BDG as they recorded higher values (1678.52 and 360.12 µm) compared to other treatments. Highest packed cell volume of 40 %; haemoglobin of 13.35 g/dL and red blood cells of 6.65x10^6/ul were recorded in rabbits fed 10% BDG. Higher urea content of 94.85mg/l was found in weaner rabbits administered 30% brewery dried grain while lower values (61.95; 60.05 and 56.90mg/l) were recorded in those fed the control, 10% and 20% BDG, respectively. The study concluded that 10% BDG as partial replacement for soyabeans meal is suitable to improve growth performance, gut functionality, haematological and serum indices in buck weaned rabbit.

Keywords: Brewery dried grain, soyabeans, partial replacement, weaner rabbit,

Running title: Alternative to soyabean in rabbit nutrition

Performance des lapins mâles sevrés nourris avec du grain séché de brasserie en remplacement partiel du tourteau de soja

Résumé

L'étude a été menée pour examiner l'influence du grain séché de brasserie comme remplacement partiel du tourteau de soja sur la performance des lapins mâles sevrés. Un total de 32 lapins mâles sevrés de race mixte (âge de 6 semaines avec un poids moyen de 568,70 g) ont été utilisés pour l'expérience pendant une période de 12 semaines. Les lapins ont été assignés à quatre traitements, qui comprenaient un régime témoin (ne contenant aucune quantité de grain séché de brasserie) ; grain séché de brasserie (GSB) remplaçant le tourteau de soja à un niveau d'inclusion de 10 % ; GSB remplaçant le tourteau de soja à un niveau d'inclusion de 20 % ; et GSB remplaçant le tourteau de soja à un niveau d'inclusion de 30 %. Huit animaux ont été assignés à chaque traitement parmi quatre réplicats (deux lapins par réplicat). Les données ont été collectées sur les indices de performance de croissance, la morphologie intestinale, l'histomorphométrie, les paramètres hématologiques et sériques. Les résultats ont révélé que les lapins sevrés nourris avec un régime contenant 10 % de GDB avaient un poids final comparativement plus élevé (1196,67 g/lapin), un gain de poids total (646,67 g/lapin) et un gain de poids quotidien (15,40 g/lapin) par rapport aux autres traitements. Des tendances similaires ont été observées dans la hauteur des villosités et l'épaisseur musculaire des lapins nourris avec 10 % de GSB, qui ont enregistré des valeurs plus élevées (1678,52 et 360,12 µm) par rapport aux autres traitements. Le volume des cellules packées le plus élevé (40 %), l'hémoglobine (13,35 g/dL) et les globules rouges (6,65 x 106/µL) ont été enregistrés chez les lapins nourris avec 10 % de GSB. Un contenu plus élevé en urée de 94,85 mg/l a été trouvé chez les lapins sevrés administrés

avec 30 % de grain séché de brasserie, tandis que des valeurs plus faibles (61,95 ; 60,05 et 56,90 mg/l) ont été enregistrées chez ceux nourris avec le témoin, 10 % et 20 % de GDB, respectivement. L'étude a conclu que 10 % de GSB comme remplacement partiel du tourteau de soja est adapté pour améliorer la performance de croissance, la fonctionnalité intestinale, les indices hématologiques et sériques chez les lapins mâles sevrés.

Mots-clés : Grain séché de brasserie, soja, remplacement partiel, lapin sevré
Titre court : Alternative au soja dans la nutrition des lapins

Introduction

Feed scarcity remains a significant challenge to livestock production, particularly in developing nations like Nigeria, where high cost of animal feeds driven by rising feed ingredient prices, has led to poor nutrition, reduced productivity, and even animal mortality (Agbede and Aletor, 2003; Nodu *et al.*, 2014). Consequently, these factors have severely impacted adequate protein intake for the growing population. However, intensive rabbit production has been identified as a potential solution to bridging the meat supply gap in Nigeria and to ensuring adequate supply of animal protein (Etim and Oguike, 2010).

The domestic rabbit (*Oryctolagus cuniculus*), as pseudo-ruminant herbivore, plays a crucial role in meat production. Rabbit meat is a valuable source of healthy food, being low in cholesterol and high in protein (Aduku and Olukosi, 1990). As an economically viable livestock species, rabbits hold significant potential in addressing Nigeria's dietary protein deficiency. Their low space requirement, lack of religious taboos, minimal capital investment, and unique digestive physiology, which allows for the efficient use of forages and agro-industrial by-products, make rabbits an attractive livestock option. Furthermore, their ability to thrive on non-conventional feedstuffs and forages, which are unsuitable for human consumption, further enhances their economic value (Esonu *et al.*, 2004). Given the scarcity and high cost of conventional protein and energy feed ingredients, especially soybean meal, it is crucial to explore alternative feed sources like brewery dried grains (BDG). The BDG is a by-product of the brewing industry, traditionally used in animal feed dating back to pre-industrial Europe when farms and monasteries brewed beer and fed the resulting by-products to their livestock (Crawshaw, 2004). Brewery dried grain represents about 20% of beer production, equating to 35–40 million tons of brewery by-products worldwide (Mussatto *et al.*, 2006). BDG, derived from barley, wheat, maize, rice, and oats, contains valuable nutrients such as crude fiber, crude protein, ether extract, and starch (Khalili *et al.*, 2011; Radzik-Rant *et al.*, 2018). When dried, BDG comprises 93% dry matter, 22.4% crude protein, 19.1% crude fibre, 48.6% nitrogen-free extract, 2,360 kcal/kg of metabolizable energy, and 6.2% ether extract (Longe and Adetola, 1983).

Previous varying reports with respect to utilization of BDG as replacement for soybeans meal in rabbit nutrition have been documented: Adeleye *et al.* (2014) observed that replacing 20-30% of soybean meal with BDG in rabbit diets resulted to comparable weight gain and feed conversion ratios (FCR). Faniyi *et al.* (2018) found that diets with 15% BDG replacement of soybean meal engender optimal growth, while higher inclusion (beyond 30%) negatively impacted the growth rates of rabbits. Given the rich nutritional value of BDG particularly during this period of high production cost of farm animal. This study investigated the potential of BDG as a partial replacement for soybean meal in rabbit diet owning to the inconsistent previous reports.

Materials and methods

Experimental site

The experiment was carried out at the Rabbitry Unit, Directorate of University Farms (DUFARMS), Federal University of Agriculture, (Latitude 7º10N and Longitude 3ºE), in Odeda Local Government Area of Abeokuta, Ogun state, Nigeria. The Area has a tropical climate characterized with annual rainfall of about 1037mm and maximum temperatures of 20.66 ºC and 35.48ºC, respectively. The vegetation lies in between the tropical rainforest and derived savannah. The Laboratory analysis was done at the Animal Production and Processing Laboratory, Department of Animal Production and Health, College of Animal Science and

Livestock Production, Federal University of Agriculture, Abeokuta, Ogun State.

Source and processing of test Material (Brewery wet spent grain)

Wet brewery spent grains for the experiment was purchased from a reputable agro-industrial by-products store in Abeokuta, Ogun State. Thereafter the spent grain was processed by sun drying for a period of three weeks until a moisture content of 12% was attained. After thoroughly drying the spent grain, it was thereafter stored in sacks and kept in a secured location away from the incidence of pest (rodent); until ready for use.

Experimental animals and management

A total of 32 mixed breed weaned rabbit bucks (6 weeks of age with average weight of 568.70g) were purchased from a reputable farm in Ogun State. Before the animals were brought into the rabbitry, the cages were thoroughly washed and disinfected then allowed to dry for seven days. The floor of each cage was covered with wire mesh to allow free passage of the animal feacal materials On arrival, the rabbits were acclimatized for a week after acclimatization the initial body weight of the rabbits was taken, and the rabbits were distributed to treatment groups in wooden cages measuring 65 x 65 x 65 cm^3 and raised 71 cm from the ground level. The rabbits were caged in clearly labeled cells. The feeding trial lasted twelve weeks while feed (Table 1) and water were given *ad libitum*.

Description of treatment groups and experimental design

Four experimental diets were formulated to reflect four treatment groups including: treatment 1 (control diet i.e. diet without BDG); treatment 2 (diet prepared to contain 10 % BDG as replacement for soyabean); treatment 3 (diet prepared to contain 20 % BDG as replacement for soyabean) and treatment 4 (diet prepared to contain 30 % BDG as replacement for soyabean). The 32 rabbits were randomly allotted to four dietary treatments in a completely randomized design, with eight rabbits per treatment replicated four times and with two rabbits per replicate.

Table 1: Gross composition of the experimental diets containing Brewery dried grain (%)

Ingredients	(0% BDG)	(10% BDG)	(20% BDG)	(30% BDG)
Maize	45.00	45.00	45.00	45.00
Wheat offal	32.50	32.50	32.50	32.50
Soya bean meal	16.00	14.40	12.80	11.20
Brewery dried grain	0.00	1.60	3.20	4.80
Fishmeal	1.00	1.00	1.00	1.00
Bone meal	3.00	3.00	3.00	3.00
Oyster shell	2.00	2.00	2.00	2.00
*Premix	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Total	**100**	**100**	**100**	**100**
Determined Composition				
ME (Kcal/kg	2561.67	2563.16	2564.65	2566.13
Crude Protein (%)	17.29	17.03	16.77	16.52
Crude Fibre (%)	10.03	11.89	12.07	12.52
Ether Extract (%)	3.57	3.64	3.69	3.76
Ash (%)	1.72	1.69	1.67	1.65

**Premix composition: Vit A: 400000 IU, Vit D: 80000 IU, Vit E: 40000 ng, Vit K 3: 800 mg, Vit B1: 1000 MG, Vit B2: 6000 mg, Vit B6: 500 mg, VitB12: 25 mg, Niacin: 6000 mg, Pantothenic acid: 2000 mg, Folic acid: 200 mg, Biotin: 8 mg, Manganese: 300000 g, Iron: 8000 mg, Zinc: 20000 g, Cobalt: 80 mg, Iodine: 400 mg, Selenium: 40 mg, Choline: 800000 g*

Data Collection

Evaluation of growth performance

After one week of acclimatization, the rabbits were weighed and distributed into different treatment groups and replicates. Subsequently, the rabbits were weighed on replicate basis weekly. The average feed intake was deduced as the difference

between quantity offered and the left over. Feed conversion ratio was calculated as the ratio of feed consumed to the weight gain. Body weight gain of the rabbit was recorded by weighing them on replicate basis as well. This was done on a weekly basis and the values were subtracted from the initial weight of the preceding week.

Determination of gut histomorphometry and organ development

At 12 weeks of age, one rabbit with weight close to the average weight for each replicate was selected and slaughtered after fasting for 10hours. Gut morphometry was evaluated by collecting the gut samples and measuring the weight and length of each segment of the gut (Small intestine). The lengths measured were expressed as centimeters (100g weight). Physiological development of the gut was evaluated by histological examination of the duodenal villi. Two centimetres (2cm) long portion of the duodenum were cut and placed in a sample bottle containing 10% formal saline, after washing the content with normal saline. The duodenal cut samples were prepared as slide for light electron microscopy as reported by Shamoto and Yamauchi (2000) to measure the villus height, crypt depth, villus width and muscular wall thickness. Additionally the organs including; liver, kidney, caecum and heart were weighed with the aid of sensitive scale and were expressed as percentage of their weight.

Determination of blood parameters

At 18 weeks of age, one rabbit from each replicate was selected and bled following procedures described by Burnett *et al.* (2003). About 2 mL of blood was collected into tubes from the marginal ear vein of each rabbit with syringe and needle. Each blood sample was divided into two parts, such that 1 mL blood was placed in a potassium (EDTA) tube for haematological study and the remaining blood placed in the plain (no anticoagulant) tube for serum chemistry determination. The samples were collected in the morning (between 7 and 8 a.m.) before feeding. The collected blood samples were kept in ice-pack and transported immediately to the laboratory. Haematological parameters (red blood cell, haemoglobin, packed cell volume, white blood cells and its differentials) and serum biochemical indices were analysed using commercially available tests kits by Randox Laboratories Limited, Crumlin, County Antrim, BT294QY United Kingdom.

Statistical analysis

Data were subjected to one way analysis of variance (ANOVA) using SPSS version 23 and significantly different means will be separated using Duncan's multiple range tests as contained in the same statistical package.

Results and discussion

Effect of brewery dried grain as partial replacement for soybean meal on growth performance of weaner rabbits

The effect of brewery dried grain on growth performance of weaner rabbit is presented in Table 2. Significant variations were noted in the final weight, weight gain (total and daily weight gain), total feed intake and daily feed intake. It was noted that weaner rabbit fed diet contain 10% brewery dried grain as partial replacement for soybean meal had higher final weight (1196.67g/rabbit), total weight gain (646.67 g/rabbit) and daily weight gain (15.40 g/rabbit) relative to other treatments. This observation aligns with the findings of Bamikole *et al.* (2010) that moderate inclusion of alternative high-fiber ingredients, such as BDG, improved feed efficiency in growing rabbits. Equally, Adeniji and Balogun (2002) found that replacing up to 10% of soybean meal with agro-industrial by-products in rabbit diets led to improved growth rates; as long as the fiber content remained manageable. On the other hand, higher BDG inclusions (20% and 30%) led to comparative decline in growth performance indices which was consistent with the reports of Ajayi *et al.* (2017), who found that high levels of fibrous by-products can negatively impact weight gain due to diminished or poor digestibility and energy utilization. This decline in performance at higher inclusion levels is also in accordance with the work of Amaefule *et al.* (2009), who noted that excessive use of fibrous feedstuffs may compromise nutrient availability, affecting overall growth and feed efficiency

Table 2: Effect of brewery dried grain as partial replacement for soybean meal on growth performance of weaner rabbits

Parameters	Control	10% BDG	20% BDG	30% BDG
Initial weight (g/rabbit)	593.33±21.86	550.00±28.87	576.67±33.33	556.67±34.80
Final weight (g/rabbit)	1140.00±98.66^{ab}	1196.67±41.77^{a}	1040±32.15^{ab}	936.67±81.72^{b}
Total weight gain(g/rabbit)	546.67±80.07^{ab}	646.67±68.88^{a}	463.33±61.73^{ab}	380.00±52.92^{b}
Daily weight gain (g/rabbit)	13.02±1.91^{ab}	15.40±1.64^{a}	11.03±1.47^{ab}	9.05±1.26^{b}
Total feed intake (g/rabbit)	1210.00±62.45^{a}	996.67±88.76^{ab}	1143.33±3.33^{ab}	913.33±91.71^{b}
Daily feed intake (g/rabbit)	28.81±1.49^{a}	23.73±2.11^{ab}	27.22±0.08^{ab}	21.75±2.18^{b}
Feed conversion ratio	2.32±0.41	1.60±0.28	2.55±0.33	2.55±0.54

^{a,b}: Means with different superscript along the same row are significantly ($p<0.05$) different BDG: Brewery dried grain

Effect of brewery dried grain as partial replacement for soybean meal on gut morphology and histomorphometry of weaner rabbits

In Table 3, the effect of brewery dried grain as partial replacement for soybean meal on gut morphology of weaner rabbits is presented. In all the parameters measured, significant difference ($p<0.05$) was noted only in the jejunum percent. The highest jejunum percent of 3.21% was found in weaner rabbit fed 10% brewery dried grain as partial replacement for soybean meal; while the lowest (1.92 and 1.48%) jejunum percent were recorded in the weaner rabbit offered 20% and 30% brewery dried grain. Also in Table 4, the effect of brewery dried grain as partial replacement for soybean meal on gut histomorphometry of weaner rabbits is presented. Similar trends were seen in villi height and muscle thickness with rabbit fed 10% brewery dried grain recording higher values (1678.52 and 360.12 µm) compared to other treatments. The growth of rabbit is dependent on the digestion and absorption of nutrients, which is related to the morphological and functional development of the small intestine. Dietary composition may affect villous morphology and its arrangement (Chiou *et al.,* 1994). It also depends on species and genetic strain (Knehans and O'Dell 1980; Moore *et al*., 1988). The length of villi and crypt depth are the most direct indicators of the morphological integrity of small intestine mucosa. The longer length of villi in the small intestine means the larger absorption area, the stronger absorption and utilization of nutrients. Intestinal crypt depth indicates the maturity rate of epithelial cells. The shallower the crypt, the better the digestion and absorption function.

Table 3: Effect of brewery dried grain as partial replacement for soybean meal on gut morphology of weaner rabbits

Parameters	Control	10% BDG	20% BDG	30% BDG
Live weight (g/rabbit)	1220.00±100.00	1075.00±175.00	1065.00±15.00	1025.00±75.00
Duodenum (%)	0.86±0.14	1.32±0.21	1.18±0.06	1.11±0.08
Jejunum percent	$2.67±0.21^{ab}$	$3.21±0.26^{a}$	$1.92±0.27^{b}$	$1.48±0.46^{b}$
Ileum (%)	2.31±0.04	1.97±0.81	1.39±0.28	1.76±0.31
Liver (%)	2.57±0.18	2.98±0.64	2.98±0.14	3.27±0.19
Kidney (%)	0.54±0.09	0.56±0.07	0.41±0.00	0.60±0.05
Caecum (%)	10.88±3.69	12.86±0.44	12.26±0.52	12.43±5.85
Heart (%)	0.24±0.02	0.21±0.01	0.24±0.03	0.23±0.02

^{a,b}: Means with different superscript along the same row are significantly ($p<0.05$) different BDG: Brewery dried grain

Table 4: Effect of brewery dried grain as partial replacement for soybean meal on gut histomorphometry of weaner rabbits

Parameter	Control	10% BDG	20% BDG	30% BDG
Villi height (µm)	$1152.40±81.17^{c}$	$1678.52±1345^{a}$	$1338.72±6.79^{b}$	$1118.17±62.52^{c}$
Villi width (µm)	291.85±34.57	297.17±41.05	251.93±11.21	215.36±13.11
Cryptal depth (µm)	$450.28±40.21^{b}$	$438.85±46.55^{b}$	$840.29±3.82^{a}$	$459.54±12.28^{b}$
Muscles thickness (µm)	$250.95±17.25^{c}$	$360.12±8.70^{a}$	$317.72±5.96^{b}$	$274.65±14.82^{c}$

^{a,b}: Means with different superscript along the same row are significantly ($p<0.05$) different BDG: Brewery dried grain

The improvement in % jejunum, villi height and crypt depth, when rabbits were fed 10% BDG is an indication that the diet adequately stimulated and improved digestive and absorptive capacity of the weaner rabbit. This outcome is consistent with Khalil *et al.* (2018), who observed that moderate levels of dietary fibre increased villi height, thereby enhancing the surface area for nutrient uptake. Mateos *et al.* (2006) also noted that moderate fibre inclusion in diets enhances gut morphology by stimulating gut muscle thickness and villi growth, leading to better

digestive efficiency. Conversely, the reduction in villi height and the increase in cryptal depth observed in the 20% BDG group are consistent with Onifade and Babatunde (1997), who opined that higher fibre content in alternative feed sources may cause intestinal stress, leading to reduced absorption efficiency. This was also supported by Montagne *et al.* (2003), who observed that high-fibre diets can increase crypt depth due to the increased need for cellular turnover in the intestinal lining, which is linked to lower digestive efficiency.

Effect of brewery dried grain as partial replacement for soybean meal on haematological and serum parameters of weaner rabbits

Table 5 shows the effect of brewery dried grain as partial replacement for soybeans meal on haematological parameters of weaner rabbits. There were significant ($p<0.05$) differences among the treatments for packed cell volume, haemoglobin, red blood cells, basophil and mean corpuscular haemoglobin. Highest packed cell volume 40 %; haemoglobin 13.35 g/dL and red blood cells $6.65x10^6$/ul were recorded in rabbits fed 10% brewery dried grain as partial replacement for soybeans meal relative to the other treatment groups. Furthermore, higher basophil and Mean corpuscular haemoglobin (1.50% and 20.05 *pg*) were recorded in rabbits offered 10% brewery dried grain as partial replacement for soybeans meal when compared to the other treatments. In Table 6, the effect of brewery dried grain as partial replacement for soybean meal on serum biochemical parameters of weaner rabbits is presented. The higher urea content of 94.85mg/l was found in weaner rabbits administered 30% brewery dried grain while lower (61.95; 60.05 and 56.90mg/l) contents were recorded in weaner rabbits under the control, 10% and 20% BDG, respectively.

Haemato-biochemical investigations are useful tool for diseases diagnosis and assessment of the level of nutrient utilization in the body of living organisms. The result of this study indicated that the packed cell volume, haemoglobin content and red blood cell count have improved values in rabbits fed 10% brewery dried grain as partial replacement for soybeans meal. The values observed for RBC, PCV, Hb, MCV, MCH, MCHC, WBC in the study were consistent with the normal reference ranges of 5.46 – 7.94 x 10^6/µL, 33-50%, 10.14-17.4g/dL, 58.5-66.5 fL, 18.7-22.7 pg, 5.5- 12.5 $x10^3$/µL, respectively reported by Mitruka and Rawnsley (1977); Jain (1986). The positive impact of 10% BDG on PCV, Hb, and RBC observed in the study is comparable to that of Ajibade *et al.* (2019) who fed rabbits with diets containing 15% BDG as replacement for soybean meal and found that the hematological indices, including packed cell volume (PCV), hemoglobin, and total white blood cell counts were stable without negative implication on immunity or blood health. Similarly, Akinmutimi (2004) observed that animals on diets containing moderate fibre showed better hematological indices, which is indicative of good overall health and nutrient absorption. The reduction in these parameters at higher BDG inclusion levels (20% and 30%) in this study aligns with Ewuola *et al.* (2004), who noted that excessive fibre can lead to subclinical anemia, as indicated by lower Hb and PCV values, due to nutrient dilution or impaired protein utilization. This is also consistent with Olafadehan *et al.* (2011), who linked high dietary fibre with reduced RBC counts, potentially due to malabsorption of essential nutrients like iron and amino acids required for red blood cell production

Table 5: Effect of brewery dried grain as partial replacement for soybean meal on haematological parameters of weaner rabbits

Parameters	Control	10% BDG	20% BDG	30% BDG
PCV (%)	37.00±0.00^{b}	40.00±1.00^{a}	34.00±0.00^{c}	30.50±0.50^{d}
Haemoglobin (g/dL)	12.30±0.00^{b}	13.35±0.35^{a}	11.15±0.15^{c}	10.15±0.15^{d}
RBC (x10^{6}/µL)	6.20±0.00^{b}	6.65±0.15^{a}	5.65±0.50^{c}	5.10±0.10^{d}
WBC (x10^{3}/µL)	6.95±0.50	6.25±0.25	7.00±1.00	7.05±0.85
Heterophil (%)	34.50±2.50	34.50±0.50	33.50±0.50	32.50±2.50
Lymphocyte (%)	64.00±3.00	63.50±0.50	65.50±0.50	67.00±2.00
Eosinophil (%)	0.50±0.50	0.00±0.00	0.50±0.50	0.50±0.50
Basophils (%)	1.00±0.00^{ab}	1.50±0.50^{a}	0.50±0.50^{ab}	0.00±0.00^{b}
Monocyte (%)	0.00±0.00	0.50±0.50	0.00±0.00	0.00±0.00
MCV (*fl*)	59.70±0.00	60.15±0.15	60.15±0.55	59.80±0.20
MCH (*pg*)	19.80±0.00^{ab}	20.05±0.71^{a}	19.70±0.10^{b}	19.90±0.10^{ab}
MCHC (%)	33.20±0.00	33.35±0.50	32.80±0.40	33.25±0.50

^{a,b,c,d}: Means with different superscript along the same row are significantly ($p<0.05$) different

Table 6: Effect of brewery dried grain as partial replacement for soybean meal on serum biochemical parameters of weaner rabbits

Parameters	Control	10% BDG	20% BDG	30% BDG
Total protein(g/L)	5.30±0.10	5.30±0.90	6.15±0.55	7.20±0.80
Albumin (g/L)	3.10±0.30	3.75±0.05	3.45±0.25	3.85±0.55
Globulin (g/L)	2.20±0.40	1.55±0.85	2.70±0.30	3.35±0.25
Creatinine (mg/dL)	1.34±0.67	1.28±0.15	0.52±0.45	1.21±.032
Triglyceride	138.50±14.50	140.90±26.50	154.75±42.75	188.45±12.65
Cholesterol (mg/dL)	136.55±1.05	134.95±18.85	131.75±4.85	161.80±15.60
Urea (mg/dl)	61.95±12.45^{b}	60.05±1.35^{b}	56.20±9.20^{b}	94.85±1.35^{a}
AST (IU/L)	95.50±10.50	109.00±14.00	83.50±0.50	117.50±0.50
ALT (IU/L)	64.50±0.50	72.50±9.50	56.00±4.00	70.00±1.00
ALP (IU/L)	91.00±2.00	93.00±13.00	104.00±9.00	122.50±13.50
VLDL (mg/dL)	27.70±2.90	28.20±5.30	30.95±8.55	37.70±2.50
LDL (mg/dL)	40.85±1.05	41.80±11.40	46.80±0.20	46.10±3.60
HDL (mg/dL)	68.00±2.90	64.95±2.15	54.00±3.50	78.00±14.50

^{a,b}: Means with different superscript along the same row are significantly ($p<0.05$)different. BDG: Brewery

The study observed elevated (though not significantly different across the treatment) total protein and albumin levels in rabbits fed 30% BDG, which could be due to enhanced protein metabolism as a compensatory mechanism for the higher fibre content. This is in agreement with Etim *et al.* (2014), who observed that high-fibre diets can result to increased serum protein levels as the body adapts to higher protein demands for fibre digestion. However, the author also cautioned that excessive protein metabolism can put stress on the liver, which could explain the elevated liver enzyme levels (AST, ALT, ALP) seen at higher BDG inclusion levels.

Additionally, numerically higher cholesterol and triglyceride levels at 30% BDG inclusion are in line with findings from Agbede and Aletor (2003), who reported that diets rich in fibre can increase lipid metabolism, potentially leading to elevated serum cholesterol and triglyceride levels. This might be a reflection of increased fat mobilization as an energy source due to reduced carbohydrate digestibility from the high fibre content. Additionally, Onyimonyi and Ugwu (2007) observed similar trends in rabbits fed alternative fibre-rich diets, where lipid profiles were elevated as the dietary fibre increased. The significantly elevated urea in rabbits fed 30% BDG are consistent with Raharjo *et al.* (1986), who noted that higher levels of dietary fiber can increase nitrogenous waste due to reduced protein digestibility and utilization. This effect indicates potential renal stress when excessive BDG is included in the diet, a trend also observed by Adejumo *et al.* (2005), who linked high urea levels to decreased protein efficiency in high-fibre diets.

Conclusion

This study found that moderate inclusion of BDG (up to 10% as partial replacement for soyabeans) in rabbit diets can be adopted for improved growth performance, enhanced gut morphology; histomorphometry, and healthy hematological and biochemical indices.

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