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Nutrient Digestibility and Physiological Parameters of Crossbreed Weaner Rabbits Provided Dehydrated Bovine Rumen Digesta

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ABSTRACT

The effect of dehydrated bovine rumen digesta (DBRD) on crossbreed weaner rabbits were tested. A total of 48 four-weeks-old crossbreed (New Zealand × Chinchilla) weaner rabbits of average initial weight of 0.88±0.02 to 0.92±0.02kg were assigned randomly into four dietary treatment groups with three replicates of four rabbits each. Dietary treatments include: DBRD0, DBRD5, DBRD10, and DBRD15. Body weight and daily weight gain of crossbreed weaner rabbits that consumed DBRD15 were higher (P<0.05) compared to those in other groups. Rabbits on DBRD15 consumed less (P<0.05) diet than those provided DBRD5 and control (DBRD0) diet. Rabbits that consume DBRD15 had the lowest (P<0.05) feed gain ratio value than those fed in other groups. Rabbits fed DBRD15 recorded the highest (P<0.05) digestibility of crude protein (CP), crude fiber (CF), and dry matter (DM). The digestibility of crude fat increased (P<0.05) in crossbreed weaner rabbits fed DBRD10 and DBRD15. Rabbits fed DBRD10 and DBRD15 had the highest (P<0.05) hemoglobin and packed cell volume production. Red blood cell production was significantly higher (P<0.05) for crossbreed weaner rabbits that consumed DBRD15. Rabbits fed dietary DBRD10 and DBRD15 had the lowest (P<0.05) lymphocyte counts than those provided the control (DBRD0) diet. The carcass weight was higher (P<0.05) for rabbits fed DBRD15. There was an increased (P<0.05) length of the large intestine for rabbits fed DBRD10 and DBRD15. Liver, heart, kidney, spleen, and lungs weights were higher (P<0.05) for rabbits fed DBRD10 and DBRD15. We concluded that 15% graded levels of DBRD improved the growth performance, nutrient digestibility, and health status of crossbreed weaner rabbits.

Key words: Abattoir Waste, Body Weight, Carcass, Crude Fiber, Hematology, Visceral Organ.

INTRODUCTION

The acute shortage of animal protein in developing countries is significant and has resulted in malnutrition of many individuals since the population growth far exceeds the production of animal protein (Oyeagu et al. 2016). Essential amino acids from animal protein are more readily available and nutritionally balanced for consumption than those from plants (Henchion et al. 2017). The low cholesterol and sodium content of rabbit meat helps to prevent vascular disease. Meat from rabbits is a good protein source for those suffering from coronary heart disease (Okpanachi et al. 2010). Apart from the medicinal value of rabbit meat, it is also a good alternative to chicken, pork, beef, etc. In order to increase the production of rabbit meat considering its importance, there is a need to provide diets high in protein and energy on a daily basis. However, the use of conventional energy feedstuff is not sustainable because of the high market prices and their increased needs from livestock, humans, as well as the biofuel sector (Marareni and Mnisi 2020). Indeed, conventional energy (maize) feedstuffs have been frowned upon due to their increased market prices (Arru et al. 2019). To achieve a continuous supply of cheaper rabbit meat, there is a need to adopt an alternative waste product that can compete with conventional feedstuff with little or no importance to humans (Oladunjoye and Ojebiyi 2010; Pinotti et al. 2021). The alternative waste product under study is an abattoir by-product that constitutes environmental pollution and can be used as protein and energy feedstuff in the rabbit (Alao et al. 2017). The utilization of the abattoir waste product in the rabbit diet serves to reduce environmental pollution and cost of production which is of great importance to the livestock industry (Onu and Ogbuagu 2013).

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Rabbit production is gaining attention in some developing countries of the world because of the short generation interval of 28-30 days, and it can produce up to 14 kittens. It is a monogastric herbivorous that can be managed easily, and it has the ability to convert up to 80% forage into flesh (muscle) deposits (Liang et al. 2022). The meat of rabbits is highly digestible with increased nutrients such as protein, minerals, low fat, steric and oleic acids compared to meat of most animals (Adeniji 2008). There are no consumption restrictions (religious taboos) on rabbit meat and the major constraint in the proliferation of rabbit farming in most developing countries is the feeding strategies that can unleash their growth potential.

The abattoir is where bovine rumen digesta is generated and the rumen can serve as cheap, locally available alternative feedstuff with no competition in consumption between human and livestock. As the cattle is slaughtered, the content of its rumen is harvested and it holds feed substances at different phases of digestion. It also contains microbes and it metabolic actions such as proteins, peptides, amino acids, lipids, vitamins and volatile fatty acids (Efrem et al. 2016). The nutritional content of rumen includes 92% dry matter, 7.49% ash, 17.13% crude protein, 2.81% ether extract, 24.58% crude fiber, 40.82% nitrogen free extract and 2278.50kcal/kg as estimated metabolic energy (Gao et al. 2015). It has been utilized as feedstuff in broilers (Colette et al. 2013), catfish (Agbabiaka et al. 2011), Nile tilapia (Abdel-Hakim et al. 2008), feedlot lambs (Salinas-Chavira et al. 2007), rabbits (Okpanachi et al. 2010) and cattle (Rios et al. 2010; Cherdthong et al. 2014). The utilization of dried rumen contents as animal feedstuff will permit the ease of formulating a diet and alleviate the problems linked with the pollution of the environment. However, dehydrated bovine rumen digesta (DBRD) has not yet been used as an energy source to determine nutrient digestibility and physiological parameters of crossbred rabbits. Thus, this research aimed to determine the effect of dehydrated bovine rumen digesta (DBRD) on nutrient digestibility, blood biomarkers, carcass, growth performance, and organ weight of crossbreed weaner rabbits.

MATERIALS AND METHODS

Ethical Consideration

Ethical policies that guide research of this nature were observed by the authors during the research. The ethical approval was granted by the ethical committee of the University of Nigeria, Nsukka, Nigeria with ethical number MUC271SOYE01.

Location of the Experiment

The trial was conducted at the rabbit section of the animal science teaching and research farm University of Nigeria, Nsukka, Nigeria. The trial location is found within latitude 06º 52' 24"N and Longitude 07º 39' 23" E with 550-meter above sea level. Humid tropics characterized the climatic condition of the research area with an average annual rainfall of 1690 mm. The mean ambient temperature of the research area is 26.6ºC (Breinholt et al. 1981).

Experimental Diets

The rumen content was sourced from Nsukka abattoir, Enugu State Nigeria. It was dried to a constant moisture content of 11.95% in the sun. The chemical composition (Table 1) of dehydrated bovine rumen digesta (DBRD) was determined according to the methods of Oyeagu et al. (2019).

The DBRD lumps were crushed to obtain a more homogenous texture using a crushing and mixing machine from Nukor Group, South Africa, before incorporation into the diet. Four dietary experimental feeds were produced to contain 0, 5, 10, and 15% dehydrated bovine rumen digesta (DBRD) represented as DBRD0, DBRD5, DBRD10, and DBRD15 respectively. The percentage content of the feed and chemical analysis is shown in Table 2.

Table 1: Chemical and nutrient composition of dehydrated bovine rumen digesta

Nutrients	Composition (%)
Crude protein	15.64
Crude fat	5.49
Moisture	11.95
Crude fiber	19.74
Ash	12.30
Nitrogen free extract	48.69
Sodium	2.64
Phosphorous	1.41
Potassium	0.75
Calcium	0.68
Magnesium	0.94

Table 2: Percentage nutrient and chemical composition of experimental diets

Ingredients	DBRD0	DBRD5	DBRD10	DBRD15
Maize	48.00	43.00	38.00	33.00
Wheat offal	19.00	19.00	19.00	19.00
DBRD	0.00	5.00	10.00	15.00
GC	12.75	12.75	12.75	12.75
PKC	16.00	16.00	16.00	16.00
Bone meal	4.00	4.00	4.00	4.00
Salt	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Chemical composition				
Dry matter	84.00	85.00	85.00	85.00
Crude protein	15.95	16.04	16.12	16.14
Ash	10.09	10.80	10.02	10.60
Ether -extract	5.25	5.30	5.20	5.15
Crude fiber	10.28	16.30	18.29	20.31
NFE	53.52	54.36	54.99	56.40

DBRD=Dehydrated bovine rumen digesta, NFE=Nitrogen-free extract, GC=groundnut cake and PKC=palm kernel cake.

Experimental Animals and Management

A total of 48 four-weeks-old crossbreeds (New Zealand × Chinchilla) weaner rabbits were used for this research study. Twelve crossbreed weaner rabbits were randomly assigned to four dietary groups (DBRD0, DBRD5, DBRD10, or DBRD15). Each dietary group was replicated into three pens, while four crossbreed weaner rabbits were assigned to each pen. The initial weight of the crossbreed weaner rabbits used for the research study was 0.88±0.02 to 0.92±0.02kg. The crossbreed weaner rabbits were obtained from Enugu Metropolis Farm, Enugu State, Nigeria. The crossbreed weaner rabbits were dewormed with pirazine (piperazine citrate is the active ingredient) on arrival. They were provided *Centrosema pupescens* and grower mash for one week after arrival for acclimatization before the introduction of the experimental diet. The crossbreed weaner rabbits were provided feeds and clean water *ad libitum* all through the research trial. A three-tier cage was used to house the rabbits with 4 rabbits housed per cage denoting a replicate. The feeding was done around 8:00 am and 16:00 pm daily. The research study lasted for eight weeks.

Growth Performance

Feed consumption was determined daily by the difference of feed offered minus feed refusal divided by the number of rabbits in each replicate. The weight of the crossbreed weaner rabbits was determined weekly. The feed and live weight were determined by using a 10.1kg capacity precision weighing balance GF-10K, made in Japan. The feed conversion ratio was calculated by dividing feed consumed with weight gain.

Carcass and Organ Sizes Assessments

A total number of six (6) crossbreed weaner rabbits per treatment was selected at random and slaughtered for carcass and organ size determination. At 52 days of the experimental trial, the rabbits were taken to Ikpa Market abattoir (Nsukka, Enugu State, Nigeria) for slaughter. All the rabbits were humanely stunned by exposing them to relatively low concentrations of carbon dioxide (<40% by volume in air), and then, once they were unconscious, exposed to a higher concentration (approximately 80 to 90% by volume in air). The rabbits were then slaughtered by cutting the jugular vein with a sharp knife and they were left hanging until bleeding stopped. Immediately after slaughter, the fur was removed as well as the gastrointestinal tract (GIT). The carcasses were then weighed to obtain the carcass weight of the rabbits The liver, heart, kidney, lungs, and spleen were weighed using Dymo 2kg weight capacity digital weighing balance, made in UK. The length of the small intestine, large intestine, and stomach were determined using Dymo 2kg weight capacity digital weighing balance, made in UK.

Nutrient Digestibility

One week before the end of the research, two crossbreed weaner rabbits from each replicate were moved to clean metabolic cages measuring 1.1m length × 1.1m width × 1.1m height for each rabbit. There were three days of adaptation before the four-day fecal collection. The feces were air dried at room temperature. Dried fecal samples were ground and analyzed according to AOAC (2006) methods. Nutrient digestibility was calculated thus:

$$Nutrient\ Digestibility = \frac{\text{dietary intake x nutrient in feed} - \text{feces x nutrient in feces}}{\text{dietary intake x nutrient in feed}} X\ 100$$

Biomarker Assessment

At 52 day of the trial, six (6) crossbreed weaner rabbits were used from each dietary treatment (two rabbits per replicate). The collection of the blood was done at the ear tip and the area (ear tip) was warmed to achieve blood vessel dilation to ease blood collection. Blood samples (3mL) were collected with sterile needles. Sterilized tubes with labels that contain anticoagulant were used for blood collection. The biomarker traits analyzed include, hematocrit, hemoglobin (Hb), red blood cell (RBC) and white blood cells (WBC) using IDEXX automated Vet Test Hematology analyzer by IDEXX corporation, Johannesburg South Africa. However, other biomarker traits such as, mean corpuscular volume, mean corpuscular hemoglobin and mean cell hemoglobin were calculated according to Mitruka and Rawnsley (1977).

Research Design and Analysis

The trial was analyzed with completely randomized design (Steel and Torrie 1980) using SAS's General Linear Model Procedure (2010). The model of the statistics is shown below:

$$Aij = \mu + Bi + Eij.$$

Where:
Aij = Dependent variable;
μ = Overall mean;
Bi = Dietary treatment effect; and
Eij = Residual error
The LSD test was used for mean significance at P<0.05.

RESULTS

Growth Traits

The effect of varying dietary portions of dehydrated rumen digesta (DBRD) on growth traits of crossbreed weaner rabbits is shown in Table 3.

All the growth parameters of crossbreed weaner rabbits fed DBRD measured were significant (P<0.05) except for initial body weight (IBW) which did not change (P>0.05). The final body weight (FBW) and average daily weight gain (ADWG) of crossbreed weaner rabbits fed DBRD15 were higher (P<0.05) compared to those provided DBRD0 diet. Crossbreed weaner rabbits consumed less (P<0.05) of DBRD15 compared to those provided DBRD5 and DBRD0 diets. Crossbreed weaner rabbits that consume DBRD15 recorded the lowest (P<0.05) FCR of 2.06 while a higher (P<0.05) FCR of 2.60 and 2.50 was found in crossbreed weaner rabbits fed DBRD0, and DBRD5, respectively.

Nutrient Digestibility

The apparent nutrient digestibility of crossbreed weaner rabbits fed dehydrated bovine rumen digesta fed different dehydrated bovine rumen digesta is shown in Table 4. The result showed that all the nutrient digestibility traits of crossbreed weaner rabbits were significant (P<0.05) except for nitrogen-free extract (NFE) which did not change (P>0.05). Crossbreed weaner rabbits fed DBRD0 recorded the lowest (P<0.05) digestibility of crude protein, crude fat, crude fiber, and dry matter. The digestibility of crude fat was highest (P<0.05) for birds fed DBRD10 and DBRD15 compared to those provided DBRD0 diet. Crossbreed weaner rabbits that consumed dietary DBRD15 had the best (P<0.05) crude protein, dry matter, and crude fiber digestibility compared to those fed other dietary treatments.

Table 3: Growth traits of crossbreed weaner rabbit fed graded levels of dehydrated bovine rumen content

Parameters	DBRD0	DBRD5	DBRD10	DBRD15	P value
IBW (g)	920±0.02	880±0.02	900±0.02	900±0.03	0.11
FBW (g)	2403±0.26c	2415±0.06c	2524±0.04b	2652±0.07a	0.05
ADWG (g)	41.27±1.92c	41.55±1.13c	43.46±0.74b	45.75±1.23a	0.02
DFI (g)	107.29±0.47a	103.69±0.36ab	98.51±0.21b	94.11±0.22c	0.03
FCR	2.60±0.27a	2.50±0.06a	2.27±0.04b	2.06±0.07c	0.01

Mean values within a row with same alphabets do not differ significantly (P>0.05). IBW=Initial body weight, FBW=Final body weight. ADWG=Average daily weight gain. DFI=Daily feed intake. FCR=Feed conversion ratio. DBRD=Dehydrated bovine rumen digesta.

Table 4: Effect of different levels of dehydrated bovine rumen digesta on apparent nutrient digestibility (%) of crossbreed weaner rabbit

Parameters	DBRD0	DBRD5	DBRD10	DBRD15	P value
Crude protein	60.23±0.12c	62.63±0.16c	71.48±0.10b	80.68±0.13a	0.02
Crude fat	58.15±0.12c	60.06±0.13c	67.64±0.09a	70.98±0.13a	0.04
Crude fiber	54.73±0.11c	56.71±0.15bc	61.76±0.03b	76.27±1.05a	0.01
NFE	68.06±0.40	67.78±0.45	67.73±0.28	67.25±0.10	0.07
Dry matter	60.46±0.23d	67.76±0.13c	73.89±0.13b	81.64±0.11a	0.02

Mean values within a row with same alphabets do not differ significantly (P>0.05). NFE=nitrogen free extract. DBRD=dehydrated bovine rumen digesta.

Biomarker Traits

Table 5 presents the results on the effect of different inclusion levels of dehydrated bovine rumen digesta on the biomarker parameters of crossbreed weaner rabbits. The biomarker traits of crossbreed weaner rabbits such as MCH, MCHC and MCV did not differ (P>0.05) with the inclusion of different dietary treatments of DBRD.

The lowest (P<0.05) WBC counts were reported for crossbreed weaner rabbits fed DBRD15 compared to those (DBRD0 and DBRD5) with the highest (P<0.05) counts of WBC. Crossbreed weaner rabbits fed DBRD10 and DBRD15 had the highest (P<0.05) Hb and PCV production compared to those in other treatment groups. The red blood cell production was significantly higher (P<0.05) for crossbreed weaner rabbits fed DBRD15 than those provided with other treatment diets.

Carcass and Organ Size Traits

The impact of dehydrated bovine rumen digesta on the carcass, organ weight, and sizes of crossbreed weaner rabbits is shown in Table 6. All the traits considered were significant (P<0.05) except for stomach and small intestinal length which did not differ (P>0.05).

The live weight and carcass were higher (P<0.05) for crossbreed weaner rabbits fed DBRD15 than those fed DBRD0, DBRD5, and DBRD10 diets. There was an increased (P<0.05) length of the large intestine for crossbreed weaner rabbits that consumed dietary DBRD10 and DBRD15 compared to those fed the control (P<0.05) diet. Liver, heart, kidney, spleen, and lungs weights were higher (P<0.05) for crossbreed weaner rabbits fed DBRD10 and DBRD15 while their lowest (P<0.05) weight was recorded for those provided DBRD5 and the control (DBRD0) diet.

DISCUSSION

Growth Traits

Growth is the increased weight and size of the animal body and it happens as a result of the proliferation of cells as well as enhanced intracellular substance. The best FBW and ADWG were recorded for crossbreed weaner rabbits fed DBRD15 with the lowest feed consumption. This showed that dehydrated bovine rumen digesta inclusion in the present study can produce a better weight compared to the control diet. The lower diet consumption of crossbreed weaner rabbits fed DBRD15 could be due to the higher energy content of the diet. Onu and Ogbuagu (2013) reported that the lower feed consumption of animals indicates that they feed to meet their energy requirement. The higher feed intake recorded for crossbreed weaner rabbits fed DBRD0 and DBRD5 may be due to the lower energy composition of feed which increased their feed consumption to meet up with their energy requirement. According to Efrem et al. (2016), animals must consume more to satisfy their energy requirement to maintain quick growth and development. The better FCR and improved body weight of crossbreed weaner rabbits fed DBRD15 could be attributed to the positive effect on nutrient digestibility (Onu 2010; Ian et al. 2018). The microbial population balance in the gut will increase the efficiency of digestibility and utilization of nutrients for enhanced growth (Yadav and Jha 2019). The higher body weight of crossbreed weaner rabbits fed DBRD15 than the control may be due to the composition of the rumen content (contains microbes and it metabolic actions such as proteins, peptides, amino acids, lipids, vitamins and volatile fatty acids) (Efrem et al. 2016) that ensures the reduction of the pathogenic bacteria in the gut which will encourage efficient utilization of nutrients and conversion of feed to meat (Onu and Aja 2011). Volatile fatty acids are produced in large amounts via rumen digesta fermentation and it is very important because it provides more than 70% of the energy supply which results in improved weight of rabbits (Anuthida and Anusorn 2020). Our results suggest that dietary DBRD15 was not inferior to the control diet. According to Slama et al. (2019), the quantity and make-up of fiber in the feed have a significant effect on non-ruminants. There is also an effect of fiber on non-ruminants based on the type of animal and the developmental stage of the animal. There is an enhanced BW and a better FCR for monogastric animals fed a low fiber diet (Jha and Mishra 2021). The crossbreed weaner rabbits fed DBRD15 had a better performance compared to the control. This may be attributed to more feed protein involvement (protein microbes), long chain

Table 5: Biomarker traits of crossbreed weaner rabbits provided different portions of dehydrated bovine rumen digesta

Parameters	DBRD0	DBRD5	DBRD10	DBRD15	P value
Hb (g/100mL)	14.80±0.15b	14.13±0.08b	15.40±0.05a	15.99±0.14a	0.02
PCV (%)	41.56±0.56b	44.25±1.25b	50.21±0.16a	52.08±0.23a	0.05
RBC (x10^6/cm^3)	7.18±0.16c	8.98±0.07c	10.38±0.08b	13.16±0.11a	0.03
WBC (x10^6/cm^3)	19.01± 0.75a	18.10±0.75a	16.10±1.10ab	15.34±2.80b	0.01
MCH (pg)	212.00±3.00	220.00±5.00	205.50±5.50	229.00±16.00	0.06
MCHC (%)	42.93±0.07	40.15±0.20	41.92±0.08	40.37±0.16	0.09
MCV (um3)	71.90±0.10	70.18±0.18	69.89±0.19	69.14±0.72	0.07

Mean values within a row with same alphabets do not differ significantly (P>0.05). Hb=hemoglobin, PCV=packed cell volume, RBC=red blood cell, WBC=white blood cell, MCH=mean corpuscular hemoglobin, MCHC=mean corpuscular hemoglobin concentration, MCV=mean cell volume and DBRD=dehydrated bovine rumen digesta.

fatty acids and partially digested feed protein (Gugołek and Kowalska 2022; Wessels 2022). The enhanced growth activities may be a result of tolerable level of fiber in the diet. The activities of the dietary fiber in rabbits increased the peristalsis movement of the intestine, it also encourages commensal microbial production which results in efficient digestion and absorption of nutrients for enhanced growth (Elfaki et al. 2015; Cronin et al. 2021). The enhanced weight gain of crossbreed weaner rabbits fed DBRD15 is in accordance with the findings of Holscher (2017).

Nutrient Digestibility

Digestion studies assess the quantity of a specific nutrient absorbed from the intestine. The concept can be used to find the digestibility of different diet constituents which involves the overall nutrient class or a particular constituent within the class. The crossbreed weaner rabbits that were offered the highest dehydrated bovine rumen digesta (DBRD15) had an improved digestibility of crude fat, DM, CP, and CF compared with those provided with other treatment groups. It is important to note that the quality of bovine rumen content depends on the type of pasture consumed by the animal and even the location, because the different locations may have different soil mineral content that supports the pasture (Avondo et al. 2013). The digestibility of crude fat, DM, CP, and CF recorded in our study had higher values compared to the results of Agbabiaka et al. (2011) and Colette et al. (2013). The differences may be attributed to the effect of the diversity of vegetation and pasture found in different locations for ruminants. The present result is consistent with the proposition that the composition of the rumen content depends on the type of feed the animal was exposed to before slaughter and the length of time the already consumed feed will stay in the rumen before Efrem et al. (2016). The variation could also be attributed to the chemical constituents of the type of pasture consumed by the slaughtered animal and species differences (Vega-Britez et al. 2020). Fresh rumen content of ruminants fed an adequate diet can be transferred to other specific ruminants to improve their rumen microbes. Fresh rumen content from buffalo was harvested and transferred to cattle in a 14 days trial (Wanapat and Rowlinson 2007). The authors recorded a better rumen ecology and activities of bacteria in cattle as opposed to fresh rumen content from cattle. The inclusion of bovine rumen digesta in the concentrate diet of crossbreed weaner rabbits in our study improved fiber utilization better than those provided with no inclusion of bovine rumen digesta (DBRD0) in their concentrate diet. The better fiber utilization may be due to the presence of bacteria in the cecum that acts effectively on the fiber material (Mohammed et al. 2013). The biological value of microorganisms in bovine rumen digesta was higher (Agbabiaka et al. 2012; Adewole and Olaleye 2014). Increased minerals, vitamin B, and end-products of rumen fermentation were found in the rumen digesta (Anuthida and Anusorn (2020), which may result in enhanced microbial production and improved the digestibility of CF and CP. The highest crude protein digestibility was seen in crossbreed weaner rabbits fed DBRD15. It may be that dietary DBRD15 has adequate nutrients such as energy (molasses), nitrogen (urea), and minerals as well as essential ingredients from the rumen digesta to complement enhanced proliferation of microbial cells, thus resulting in better microbial activities to degrade diet (Uddin et al. 2015). It could also be linked to the manifestation of dynamic fungal zoospore which always results to better CP digestibility.

According to Anuthida and Anusorn (2020), a strain of the ruminal fungus (*Neocallimastix frontalis*) obtained from the rumen of sheep, had better proteolytic activities, that increase the digestibility of CP. Cherdthong and Wanapat (2013) reported that the supplemental 8% dehydrated rumen digesta could enhance the in-vitro

Table 6: Carcass, organ weight and sizes of crossbreed weaner rabbits fed varying levels of dehydrated bovine rumen digesta

Parameters	DBRD0	DBRD5	DBRD10	DBRD15	P-value
Live weight (g)	2403±0.26c	2415±0.06c	2524±0.04b	2652±0.07a	0.05
Dressed carcass (g)	1903±0.10c	1915±0.15c	2024±0.09b	2152±0.03a	0.03
Liver (g)	43.65±0.75b	41.25±0.75b	55.10±1.10a	55.20±2.80a	0.01
Heart (g)	6.78±0.28b	6.60±0.20b	8.13±0.13a	8.23±0.23a	0.02
Kidney (g)	10.42±0.20b	10.72±0.28b	11.98±0.03a	12.58±0.43a	0.04
Spleen (g)	0.93±0.03ab	0.75±0.05b	0.94±0.06ab	1.08±0.13a	0.01
Lungs (g)	8.92±0.69b	8.70±0.70b	11.82±0.17a	12.38±0.53a	0.03
Stomach length (cm)	11.50±0.50	11.00±0.00	12.50±0.50	12.50±0.50	0.09
Small intestine (cm)	11.50±0.50	11.00±0.00	12.50±0.50	12.50±0.50	0.07
Large intestine (cm)	67.50±2.50b	63.00±4.00b	82.50±2.50a	87.50±2.50a	0.05

Mean values within a row with same alphabets do not differ significantly (P>0.05). DBRD = dehydrated bovine rumen digesta.

digestibility of CP by 11.5%. Previous research showed that the inclusion of dehydrated rumen digesta in the diets of rabbits (Okpanachi et al. 2010) or beef cattle (Cherdthong et al. 2014) could increase energy and CP digestibility compared to the group that did not consume dehydrated rumen digesta. Our study recorded higher crude fat digestibility compared to that reported by Agbabiaka et al. (2012) and Gebrehawariat et al (2016). The differences in the crude fat digestibility could be due to the diversity and the stage of maturity of the consumed forage material and the activities of rumen microbes in the digestion of crude fat. Fats contain higher long-chain fatty acids as well as triglycerides, phospholipids, non-esterified fatty acids, and salts of long-chain fatty acids. Long-chain fatty acids have higher energy than other fatty acids (Shimizu et al. 2020). They are sources of energy for maintenance, milk production, and weight gain. Higher dry matter and its digestibility was recorded for crossbreed weaner rabbits fed DBRD15. High dry matter content is good for the rumen function of ruminants and pseudo-ruminants (such as rabbits) as they serve as substrates for fermentation by microbes (Mi et al. 2018). Our result is similar to the findings of Mahmoud et al. (2015) and Al-Wazeer (2016) for dried rumen digesta obtained from cattle, sheep, and goat.

Biomarker Traits

There was an expectation that dietary inclusion of dehydrated bovine rumen digesta would reduce the cost of production without compromising the health status and physiological conditions of the crossbreed weaner rabbits. Blood biomarkers usually reflect the physiological responsiveness of animals **to** their internal and external environment which serves as an essential tool for monitoring animal health (Oyeagu et al. 2019). The type of nutrient for animals affects their blood biomarkers (Alikwe et al. 2010). Our results showed that higher Hb, RBC, and PCV were recorded for crossbreed weaner rabbits fed DBRD15, while WBC count was lower for those provided DBRD10 and DBRD15. The WBC counts represent the immune cells that shield the body against infections. The rumen fluid contains different bacteria and other microbes such as hundreds of bacterial polysaccharides. The strong antigen of these bacteria may encourage antibody production when needed (Shah et al. 2020). The bacteria polysaccharides found in the rumen fluid encourage the creation of antibodies. They also combine with other antigens to create lymphocytes (WBC) in order to release cytokines when needed (Sun et al. 2010). The activities and growth of cells of the blood and immune system are controlled by the small protein called cytokines (MGuillermo and Eescoteaux 2014). The inflammation responses are regulated by cytokines (Stow and Murray 2013). The secretion of cytokines indicates the production of the immune system to fight against foreign bodies (antigens). The observed higher WBC counts for crossbreed weaner rabbits fed the control (DBRD0) diet may be a result of the stress and diseases the animal is fighting. This is consistence with the studies of Sugiharto et al. (2014) and Oyeagu et al. (2019) who shared the same view. According to Obidinma (2009) and Oyeagu et al. (2019), they reported higher WBC counts when they included different levels of brewers dried grain, and they attributed it to the anti-nutritional inhibitors which chelate divalent metal use in animal metabolism. These challenges could be responsible for the reduced body weight and poor feed conversion ratio (Table 3) observed in crossbreed weaner rabbits fed DBRD0. It was argued that the animal with higher WBC counts shows the capacity to respond to infection (Sugiharto et al. 2016). The RBC are made up of hemoglobin (hemin, globulin, iron, and protein) molecules. There is an association between hemoglobin and oxygen in the blood to generate oxy-hemoglobin which is transport oxygen to needy tissues. Red blood cells conveyed oxygen, carbon dioxide, hormones, heat, nutrients, and wastes. They also control pH, temperature, and water content of the cells (Sender et al. 2016). Hemoglobin and packed cell volume are all parts of red blood cells. The decreased values of RBC, Hb, and PCV recorded for crossbreed weaner rabbits fed the control (DBRD0) diet explains the anemic condition of the animal. The anemic condition may result in inefficiency of red blood cells to transport valuable substances including nutrients to the needy body tissues. According to Oyeagu et al. (2019) and Nath et al. (2022), erythrocytes are degraded because of the anti-nutrient effect which may reduce the oxygen-carrying ability in the blood of the animal, leading to resulting in reduced rabbit weight.

Carcass and Organ Size Traits

The crossbreed weaner rabbits fed DBRD15 had a better carcass weight as a result of their improved live weight than those provided DBRD0. Our results confirm the earlier claim of Elfaki et al. (2015) that rumen digesta improves the carcass yield of rabbits. The rumen content contains different nutrients, including amino acids, volatile fatty acids (such as acetic, propionic, butyric, malic, and salicylic acids), vitamins, and minerals (Elfaki and Abdelatti 2018). The compounds encouraged beneficial bacteria growth in the gut which results in enhanced digestibility for improved carcass weight. Essential organs (liver, heart, kidney, spleen, and lungs) were measured in our study. The sizes of these organs increased for crossbreed weaner rabbits fed DBRD15 compared to those provided with the DBRD0 diet. Spleen change the diets in the body to produce some trace elements, lipids, amino acids, and glucose among others (Wu et al. 2014; Kandola 2021). Their (spleen-stomach) transporting ability ensures the absorption of salt and water (Zhang et al. 2019). 2008). It may be suggested that bovine rumen digesta inclusion accelerated the development of immune-related organs such as the spleen. The spleen synthesized antibodies (Lewis et al. 2019) and they serve as a tank where the majority of the monocytes reside (Paola and Diana 2014). The phagocytic actions of monocytes allow it to ingest or engulf germs (Oyeagu et al. 2019). The immune defence organ (spleen) constitutes the component of the peripheral lymphoid tissue (Lewis et al. 2019). It is possible that the development of the spleen showed that rumen digesta inclusion in the diets enhanced the immune make-up of the crossbreed weaner rabbits. The spleen eliminates old red blood cells and serves as a blood reservoir which is essential if a hemorrhagic shock occurs (Vaishali et al. 2022). The inclusion of DBRD in the diets of crossbreed weaner rabbits kept the vital organs (liver, heart, kidney spleen, and lungs) in good shape and health, and did not diminish their sizes while carrying out their enormous work and functions in the body of the animals. The heart pumps blood to deliver a continuous supply of oxygen and other nutrients to other parts of the body, while the lungs help to convey oxygen breathed air efficiently to the red cells in the blood. The Kidneys also filtered blood effectively and remove waste products through urine. Dietary bovine rumen improved liver tissue integrity and general health (Rezai et al. 2020) as they continue to detoxify toxins in the blood. Lower inflammation and cell injury of the liver are guaranteed where there is better overall health status and active immune system (Adeyemo and Longe 2007). The metabolism of the liver involves digestion, absorption, excretion, detoxification, material transportation, energy metabolism, and immunity (Zhang et al. 2019). Most essentially, the absorbed nutrients from the small intestinal villi of the digestive tract in ruminants pass through the liver into the circulatory system (Jiang et al. 2014).

Conclusion

The study showed that dehydrated bovine rumen digesta up to 15% improved the growth and digestibility traits. They also facilitate the development of immune-related and other sensitive organs. The rumen digesta also improved the blood biomarkers which promoted the health status of the crossbreed weaner rabbits. However, further studies are required to determine the inclusion effect of dehydrated bovine rumen digesta beyond 15%.

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Conflict of interest statement

There were no conflicts of interest reported.

Author's Contributions

UFU, OCE and AAO: Conceptualization. UFU, OCE, and AAT: Data collation. UFU, OCE, and LFB; data analysis. UFU, OCE and AAO: Methodology. AAO, AAT, and LFB: Supervision. OCE, and UFU: Writing the original draft. OCE, UFU, AAO, AAT, and LFB: Writing, review & editing. All authors have read and agreed to the published version of the manuscript.

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