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RESEARCH ARTICLE

Performance and Economics of Production of Growing Rabbits fed Brewers' Spent Grain based-Diets

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Abstract

This study was conducted to investigate the replacement of wheat bran with brewers' spent grain on growth response of rabbit. Twenty-five 12-16 week-old rabbits of mixed sexes and average weight of 1.07 kg were used and randomly allotted into five treatments D0, D25, D50, D75 and D100 of five rabbits each. Diets D0, D25, D50, D75 and D100 contained 0, 25, 50, 75 and 100% spent grain replacement of wheat bran, respectively. The study lasted 72 days and was a completely randomized block design. Rabbits in each diet were fed and served water *ad libitum.* Growth characteristics, carcass traits and economics of production were determined. Data collected were subjected to one-way analysis of variance and means compared for significant difference. Diets had no significant ($P > 0.05$) effects on final body weight, weight gain, feed intake, feed conversion ratio, protein intake and protein efficiency ratio. There were no significant ($P > 0.05$) effect of diets on carcass prime cuts expressed as % dressed weight except hindlimb ($P < 0.05$), and caecum weight expressed as % fasted live weight of caecum ($P < 0.05$). The increased level of brewers' grain in the diet cost a negative non-significant correlation ($r= -0.01$, $P > 0.05$) feed cost and a positive non-significant correlation ($r =0.41$, $P > 0.05$) benefit cost. In conclusion, incorporation of brewer's spent grains in the diets resulted in reduction in feed cost and enhanced economic returns, and can be used at 100% replacement for wheat bran in growing rabbit diet.

Keywords: Brewers' Grain, Rabbit Performance, Economics.

1. Introduction

Protein is the most fundamental component of tissues in the body. Adequate protein intake is critical for health and development. Protein of animal origin is of high quality for humans and supply the required amino acids [1]. Thus, amino acids are essential for the optimal health, growth, development, reproduction, lactation, as well as survival of humans [2]. Regular consumption of animal sourced proteins results in increase in skeletal muscles mass [3]. Plants and animals based diets contribute 60% and 40%, respectively of protein intake in human diets worldwide, compared to 35% and 65% in United States [4] alone. Animal proteins are high quality and contain sufficient and balanced amino acids. In contrast, most of the plant proteins are inferior in quality. Daily per capita supply of protein globally has increased, and 37% of all protein consumed globally is derived from animal products [5].

It has been reported that only 3% of total dietary energy is derived from meat and offal, 11% from roots and tubers and 6% from pulses, nuts and oil seeds and thus, more than two thirds of low income countries burden of disease is related to nutritional deficiencies such as kwashiorkor [6]. In many developing countries, the consumption of animal protein remains low due to inadequate output consequently, leading to lack of proper nutrition as a result of low income.

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The characteristics of the digestive physiology of rabbits allow the use of considerable amounts of fibrous feedstuffs in diets and this enables the introduction of some agro-industrial by-products such as brewers' spent grains [7] sweet orange peels [8]. Brewer's spent grain is a by-product of the brewing process and is abundant in Lesotho (3840 tonnes per annum) at low cost. It has high levels of fibre and protein, along with lipids and minerals. Its inclusion in livestock feed can therefore be an economic strategy to produce animal products at relatively cheaper cost and therefore stimulate its use in livestock feed production by farmers. Its utilisation also is beneficial in reducing the environmental impact caused by its improper disposal [9]. Therefore, this study will be undertaken to evaluate the nutritive value of brewer's spent grain available in Lesotho, and determine the effect of its incorporation into rabbit diet on growth performance and economics of production in a temperate environment.

2. Materials and Methods

2.1 Description of Experimental Site

The feeding trial and carcass yield evaluation was undertaken in the Livestock unit of the Teaching and Research Farm, at the National University of Lesotho (NUL), Roma, Maseru, between February and April, while chemical assay was at the Animal Science Department Laboratory. Maseru is in the lowlands which lies between altitudes 1830 m to 2130 m above the sea level. It experiences rainy season from early spring (November) and lasts until late autumn (March). Winter runs from May to August, and is mostly dry with no active vegetative growth. Rainfall ranges from 500 mm to 760 mm. Temperatures in the lowlands reach as high as 32°C and drops to -7°C in winter [10].

2.2 Processing of Brewers Spent Grain and Preparation of Experimental Diets

Fresh brewers spent grain was collected from the Lesotho Brewing Company, Maseru. Lightly spread out on a concrete platform and air-dried to constant weight of about 12% within 3 - 4 days. Thereafter, it was used to replace wheat bran in growing rabbit diet at 0, 25, 50, 75 and 100%, and mixed with other ingredients to compound five experimental diets D0, D25, D50, D75 and D100, respectively (Table 1).

2.3 Experimental Animals and Management

Twenty five 12-16 week old mixed breed rabbits of both sexes and mean weight of 1.07 kg obtained from NUL Farm were used for the study. The rabbits were randomly grouped into five of five rabbits each. Each group of five replicates was randomly allotted to one of the diets D0, D25, D50, D75, and D100 and housed in wire cages singly. The experiment was a

Table 1. *Gross Composition of the Experimental Diets (%)*

Ingredients	Experimental Diets (%)				
	D0	D25	D50	D75	D100
Maize	20.50	20.50	20.50	20.50	20.50
SBM	15.00	15.00	15.00	15.00	15.00
BSG	0	14.75	29.50	44.25	59.00
WB	59.00	44.25	29.50	14.75	0
Feed lime	2.00	2.00	2.00	2.00	2.00
Saw dust	2.30	2.30	2.30	2.30	2.30
BMM	1.00	1.00	1.00	1.00	1.00
Table Salt	0.20	0.20	0.20	0.20	0.20
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
CP	17.74	18.11	18.41	18.81	19.13
CF	8.92	9.19	9.43	9.68	9.93
Ca	0.12	0.14	0.16	0.19	0.21
P	0.86	0.81	0.76	0.72	0.67
ME (kcal/kg)	2509.00	2538.00	2565.00	2594,00	2623.00
Methionine	0.26	0.32	0.39	0.44	0.49
Lysine	0.95	0.96	0.99	1.00	1.01

D0 = Diet containing 0 BSG: 100 WB, D25= Diet containing 25 BSG: 75 WB, D50= Diet containing 50 BSG: 50 WB, D75= Diet containing 75 BSG: 25 WB, D100= Diet containing 100 BSG: 0 WB, SBM= Soya bean meal BMM= Broiler micro medicated, BSG= Brewers spent grain, WB= Wheat bran, ME= Metabolizable energy (37× %CP) + (81.8 × %EE) + (35.5 × % NFE)… Pauzenga, (1985) completely randomized block design. Fresh water and the experimental diets were served *ad libitum* for 72 days. Leftover from each diet was weighed weekly in order to determine feed intake. All rabbits were kept under same management conditions.

2.4 Growth Performance Parameters

The initial and weekly body weight of individual rabbit were taken using precision electronic balance (XY10002C). Weekly body weight gain (BWG) per replicate was calculated by the difference between weights of the rabbit for current week and previous week. The final body weight (FBW) and initial weights were used to calculate total weight gain. Feed intake (FI) was determined by difference between weight of feed supplied and weight of the leftover at the end of each week. Dividing the obtained value by 7 gave the daily feed intake (FI). The feed intake and body weight gain by rabbits in each treatment were used to calculate the feed conversion ratio (FCR) using formula;

FCR = FI /BWG

2.5 Carcass Characteristics

At the end of the feeding trial, three rabbits were selected per treatment with similar weight, fasted for 18hrs and slaughtered. Rabbits were singed for fur removal and then eviscerated [11]. The visceral organs: kidney, lung, liver, heart, pancreas and intestines were weighed and expressed as % live body weight. Carcass without head and feet, and carcass prime cuts namely loin, saddle + rib, shoulders, forelimb and hind limb were weighed. Carcass cuts were expressed as percentage of dressed weight.

2.6 Economics of Production

Economic evaluation was done using efficiency and production efficiency factor [12]. Economic efficiency was calculated as a ratio of net revenues and total costs, and steps involved were:

i. Total revenue / rabbit = Average body weight gain (kg) × price of kg body weight at the end of the experiment
ii. Total feed intake/ rabbit (kg)
iii. Price / kg of feed
iv. Total feed cost / rabbit = Total feed intake / rabbit (kg) × price/kg feed
v. Total cost / rabbit = Total feed intake / rabbit + cost per rabbit
vi. Net revenue = Total revenue / rabbit – Total cost /rabbit

3. Results

The result of the nutrient analysis of brewers' spent grain is shown in Table 2. The brewers' spent grain contained 92.50% dry matter, 21.23% crude protein, 21.90% crude fibre, 5.67% ash,9.97% ether extract, 33.73% nitrogen free extract, 53.33% nitrogen

Table 2. *Chemical Constituents of Brewers Spent Grain*

NUTRIENTS (% as fed)	FD1	FD2	FD3	Mean± SEM
Dry matter (DM)	92.50	92.50	92.50	92.50 ± 0.00
Crude protein	21.90	19.30	22.50	21.23 ± 0.98
Crude fibre	17.50	23.00	25.20	21.90 ± 2.29
Ash	6.00	5.50	5.50	5.67 ± 0.17
Ether extract	9.77	10.17	9.97	9.97 ± 0.12
Moisture	7.50	7.50	7.50	7.50 ± 0.00
Nitrogen free extract	37.33	34.53	29.33	33.73 ± 2.34
Acid detergent fibre	28.50	27.00	33.00	29.50 ± 1.80
Neutral detergent fibre	56.00	47.00	57.00	53.33 ± 3.18
Acid detergent lignin	10.00	5.50	9.00	8.17 ± 1.36
Hemicellulose	35.50	23.50	36.00	23.83 ± 2.17
Cellulose	13.50	19.50	14.50	21.33 ± 1.59
Phosphorus	4.30	5.20	4.72	4.74 ± 0.26
Calcium	2.50	3.00	2.50	2.67 ± 0.17
ME (Kcal/Kg DM)	2934.71	2771.83	2798.6	2835.05 ± 50.43

SEM= Standard error of mean, ME= Metabolizable energy= (37× %CP) + (81.8 × %EE) + (35.5 × % NFE)… Pauzenga, (1985).

FD1=Brewer's spent grain in replicate 1

FD2=Brewer's spent grain in replicate 2

FD3=Brewer's spent grain in replicate 3

detergent fibre, 29.50% acid detergent fibre, 8.17% acid detergent lignin, 23.83% hemicellulose, 21.33% cellulose, 4.74% phosphorus, 2.67% calcium. The calculated metabolizable energy was 2835.05 Kcal/kg.

The effect of the experimental diets on the performance of rabbit is presented in Table 3. The replacement of wheat bran with brewers' spent grain did not have significant (P > 0.05) effect on final body weight, body weight gain, daily feed intake, feed conversion ratio, protein intake and protein efficiency ratio. The final body weight, body weight gain, daily feed intake, and protein efficiency ratio had a similar pattern, with highest values recorded in the control and which also had the best feed conversion ratio of 3.17. The FBW had non-significant and negative correlation coefficient (r= -0.27, P > 0.05), BWG (r= -0.22, P > 0.05), DFI (r= -0.19, P > 0.05), and PER (r= -0.40, P > 0.05), while FCR and PI had non-significant and positive correlation coefficient r=0.15, P > 0.05, and r=0.19, P > 0.05, respectively. The weekly body weight of the experimental rabbits is presented in Figure 1. The rabbits in D0 showed a consistent increase in body weight from week 6 till the end of the trial and was higher than the average body weight in D25, D50, D75 and D100. Rabbits in D25, D50 and D75 had similar average body weight, while rabbits in D100 remained inferior in live body weight.

Table 3. *Effect of Experimental Diets on the Growth Performance of Rabbit (Mean ± SEM)*

	Experimental Diets						
Indices	**D0**	**D25**	**D50**	**D75**	**D100**	**P-value**	**r**
IBW (g)	1064.00 ± 140.40	1072.00 ± 100.20	1056.00 ± 87.00	1084.00 ± 162.70	932.00 ± 127.40	0.91	
FBW (g)	2324.00 ± 159.96	2264.00 ± 138.22	2190.00 ± 143.91	2224.00 ± 104.14	2088.00 ± 82.79	0.76	-0.27
BWG (g)	17.50 ± 1.24	16.56 ± 0.98	15.75 ± 1.00	15.83 ± 1.28	16.06 ± 0.94	0.79	-0.22
DFI (g)	55.40 ± 1.78	52.59 ± 0.85	55.13 ± 2.14	51.39 ± 1.90	53.46 ± 1.95	0.48	-0.19
FCR	3.17 ± 0.18	3.18 ± 0.17	3.50 ± 0.18	3.25 ± 0.17	3.33 ± 0.13	0.63	0.15
PI	9.83 ± 0.31	9.52 ± 0.15	10.15 ± 0.39	9.67 ± 0.36	10.23 ± 0.37	0.51	0.19
PER	1.77 ± 0.09	1.74 ± 0.09	1.55 ± 0.09	1.63 ± 0.08	1.57 ± 0.06	0.25	-0.40

[ab] Means with different superscripts in the same row differ significantly (P <0.05). r= correlation coefficient, P-value less or equal to 0.05 indicate a significant difference. * (P < 0.05), significant correlation coefficient. WS= Weight at slaughter, RW= Roasted weight, DW= Dressed weight, DP= Dressing percentage, FL= Fore limb, HL= Hind limb, BSG= brewer's spent grains, WB= Wheat bran.

D0= Diet containing 0 BSG: 100 WB
D25= Diet containing 25 BSG: 75 WB
D50= Diet containing 50 BSG: 50 WB
D75= Diet containing 75 BSG: 25 WB
D100= Diet containing 100 BSG: 0 WB

Table 4. *Effect of Experimental Diets on Carcass yield of Rabbit*

	Experimental Diets						
Carcass traits	**D0**	**D25**	**D50**	**D75**	**D100**	**P-value**	**r**
WS (g)	2516.67 ± 128.10	2230.00 ± 223.68	2183.33 ± 183.70	2186.67 ± 137.00	1956.67 ± 80.90	0.25	-0.57
RW (g)	1793.33 ± 99.05	1666.67 ± 218.28	1606.67 ± 161.69	1626.67 ± 111.00	1570.00 ± 65.06	0.83	-0.29
DW (g)	1782.33 ± 99.98	1620.00 ± 201.08	1583.33 ±168.56	1590.00 ± 90.00	1426.67 ± 52.39	0.50	-0.48
DP (g)	69.80 ± 0.66	70.82 ± 2.55	71.18 ± 1.48	71.45 ± 0.91	71.98 ± 0.75	0.86	0.33
FL (%DW)	15.43 ± 1.05	12.99 ± 1.32	15.46 ± 0.45	14.67 ± 0.34	15.19 ± 0.41	0.25	0.12
HL(%DW)	25.38^{b} ± 0.74	24.24^{b} ± 1.19	25.34 ± 1.34	31.40 ± 0.44	26.73 ± 1.88	0.02*	0.04*
Loin (%DW)	28.47 ± 1.05	30.31 ± 2.76	27.25 ± 1.95	31.40 ± 0.44	26.73 ± 1.88	0.36	-0.11
Saddle (%DW)	18.71 ± 0.87	19.19 ± 0.39	18.04 ± 0.99	16.20 ± 0.47	20.38 ± 1.30	0.06	0.03
Head (% DW)	12.02 ± 0.61	13.26 ± 1.27	12.24 ± 0.31	12.65 ± 0.68	13.10 ± 1.00	0.80	0.17

[ab] Means with different superscripts in the same row differ significantly (P < 0.05). r= correlation coefficient, P-value less or equal to 0.05 indicate a significant difference. * (P < 0.05), significant correlation coefficient. WS= Weight at slaughter, RW= Roasted weight, DW= Dressed weight, DP= Dressing percentage, FL= Fore limb, HL= Hind limb, BSG= brewer's spent grains, WB= Wheat bran.

D0= Diet containing 0BSG: 100 WB

D25= Diet containing 25 BSG: 75 WB

D50= Diet containing 50 BSG: 50 WB

D75= Diet containing 75 BSG: 25 WB

D100= Diet containing 100 BSG: 0 WB

The effect of the experimental diets on carcass yield of rabbits is shown in Table 4. The experimental diets had significant P < 0.05 effect on the hind limb but did not affect significantly (P > 0.05) weight after slaughter, roasted weight, dressed weight, dressing percentage, fore limb, loin, saddle + rib and head. The diets gave a significant negative correlation for hind limb (r= -0.04, P < 0.05) and a significant positive correlation for saddle + rib (r= 0.03, P < 0.05). The weight after slaughter, roasted weight, dressed weight, and the percent dressed weight of loin and head had negative correlation coefficients and were not significant (P > 0.05). The dressing percentage and fore limb had positive correlation but did not differ significantly (P > 0.05).

The effect of experimental diets on the visceral organ yield and intestinal morphometry is shown in Table 5. The experimental diets showed significant (P < 0.05) effect on the % live weight of caecum while kidney, lungs, liver, heart, spleen, gall bladder, stomach, small intestine and large intestine, did not differ significantly (P > 0.05). The experimental diets had no significant (P > 0.05) effect on the length of rectum, caecum, small intestine and large intestine. A positive and non-significant correlation was observed on liver (r= 0.18, P > 0.05), spleen (r= 0.38, P > 0.05), gall bladder (r=0.32, P > 0.05), stomach (r=0.57, P > 0.05) and caecum (r=0.43, P > 0.05) while, negative and non-significant correlation was observed on kidney (r=-0.29, P > 0.05), lungs (r=-0.28, P > 0.05), heart (r=-0.44, P > 0.05) and large intestine (r=-0.21, P > 0.05). The length of rectum (r=-0.31, P > 0.05), small intestine (r=-0.43, P > 0.05) and large intestine (r=-0.04, P > 0.05) recorded negative and non-significant correlation, while caecum was positively correlated but had no significant (r=0.23, P > 0.05) effect.

The effect of the experimental diets on economics of production of rabbit is illustrated in Table 6. The experimental diets had no significant (P > 0.05) effect on the cost of feed consumed per rabbit, cost of feed / BWG, total production cost, total revenue and benefit cost. A negative and non-significant correlation was observed on cost of feed consumed (r=-0.41, P > 0.05), cost of feed / BWG (r=-0.01, P > 0.05), TPC (r=-0.41, P > 0.05), BC (r=0.41, P > 0.05).

Table 5. *Effect of Experimental Diets on the Visceral organ yield and Intestinal Morphometry of Rabbit (Mean ± SEM)*

Carcass traits	D0	D25	D50	D75	D100	P-value	r
Kidney (% LW)	0.62 ± 0.06	0.53 ± 0.01	0.55 ± 0.04	0.58 ± 0.10	0.51 ± 0.01	0.50	-0.29
Lungs (% LW)	0.52 ± 0.10	0.60 ± 0.04	0.50 ± 0.02	0.50 ± 0.02	0.50 ± 0.04	0.64	-0.28
Liver (%LW)	2.23 ± 0.20	2.21 ± 0.08	2.60 ± 0.13	2.24 ± 0.20	2.39 ± 0.10	0.47	0.18
Heart (% LW)	0.32 ± 0.02	0.29 ± 0.05	0.27 ± 0.01	0.26 ± 0.03	0.27 ± 0.02	0.59	-0.44
Spleen (%LW)	0.05 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.06 ± 0.00	0.07 ± 0.00	0.48	0.38
GB (%LW)	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.06 ± 0.00	0.07 ± 0.01	0.67	0.32
Stomach(%LW)	0.91 ± 0.01	1.14 ± 0.09	1.05 ± 0.06	1.04 ± 0.10	1.23 ± 0.05	0.08	0.57
SI (% LW)	1.72 ± 0.24	1.56 ± 0.03	1.25 ± 0.12	1.76 ± 0.15	1.66 ± 0.05	0.14	0.04*
LI (% LW)	0.67 ± 0.07	0.90 ± 0.09	0.67 ± 0.08	0.56 ± 0.05	0.71 ± 0.18	0.29	-0.21
Caecum(%LW)	$0.79^b \pm 0.05$	$0.71^b \pm 0.03$	$0.68^b \pm 0.04$	$0.73^b \pm 0.01$	$0.98^a \pm 0.10$	0.02*	0.43
AF (% LW)	1.76 ± 0.19	1.34 ± 0.14	1.75 ± 0.08	1.52 ± 0.19	1.34 ± 0.21	0.27	-0,31
VF (% LW)	1.34 ± 0.17	1.00 ± 0.15	1.35 ± 0.12	1.21 ± 0.18	0.90 ± 0.08	0.17	-0.35
Rectum (cm)	6.87 ± 0.18	7.60 ± 0.38	6.87 ± 0.53	7.47 ± 0.79	5.93 ± 0.43	0.22	-0.31
Caecum (cm)	32.72 ± 2.12	28.83 ± 2.49	45.00 ± 8.66	36.67 ± 2.91	36.10 ± 5.77	0.30	0.23
SI (cm)	314.23 ± 9.08	268.40 ± 28.26	322.00 ± 15.16	284.00 ± 8.90	247.00 ± 6.35	0.08	-0.43
LI (cm)	63.07 ± 16.41	70.57 ± 6.30	62.10 ± 19.58	71.47 ± 11.64	59.87 ± 6.35	0.95	-0.04

^{ab} Means with different superscript in the same row differ significantly (P < 0.05). *(P < 0.05) significant correlation coefficient. GB= Gall bladder, SI= Small intestine, LI= Large intestine, AF= Abdominal fat, LW= live weight, r= correlation coefficient, BSG= Brewer's spent grains, WB= Wheat bran.

D0= Diet containing 0 BSG: 100 WB, D25= Diet containing 25 BSG: 75 WB, D50= Diet containing 50 BSG: 50 WB, D75= Diet containing 75 BSG: 25 WB, D100= Diet containing 100 BSG: 0 WB.

Table 6. *Effect of Experimental Diets on Economics of Production of Rabbit (Mean± SEM)*

Cost indices	Experimental Diets						
	D0	D25	D50	D75	D100	P-value	r
Cost of feed consumed ($)	1.66 ± 0.05	1.56 ± 0.02	1.61 ± 0.06	1.49 ± 0.05	1.53 ± 0.06	0.18	-0.41
Cost of feed/BWG ($)	1.33 ± 0.07	1.33 ± 0.07	1.44 ± 0.07	1.32 ± 0.07	1.33 ± 0.05	0.73	-0.01
TPC($)	2.22 ± 0.05	2.12 ± 0.02	2.17 ± 0.06	2.05 ± 0.05	2.09 ± 0.06	0.18	-0.41
TR ($)	5.55 ± 0.00	5.55 ± 0.00	5.55 ± 0.00	5.55 ± 0.00	5.55 ± 0.00	1.00	
BC ($)	3.33 ± 0.05	3.43 ± 0.02	3.38 ± 0.06	3.50 ± 0.05	3.46 ± 0.06	0.79	0.41

P-value at 5 % level of test shows significant difference. r= correlation coefficient, TPC= Total production cost (cost of feed consumed and utilities), TR= Total revenue, BC= Benefit cost, BSG = Brewer's spent grains, WB = wheat bran

D0= Diet containing 0 BSG: 100 WB

D25= Diet containing 25 BSG: 75 WB

D50= Diet containing 50 BSG: 50 WB

D75= Diet containing 75 BSG: 25 WB

D100= Diet containing 100 BSG: 0 WB

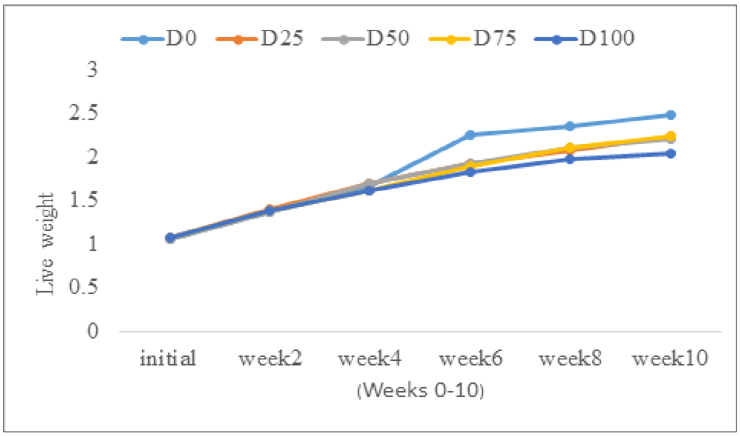

Figure 1. *Live weight of the experimental Rabbit*

4. Discussion

4.1 Proximate Composition of Brewer's spent grain

The proximate composition of brewer's spent grains revealed that the dry matter value is lower than 97% dry matter reported by Naibaho and Korzeniowska [13] but was comparable to 91.0% dry matter reported by [14]. This high dry matter content is partly an indicator of possible long storage or shelf-life for brewers' spent grain, and also of its high nutrient density. Long shelf-life of ingredients and feed is an important factor in feed technology to ensure high quality animal feed for livestock productivity and profitability. Its crude protein content is 21.23 ± 0.98% which is lower than 23.40 and 27.45% CP reported by Muthusamy [15] and [16], respectively but within the range of 19.50 - 31.90% [17]. Crude protein is a vital nutrient for rabbits, playing a crucial role in growth, reproduction and overall health. The crude fibre proportion of brewers' spent grains is 21.90 ± 2.29% and is within the range of 15.00-23.50% [18]. This high fibre level in combination with its moderately high crude protein makes it a valuable feed resource for developing suitable feed products for rabbit, a monogastric herbivore which can enhance its gut health to enhance intestinal absorption of nutrients. Ether extract content is 9.97±0.12 and it is within the range of 5.19 -10.60% obtained by [19] High fat content can help to provide some form of dietary energy for necessary metabolic activities either for maintenance and or production, but it can also stimulate oxidative rancidity in improper feed storage. The ash content of brewer's spent grain is 5.67 ± 0.17 and similar to the values obtained by [17]. Feed ash provides essential minerals which are vital for bone and teeth formation. Nitrogen free extract is 3.73% and within the range of 24.94 - 45.86% reported by [20]. Low nitrogen free extract diet has been reported to reduce rumen microbial activity, affecting fibre digestion and nutrients absorption [21].

Brewers' spent grain has neutral detergent fibre of 53.33 ± 3.18% which is comparable with 47-54.6% earlier reported [15] but higher than 40 to 50% reported by [22]. The slight variation of the neutral detergent fibre can be attributed to malting and mashing processes due to enzymatic breakdown of plant cell wall components. High feed NDF is of nutritional benefit to rabbit because it is essential in maintaining a healthy digestive system. The acid detergent fibre of 29.50 ± 1.80% is higher than 27.7% reported by [23]. This can be possibly due to the quantity of the residual fibrous components of the barley after extracting the wort. ADF helps regulate gut motility, preventing both diarrhoea and constipation by adding bulk to the faeces and stimulating the movement of feed through digestive tract in rabbit. The acid detergent lignin present in BSG is 8.17 ± 1.36% which is lower than 12-28% [24]. Lignin plays a vital role in regulating the rate of passage through the rabbit's digestive system. Hemicellulose level of 23.83 ± 2.17% is lower than 39% [25], while BSG cellulose of 21.33±1.59% is higher than 13.14% [22]. Considering the fibre fractions, brewers' spent grain has high content of neutral detergent fibre, acid detergent fibre, cellulose and hemicellulose and can be harnessed in productive and profitable feeding of rabbit a non-ruminant herbivore. Phosphorus and calcium values are 4.74 ± 0.26% and 2.67 ± 0.26%, respectively within the range of 4.2-5.9% and 2.5-2.86% reported by [25]. Thus, BSG can serve as a good supplemental source of calcium and phosphorus required for bone growth in rabbit, and some enzymatic activities in the case of phosphorus. The BSG metabolizable energy value is in line with 2400-2800Kcal/kg reported by [26] to meet the energy needs of grower rabbits.

4.2 Effect of Experimental Diets on the Performance of Rabbit

The experimental diets had no significant effect on the FBW, daily BWG, DFI, FCR, PI and PER. Though the PER did not vary significantly among the treatment means, highest value was in the control group D0. This may have stimulated the relatively higher mean final body weight of 2324.00 ±159.96 g of rabbits in the control group compared to other dietary treatments. This demonstrates the ability of dietary protein in promoting growth and muscle mass accretion. Low PER in the brewers' spent grain-based diets D25, D50, D75 and D100 may be due to the relatively high dietary fibre in brewers' spent grain-based diets which reduced the digestibility of protein. The non-significant variation of the FBW, BWG, DFI, FCR, PI and PER of rabbits regardless of different percent levels of brewers' spent grain used for wheat bran replacement in the diet, suggests its nutritional potential to serve as a replacement feed resource for wheat bran, a fibrous feed ingredient in rabbit nutrition. The result of current study is in line with [27] who stated that, inclusion of brewers' spent grain in growing rabbits diet had no adverse effect on growth performance but is efficiently utilized.

There is no significant correlation between experimental diets and FBW, BWG, DFI, FCR, PI and PER. The correlation coefficient of FBW, BWG, DFI and PER was negative and not significant as the level of dietary brewers' spent grain increased. This could be due to high fibre content and lignin an anti-nutritional factor in brewers' spent grain that can interfere with protein digestion and absorption. Though, FCR and PI tended to increase as the level of brewers' spent grain increased, higher FCR implies low feed conversion efficiency of the higher protein intake. The weekly live body weight of the experimental rabbits in Fig.1 shows that up till the fourth week, the effect of the replacement of wheat bran with brewers' spent grain gave similar live weight across the treatment groups. Thereafter there was a divergence in body live weight though not significant, in which D0 maintained a consistent higher live weight and D100 lowest weight, whereas D25, D50 and D75 had similar live weight.

4.3 Effect of the Experimental Diets on the Carcass yield of Rabbit

The experimental diets had no significant effect on the weight after slaughter, roasted weight, dressed weight, dressing percentage, fore limb, loin, saddle + rib and head, only the hind limb differed significantly across the treatment groups. The dressing percentage of the rabbits in the brewers' spent grain based-diets D25, D50, D75 and D100 increased from 70.82 ± 2.55 to 71.98±0.75% and higher than that of D0 (69.80±0.66%). These values were higher than 59% reported by [28] but comparable with 75.94 to 80.13% [29]. High dressing percentage indicates a greater yield of saleable meat and increase revenue from sale of processed rabbit. The significant variation of the % DW of hind limb did not follow a particular sequence and may not be particularly traceable to dietary effect. The correlation coefficients for weight after slaughter, roasted weight and dressed weight were negative and not significant. The results obtained for these three parameters showed decreased value as the replacement levels of brewers' spent grain increased. There is a significant and slight positive correlation effect on the saddle + rib. Correlation analysis evidenced positive relationship between experimental diets and dressing percentage, fore limb, saddle and head, which agrees with the findings of [7] that the inclusion of brewer's spent grains based diets did not cause any apparent lethal effect on the carcass cuts and dressing percentage of rabbits.

4.4 Effect of the Experimental Diets on the Visceral yield and Intestinal Morphometry of Rabbit

The experimental diets had non-significant effect on the kidney, lungs, liver, heart, spleen, gall bladder, stomach, small intestine, large intestine and on the intestinal morphometrics. However, significant effect was observed on the caecum. Whereas, there was no consistent pattern of variation observed in the relative weights of the organs, for the caecum, it was D100 that gave the highest significant relative weight. Non-significant positive correlation exists between the BSG levels used and the % LW of liver, spleen, gall bladder, stomach and caecum, and the length of caecum. Hence, with increase in the amount of brewers' spent grain in the diet, there is the possibility that the liver, gall bladder, stomach and caecum weight will increase, as a result of their increased physiological activities in digestion.

4.5 Economics of Production of Rabbit on Brewers' Spent Grain Based-Diets

The replacement of wheat bran by brewers' spent grain had no significant effect on the cost of feed consumed, cost of feed / BWG, TPC, TR and BC. The costs of feeding revealed that as the quantity of brewers' spent grain incorporated in the diet increased, the cost of feed consumed, cost of feed/ BWG and TPC tended to reduce, while the benefit cost appeared to increase. The highest cost of feeding per rabbit for the experimental duration was \$1.66±0.05 in D0 (control group), while the cost of feed per rabbit was comparatively lower in diet groups D25 to D100 and ranged from \$1.49±0.05 to 1.61±0.06. The benefit cost of replacing wheat bran with brewers' spent grain yielded higher cost of \$3.38±0.06 to 3.50±0.05 in diet groups D25 to D100 compared with the control (\$3.33±0.05). The current study agrees with the results reported by [10] who indicated that inclusion levels of brewer's spent grains above 14% reduced the feed cost and inclusion levels above 21% improved net income. The correlation coefficients for cost of feed consumed, cost of feed/BWG, total production cost were negative and not significant. This implies that with the increase in the quantity of brewers' spent-grain used to replace wheat bran the benefit cost increased.

5. Conclusions and Implication

1. Brewer's spent grain used is high in crude protein 21.23 ± 0.98%, crude fibre 21.90 ± 2.29% and metabolizable energy 2835.05 ± 50.43 Kcal/kg, thereby making it a potential replacement for wheat bran in rabbit diet.
2. The use of brewers spent grain as a replacement for wheat bran at 0%, 25%, 50%, 75% and 100% in rabbit diet did not significantly affect the growth characteristics.
3. The brewers' spent grain based-diets D25, D50, D75 and D100 had higher dressing percentage which ranged from 70.82 ± 2.55% to 71.98 ± 0.75% compared to the control group value of 69.80 ± 0.66%, and had no significant effect on the visceral yield and intestinal morphometry except % live weight of caecum which showed variation.
4. The use of brewers' spent grain as a replacement for wheat bran in rabbit diet resulted in reduction in the cost of production from \$1.66 ± 0.05 in the control to \$1.61 ± 0.06 - \$1.49 ± 0.05 in the brewers grain based-diets thereby enhancing the benefit cost of raising rabbits in the control from \$3.33 ± 0.05 - \$3.38 ± 0.06 in the brewers' spent grain based diets.

Implication

Brewers' spent grain has a good replacement feed value for wheat bran and can be used up to 100% in rabbit raising for good growth performance and economic benefits.

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