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The effect of experimental diets incorporating fermented soybean meal on growth metrics and utilization of nutrients in broiler chickens

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ABSTRACT

The aim of this study was to explore the impact of fermented soybean meal (FSBM) on the nutritional quality of feed, growth performance indicators, and nutrient utilization in broiler chickens, aiming to overcome the challenges associated with locally produced soybean meal stemming from anti-nutrients and variations in nutritional quality. The study methodology included assessing growth performance metrics through two-way ANOVA statistical analysis and evaluating nutrient utilization in broiler chickens. Results indicated that broiler chickens fed with FSBM exhibited superior performance, displaying the highest average weekly weight gain (452 grams), optimal feed conversion ratio (1.39), extended intestinal length (225 cm), increased intestinal weight (297.5 grams), and heightened activity of digestive enzymes compared to other treatment groups throughout the feeding trials. The results of this study suggest that FSBM's better digestibility helps broiler chickens grow faster. This makes it a possible replacement for animal protein sources like fish meal in poultry feed production, which is good for both local poultry feed producers and consumers.

Contribution/Originality: This study is one of the first to examine the effects of fermented soybean meal (FSBM) on broiler chickens in Zimbabwe, addressing local challenges with soybean meal quality. It provides novel insights into FSBM's impact on growth metrics, nutrient utilization, and digestive enzyme activity in broilers, offering valuable data for local poultry feed producers.

1. INTRODUCTION

Chickens have been integrated into small-scale farming systems in Zimbabwe as an expedient and cost-effective source of animal protein. Roughly 85% of rural households in Sub-Saharan Africa raise chickens to produce eggs and meat. These animal-derived products are essential for sustaining the health and nutritional well-being of communities, particularly in underdeveloped regions where protein sources are typically scarce (Choct, Dersjant-Li, McLeish, & Peisker, 2010). The abundant availability of locally produced soybean meal (SBM) at competitive prices prompts local poultry feed producers to utilize this ingredient significantly as a key substitute for animal protein sources. The Stockfeeds Manufacturers Association report in 2018 highlighted that the average monthly procurement of soybean derivatives in the first quarter of 2018 was at 11,084 metric tonnes per month (USD$6.9 million). This represented a volume increase for the first quarter of 59% (51% in value) over the same period in 2017 and a 29% increase from the last quarter of 2017 (SMA (Stockfeeds Manufacturers Association), 2018). This revealed the soybean derivative preference level and its acceptability in terms of usage by poultry feed manufacturing mills in Zimbabwe.

Nevertheless, the diverse nutritional composition and presence of various anti-nutritional elements have constrained the utilization of SBM in broiler feed (Erdaw, Bhuiyan, & Iji, 2016). Due to the absence of endogenous enzymes, poultry cannot adequately digest the carbohydrate component in SBM, which primarily consists of non-starch polysaccharides and galacto-oligosaccharides (Choct et al., 2010). Consequently, SBM exerts an adverse impact on the growth performance of broiler chickens.

Fermentation is one of the processing methods to improve the nutritional value of soybean meal. Thus reducing residual anti-nutritional factors such as trypsin inhibitors and increasing in small-size peptides free amino acid content, small-sized peptides, crude protein, and the biodiversity of content nutrients (Mukherjee, Chakraborty, & Dutta, 2016). Hence, this study focuses on using an improved nutritional profile of soybean meal in order to develop a protein-rich soybean meal for animal feed production in Zimbabwe. Thus, further improvements in the feed formulation and feed raw material development process will maximize performance and profitability in poultry production.

2. MATERIALS AND METHODS

2.1. Experimental Diet Formulation

Four diets were formulated using soybean meal (SBM) and Fermented Soybean Meal (FSBM) developed at Harare Institute of Technology. The broiler grower experimental feed was formulated based on the Agrimix mixing instructions chart in the ratios Broiler Grower: Maize Meal 65.7 kg, SBM/FSBM 31 kg, Vitamin and Mineral Premix 3.3 kg, Broiler Finisher: Maize Meal 65.7 kg, SBM/FSBM 31 kg, Vitamin and Mineral Premix 3.3 kg. FSBM was included in the formulation of the grower feeds substituting SBM, and a control feed, i.e., phase 2 broiler grower (20%CP), was purchased from Agrifoods. The broiler finisher experimental feed was formulated based on Agrimix mixing instructions chart, in the ratios shown in Table 1, precisely following the growth curve of the modern broiler bird of a 3-phase broiler feeding program. FSBM was included in the formulation of the finisher feeds substituting SBM, and a control feed, i.e., phase 3 broiler finisher (18%CP), was purchased from Agrifoods. The proximate chemical composition of experimental feeds was done according to the standard methods of AOAC (2005).

Table 1. Formula for broiler grower and finisher experimental diets.

Feed ingredients	Broiler grower (Phase 2)	Broiler finisher (Phase 3)
Maize meal	65.7kg	146.6kg
SBM/FSBM	31kg	47.2kg
Vitamin and mineral premix	3.3kg	6.2kg
Total	100kg	200kg

2.2. Experimental Design and Animal Management

A total of 450 commercial day-old broilers of the Cobb breed, all from a single hatch, were procured from a local hatchery and distributed randomly into 3 treatment groups, each with 3 replicates of 50 chicks. The chicks were raised in broiler cages within a gable-roofed, double-open-sided structure. They were provided with consistent floor, feeder, and water space and were managed under standard conditions for six weeks following the guidelines outlined in the Profeeds Zimbabwe Poultry Management Guide. Throughout this period, data on bird live weight and feed consumption were collected weekly, while any instances of mortality were duly noted. Utilizing this information, feed efficiency and survival rates were computed. Upon reaching 42 days of age (i.e., 6 weeks), five birds from each treatment group were humanely slaughtered for measurements of live body weight, intestinal weight, and length. The contents of the small intestine were extracted individually, stored at -20°C, and prepared for analysis of digestive enzymes.

2.3. Intestinal Enzymes Activity

The supernatant of the digesta was extracted and diluted to a ratio of 1:1000 with 0.9% saline solution. The evaluation of amylase activity in the digesta was conducted following the procedure outlined by Coles (1967) while the assessment of lipase activity was carried out using the method described by Boutwell (1962). Hawk, Oser, and Summerson (1947) detailed a technique for determining the trypsin activity in the digesta.

$$Amylase\ activity\ \left(\frac{Units}{ml}\right) = \frac{(\,OD\ of\ control - OD\ of\ test\,)}{OD\ of\ Control}\ x\ Volume\ of\ supernant\ x\ Dilution\ factor$$

$$Lipase\ activity\ \left(\frac{Units}{ml}\right) = \frac{(\,Titre\ value\ of\ test - Blank\,)}{Weight\ of\ the\ intestine\ content\ (g)} x\ Dilution\ Factor$$

2.4. Production Parameter Calculations

Growth performance, protein utilization and feed utilization of broilers were calculated as described by Sveier, Nordås, Berge, and Lied (2001) as follows:

Weight gain = W2 – W1.

Specific Growth Rate (SGR) = 100 (ln W2 – ln W1) / T.

WhereW1 and W2 are the initial and final broiler weight, respectively, and T is the number of days in the feeding period.

Feed Conversion Ratio (FCR) =Feed intake / Weight gain.

Survival rate = (Total number of broilers reached 6 weeks / Total number of broilers stocked) x 100.

In-vitro nutrient digestibility (%) = (original nutrient amount – residual nutrient amount) /original nutrient amount.

2.5. Statistical Analyses

All the data underwent analysis using a completely randomized design following the methodology outlined by Ridgman (1990). Statistical significance was assessed at the 0.05 and 0.1% probability levels for comparisons.

3. RESULTS

3.1. Proximate Nutrient Composition of Experimental Grower and Finisher Feeds

Grower and finisher phase experimental feeds containing SBM and FSBM formulations were carried out using the Agri-mix mixing chart. Table 2 displays the proximate nutrient composition of the experimental grower feeds containing FSBM and SBM. Diet #3, containing SBM, had the highest CP content, NDF content, and DM content, 25.4, 62.03, and 90.8 respectively compared with the other diets. Diet #1: Control had the highest ash, calcium, and phosphorus content, 5.32, 1.39 and 0.55, respectively compared with the other diets. Diet #2, which contained FSBM, had the highest fat content (5.32), when compared to the other diets. Hence the grower phase experimental feed Diet #3, which contained SBM had the highest nutritional value compared to the other grower phase feed.

Table 2 displays the proximate nutrient composition of the experimental finisher phase feeds containing FSBM and SBM. Diet #3, which contained SBM, had the highest DM and fat content, 90.8 and 9.37, respectively, compared with the other diets.

Diet #1: Control had the highest CF, NDF, ash, calcium, and phosphorus content, 4.05, 53.51, 5.60, 1.41, and 0.54, respectively, compared with the other diets. Diet #2: containing FSBM had the highest CP content of, 20.3 compared with the other diets. Hence the finisher phase experimental feed, Diet #1: Control, had the highest nutritional value compared to the other finisher phase.

Table 2. Proximate nutrient composition of the experimental grower phase and finisher phase feeds containing FSBM and SBM.

Test parameter (%)	Grower phase 2			Finisher phase 3		
	Diet #1: Control	Diet # 2: FSBM	Diet # 3: SBM	Diet #1: Control	Diet # 2: FSBM	Diet # 3: SBM
DM	84.4	88.1	90.8	88.4	90.1	90.8
CP	20.6	22.3	25.4	18.5	20.3	17.6
CF	4.16	4	4.66	4.05	2.8	3.34
NDF	53.6	38.56	62.03	53.51	28.56	52.03
Fat	5.32	9.37	7.37	3.42	6.84	9.37
Ash	5.25	5	4.9	5.6	4.9	5
Ca	1.39	0.95	0.12	1.41	1.04	0.95
P	0.55	0.52	0.43	0.54	0.51	0.35

Note: Ca-Calcium; P- Phosphorus; CP- Crude protein; Fat; DM-Dry matter; NDF-Neutral detergent fiber; ME-Metabolisable energy.

3.2. Average Weekly Body Weight

Table 3 presents the average weekly live weights of the broilers from day-old to six weeks of age from different groups. An overall increase in the average body weight of broiler chickens from the 1st week up to the 6th week of age was revealed from the data. The average body weight of the control fed-group was higher than SBM and FSBM fed-group on the 5th week. The broilers fed with the control diet had the highest average body weight (2002 grams), while the group fed with SBM-containing feed was the lowest, with an average live weight of 1858 grams at week-6 of the feed trials.

Table 3. The experimental diets on average body weight of broiler chickens.

Feed type	Day old	Week-1	Week-2	Week-3	Week-4	Week-5	Week-6
Average body weight (± S.E.) of broilers from 1 to 6 weeks of age.							
Control	42.31 ±1.19	161.31 ± 12.41	393.49 ± 33.32	810.10 ± 51.12	1253.59 ± 132.58	1600.06 ±195.01	2002.90 ± 170.56
SBM	43.02 ± 1.54	148 ± 8.60	351.16 ±20.44	752.65 ± 17.82	1182.65 ± 113.03	1402.43 ± 151.35	1858.22 ± 125.68
FSBM	42.29 ± 1.19	169.88 ± 10.22	420.27 ± 23.13	872.57 ± 41.87	1256.20 ±162.38	1545.61 ± 133.61	1937.90 ± 239.02

Table 4. The experimental diets on growth performance and nutrient utilization of broiler chickens.

Feed type	Week-1	Week-2	Week-3	Week-4	Week-5	Week-6
Mean weekly weight gain (± S.E.) of broilers from 1 to 6 weeks of age.						
Control	167 ± 0.23	467.67± 0.34	985± 0.45	1552± 0.56	2112± 0.25	2698.01± 0.45
SBM	147 ± 0.87	418.04± 0.49	913.92 ± 0.36	1466.7± 0.45	1778.59± 0.8	2440.13± 0.67
FSBM	165 ± 0.35	444.57± 0.56	1045.33± 0.67	1546.53± 0.48	2134.5± 0.78	2694.7± 0.65
Mean feed consumption (± S.E.) of broilers from1 to 6 weeks of age.						
Control	119 .00±12.50	232.18 ±35.13	416.61 ± 51.97	443.49 ±140.53	346.47 ± 241.94	402.84 ± 254.50
SBM	105.92 ± 8.74	232.18 ± 35.13	401.49 ±29.27	430.00 ± 110.77	219.78 ± 168.29	455.78 ± 216.22
FSBM	127.59 ± 10.17	250.39 ± 25.86	452.29 ± 50.32	383.63 ± 167.72	289.41 ± 222.28	392.29 ±300.42
Mean feed conversion ratio (± S.E.) of broilers from 1 to 6 weeks of age.						
Control	1.04 ± 0.08	1.19 ± 0.10	1.22 ± 0.07	1.25 ± 0.13	1.33 ± 0.15	1.23 ± 0.15
SBM	0.99 ± 0.05	1.19 ± 0.06	1.21 ± 0.02	1.25 ± 0.13	1.28 ±0.13	1.20 ±0.14
FSBM	0.97 ± 0.05	1.06 ± 0.05	1.20 ± 0.05	1.25 ± 0.19	1.39 ± 0.12	1.22 ±0.21

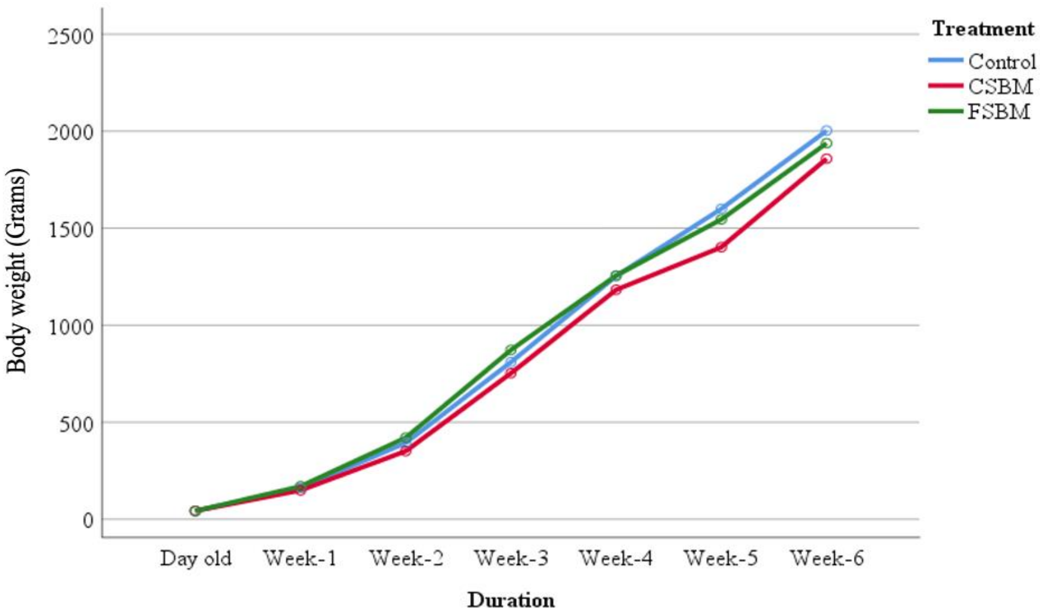

Figure 1. The effect of experimental diets on the average body weight of broiler chickens.

There was a statistically significant interaction effect between the ages of the broiler chickens and the average weekly body weight between the experimental feed diets (Treatments) ($P \leq 0.05$). Hence there was an interception between the average body weight of the FSBM and control-fed group during the 1st, 2nd, and 4th weeks of age of the broiler chickens, as observed in Figure 1.

3.3. Mean Weekly Gain

The data for mean weekly gain in weights of the birds from day-old to the 6th week is presented in Table 4. The mean weekly weight gain between the treatment groups differed from 1st week up to 6th week. The FSBM-fed group had a higher mean weekly weight gain than other treatment groups throughout the feed trials. The SBM-fed group had the lowest mean weekly gain of 219 grams compared to FSBM and control-fed groups, 289 grams and 346 grams, respectively, in the 5th week. However, in the 6th week, the SBM fed group had the highest weekly weight gain of 455 grams compared to 402 grams and 392 grams of the control and FSBM-fed groups, respectively. The mean weekly weight gain between the treatment groups differed significantly ($P<0.05$) from 1st week up to 6th week. The FSBM-fed group was significantly ($P<0.05$) higher than other treatment groups, however, with no significant difference amongst the three treatment groups from 1st week up to 3rd week of age.

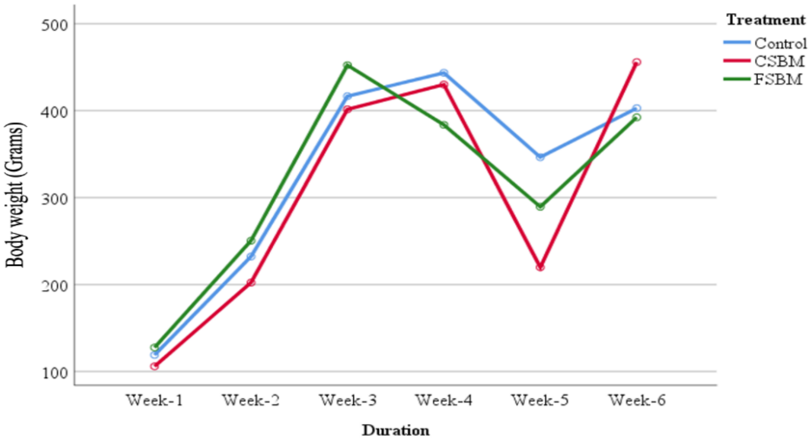

Figure 21. The effect of experimental diets on the weekly gain of broiler chickens.

From the 4th week up to the 5th week, the mean weekly gain in all treatments was high hence a significant difference between the treatments groups. The SBM-fed group had the lowest mean weekly gain in the 5th week and the highest in the 6th week of age; hence, there was a significant difference between the SBM-fed group and FSBM and the control groups, while there was no difference between the FSBM and control groups at week 6 of age.

3.4. Average Weekly Feed Intake

Table 4 presents the average weekly feed intake data for birds from day-old up to the 6th week of age from three treatment groups. The highest feed intake was recorded by the broilers from the control-fed group, as shown in Figure 3. An increase in the feed intake of the birds from the control and FSBM-fed groups was also reflected in the improved body weights as compared to the SBM-fed group, as shown in Table 4.

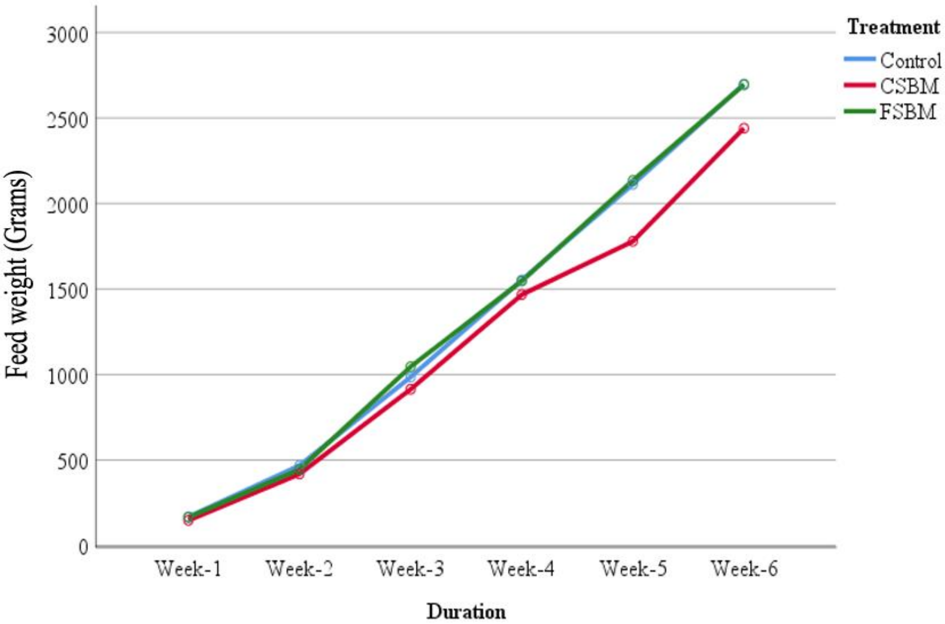

Figure 3. The effect of experimental diets on the feed intake of broiler chickens.

3.5. Average Weekly Feed Conversion

The data concerning the average weekly feed conversion ratios in terms of feed intake per unit gain in weight for the three treatment groups, from day-old to the 6th week of age, are presented in Table 4. During 5th weeks and 6th weeks, the FSBM-fed group recorded higher FCR values than other groups. Hence, the FSBM-fed group recorded the highest FCR value, and CSBM-fed group recorded the lowest FCR value in the 6th week, as shown in Figure 4. There was a significant difference in the FCR values with relation to the treatment, as shown in Figure 4.

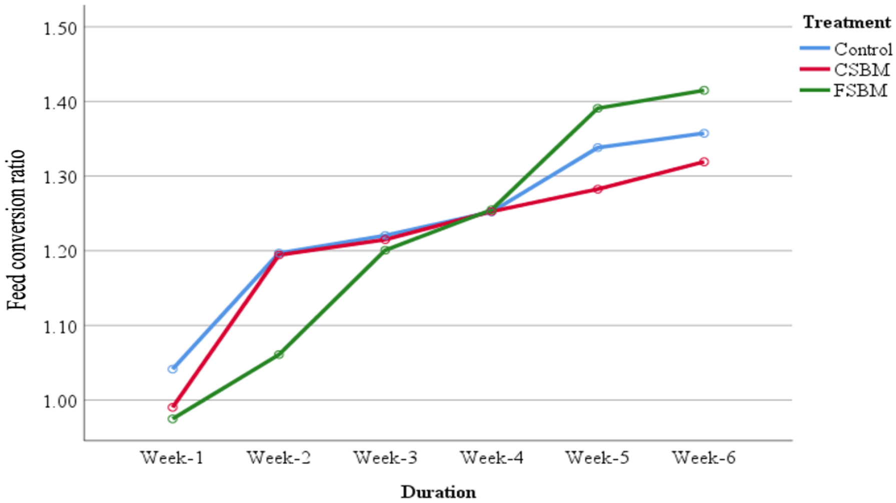

Figure 4. The effect of experimental diets on the feed conversion ratio of broiler chickens.

Table 5. Mean carcass and intestinal weight, intestinal characteristics and digestive enzymes activity of broiler chickens at week 6.

Characteristics	Parameters	Control	SBM	FSBM
Mean carcass and intestinal weight	Live weight (Grams)	1983 ± 0.45	1845 ± 0.34	1983.5 ± 0.24
	Intestinal weight (Grams)	216 ± 0.62	243.6 ± 0.30	297.5 ± 0.35
	Carcass weight (Grams	1424.5 ± 6.81	1267.3 ± 3.56	1371 ± 4.09
Mean intestinal characteristics	Intestinal length (cm)	192 ± 0.06	201± 10.50	225 ± 9.82
	pH intestinal content	6.39 ± 0.03	6.79 ± 0.03	6.69 ± 0.09
	Ileum villi length (µm)	1650.54 ± 47.02	1528.28 ±33.41	1495.25 ± 40.25
	Ileum villi width (µm)	155.49± 9.50	159.60 ± 8.39	160.00 ± 9.87
	Ileum crypt length (µm)	157.29 ± 9.33	148.12 ± 8.31	167.68 ± 7.00
	Ileum crypt width (µm)	65.59 ± 2.27	65.95 ± 1.98	65.08 ± 1.28
Digestive enzymes activity (U/ ml of intestinal content)	Amylase	83.31 ± 11.96	70.54 ±11.93	75.25 ±12.65
	Lipase	10.58 ± 1.08	7.33 ± 1.17	8.08 ± 1.36
	Trypsin	14.00 ± 1.30	10.66 ± 2.13	13.3 ±2.50

3.6. Mean Carcass and Intestinal Weight

Table 5 presents the data on mean carcass and intestinal weight for all feed trial groups during the experimental period. The live body weight of both the FSBM and control fed group were higher than that of the SBM-fed group, as shown in Figure 5. The intestinal weight of the FSBM-fed group was higher than in other treatment groups. The control fed group has the highest carcass weight followed by the SBM fed group which has the lowest.

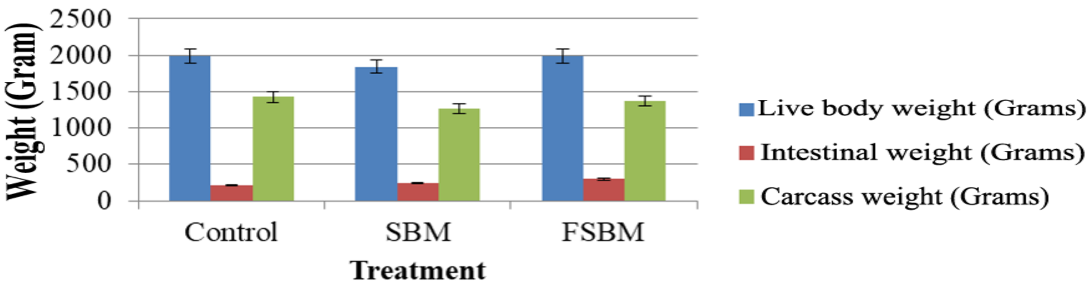

Figure 5. Carcass and intestinal weight of broiler chickens at 6 weeks of age.

3.7. Mean Intestinal Characteristics

Table 5 presents the data pertaining to the mean intestinal characteristics of broilers at 6 weeks of age for the three treatment groups. The pH of intestinal content was lower in the control group as compared to the SBM and

FSBM fed groups. The ileum villi length was higher in the control group compared to SBM and FSBM-fed groups. Similarly, the ileum villi width was higher in SBM and FSBM-fed groups. While the control fed group recorded lower width as compared to the SBM and FSBM fed groups. The crypt length was higher in the FSBM group than the control and SBM groups compared to the control and SBM. The ileum crypt width was not different between treatment groups.

3.8. Digestive Enzymes Activity

The data pertaining to mean digestive enzyme activity of broilers at 6 weeks of age for the three treatment groups are presented in Table 5. The lipase activity was higher in the control group than in other groups. However, the difference did not exist between FSBM and the control group lipase activity. There was an increase in digestive enzyme activity in the FSBM-fed group compared to the SBM-fed group.

4. DISCUSSION

4.1. Proximate Nutrient Composition of Experimental Grower and Finisher Phase Feeds

According to the Agrimix instruction, the grower and finisher phases must contain 20% CP and 18% CP, as observed in Table 1. The crude protein variability and discrepancies of FSBM and SBM experimental feeds were due to the formula mixing ratios that were followed. This was probably caused by many different factors, such as species, genotype, plant fraction and stage of maturity, location of growth, soil fertility, and season and year of growth of soybeans in Zimbabwe. Therefore, a deviation of the CP content in the experimental feed was due to the differences in the crude protein content of FSBM and SBM.

4.2. Growth Performance Indices

During the 1^{st} up to 2^{nd} week, all broiler chicks in the experiment were fed the same type of feed, i.e., Agri-Foods starter feed, which has a crude protein content of 22%. Hence the observation of the interaction effects during the 1^{st} week and 2^{nd} week of the experiment was observed across all growth performance indices. This contributed to a significantly similar, average body weight, mean weekly gain of broiler chickens, and mean feed intake in the first two weeks of the feed trials across all experimental diets, as shown in Figures 1, 2, 3, and 4, respectively. The experimental diets varied in the nutritional composition and ingredients used in formulation of the diets. The positive control had the highest average body weight, yet it was not significantly different from the average body weight of the FSBM-fed group. Both diets contain processed soybean meal either by microbial fermentation of heat processing, that is, the FSBM experimental feed and the control diet, respectively.

The observed increase in average body weight of broiler chickens aligns with the findings of Baker and Stein (2009). They reported that soybean meal, which has been extruded, rather than extracted, was found to have greater amino acid digestibility in monogastric animals. Hence the bioavailability of the amino acids to broiler chickens in the control and FSBM experimental feed increased the overall growth performance of broilers and the mean weekly weight gain as shown in Figure 2. Thus, the observed results are in agreement with the work done by Palacios et al. (2004) comparing the growth performance of broiler chickens. The study showed that chicks and piglets fed anti-nutritional free soybean meal had a higher body weight compared to animals fed raw soybean meal.

However, the average body weight and the mean weekly weight gain of the group fed with SBM experimental feed were significantly lower than the FSBM-fed group. This is due to the presence of allergenic proteins such as glycinin and β-conglycinin in SBM diet; thus, their presence has a negative effect on the poultry growth performance (Zhao, Qin, Sun, Zhang, & Wang, 2010). In poultry diets containing high amounts of soluble Non-Starch Polysaccharides (NSP), the digesta increases its viscosity. This decreases the nutrient and enzyme interaction in the intestine and negatively affects the digestibility of other nutrients (Smits & Annison, 1996). Hence resulting in slow growth rate, thus lower average body weight and the mean weekly weight gain of the group fed with SBM experimental feed as shown in Figures 2 and 3. In addition to its allergenic properties, soybean meal (SBM) contains high levels of various anti-nutritional factors, including trypsin inhibitors, lectins, and phytic acid. These components can impede animal digestion and nutrient absorption. For instance, protease inhibitors bind to proteases, rendering them inactive and reducing the animals' ability to break down proteins effectively. Moreover, phytic acid in SBM can bind to essential minerals like zinc and calcium, diminishing their availability for absorption in the gut. This interference can lead to a slower growth rate in broiler chickens, as illustrated in Figures 2 and 3 (Zhao et al., 2010). Because monogastric animals like broilers lack phytase, additional inorganic phosphorus supplementation is necessary in their diets. Consequently, the inclusion of SBM in experimental feeds can result in reduced growth rates, lower average body weight, and decreased weekly weight gain, as depicted in Figures 2 and 3.

4.3. Mean Intestinal Characteristics

Compared to groups fed the control and SBM experimental feeds, broiler chickens fed the experimental feed containing fermented soybean meal (FSBM) showed notable enhancements in villus length and crypt depth. This finding aligns with the research conducted by Yang, Xiong, and Yin (2013) who concluded that incorporating FSBM into broiler diets leads to improvements in the mucosal structure of ileum villi. Consequently, FSBM is linked to reduced morphological alterations, such as microvilli disintegration and the absence of granulated pinocytotic vacuoles. Lower levels of trypsin inhibitors and lectins contribute to the advantageous effects of FSBM. This allows for favorable interactions with the brush border of intestinal epithelial cells, thereby promoting cell viability, enhancing crypt function, and influencing tissue weight positively (Liener, 1994).

4.4. Digestive Enzymes Activity

The intestinal enzymatic activities improved in birds with the control and the FSBM experimental feeds rather than with the SBM experimental feed. Either heat processing or microbial fermentation of SBM reduces the levels of anti-nutritional factors and allergenic proteins. The increase in enzyme activity of trypsin indicates that there is a decrease in the levels of anti-nutritional factors and allergenic proteins.

The impact of experimental feeds on growth metrics and nutrient utilization in broiler chickens varies depending on their age. Consequently, there is substantial statistical evidence to refute the null hypothesis and endorse the primary hypothesis regarding interaction effects, as detailed in Table 3. The inclusion of FSBM in feeds leads to enhanced growth performance and improved health of broiler chickens, attributed to the beneficial changes induced by soybean meal fermentation. Across various animal species, the benefits of using FSBM as an alternative protein source are apparent. By addressing concerns related to immune responses, subpar growth parameters, and other health issues, FSBM proves to be a valuable solution in comparison to feeds containing untreated SBM.

5. CONCLUSION

The growth performance and nutrient utilization of broiler chickens improved with the advancement of age within the FSBM-fed group. Feeding broilers with fermented soybean experimental feed resulted in increased body weight, enhanced feed consumption, and improved feed conversion ratios. The FSBM feed likely induces intestinal pH modulation, which creates a more favourable environment for nutrient absorption, leading to these enhancements. These results demonstrate that the use of FSBM-containing feeds leads to superior growth performance and improved health in broiler chickens, credited to the benefits derived from soybean meal fermentation. The positive impacts of FSBM utilization are evident in various animal species, as it addresses issues such as immune responses, suboptimal growth rates, and other health concerns. Further research is warranted to explore the probiotic effects of FSBM at different inclusion levels and among diverse age groups of broiler chickens. This investigation aims to optimize feed formulation costs and determine the ideal inclusion rate of FSBM that maximizes positive effects on broiler growth performance.

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Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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