ISSN: 2224-0616
Int. J. Agril. Res. Innov. Tech. 13(1): 6-14, June 2023
DOI: https://doi.org/10.3329/ijarit.v13i1.67945

OPEN ACCESS
Available online at https://ijarit.webs.com
https://www.banglajol.info/index.php/IJARIT

Growth performance, nutrient digestibility and carcass characteristics of grower rabbits fed graded levels of Bamboo (*Bambusa vulgaris*) leaf meal

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Received 14 December 2022, Revised 11 May 2023, Accepted 27 June 2023, Published online 30 June 2023

A B S T R A C T

This study aimed at determining the growth performance, nutrient digestibility and carcass characteristics of grower rabbits fed diets containing graded levels of *Bambusa vulgaris* leaf meal (BVLM). Thirty rabbits weighing an average of 999 g were allocated in a Completely Randomized Design (CRD) to five treatments (BVLM 0%, which was the control diet, BVLM 5%, BVLM 10%, BVLM 15% and BVLM 20%) with six replicates. The rabbits were adapted to the assigned diets for one week and fed for ten weeks. Feed intake, live weight changes and feed conversion ratio were the performance parameters measured. Existing market prices for feed items were used to appraise the diets economically. A digestibility study was undertaken during the 10th week. No mortality was recorded during the study. Before termination of the feeding trial, 15 rabbits (3 from each treatment) were selected randomly, taken off feed for 24 hours and humanely slaughtered. Carcass parameters and weights of internal organs were measured and recorded. Results revealed that live weight changes, feed intake and feed conversion ratio were similar for all treatments. However, the cost of feed/kg and feed/kg gain decreased linearly with an increase in the inclusion level of BVLM. The results also showed that BVLM could be utilized in up to 15% of grower rabbit diets without lowering nutrient digestibility and dressing percentage. It was concluded that BVLM could be used up to 20% of the diet of grower rabbits to reduce the cost of feed/kg and cost of feed/kg gain without any adverse effects on live weight changes and weights of internal organs.

Keywords: Leaf meal, *Bambusa vulgaris*, Feed cost, Nutrient digestibility, Carcass

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Cite this article as: Osman, A., Aziz, Y.A., Amoah, K.O., Osafo, E.L.K., Kotoku, V.A. and Sasu, P. 2023. Growth performance, nutrient digestibility and carcass characteristics of grower rabbits fed graded levels of Bamboo (*Bambusa vulgaris*) leaf meal. *Int. J. Agril. Res. Innov. Tech.* 13(1): 6-14. https://doi.org/10.3329/ijarit.v13i1.67945

Introduction

It has been reported by Gerland *et al.* (2014) that the population of the world could reach 9.6 billion by 2050. This figure would undoubtedly increase the demand for animal feed by 235% and necessitate 70% additional livestock output (Herman and Schmidt, 2016). Consequently, there is the need to evaluate suitable and cheaper feed substitutes that can help prevent the anticipated shortfall in livestock output. In this regard, assessing under-utilized plant feed resources as alternatives for feeding rabbits is becoming more widespread in tropical regions (Oloruntola *et al.,* 2015). This is because proteins, phytobiotics, antioxidants (Dhama *et al.,* 2015), vitamins and oxycarotenoids (Jiwuba *et al.,* 2017) may be derived from plants when fed or added to the diet of livestock. The utilization of leaf meals in the diet can lower feed costs and, subsequently, the price of animal protein (Oloruntola *et al.,* 2018).

Bamboo (*Bambusa vulgaris*) is an indigenous plant whose leaves offer great promise as animal feed but has been under-utilized in Ghana. Some species of bamboo (*B. vulgaris vittata*, *B.*

vulgaris vulgaris, *B. ventricosa* and *O. abyssinica*) have been cited as having relatively high crude protein (CP) and fibre contents ranging from 18.39 to 19.39% and 18.39 to 19.39% for CP and fibre, respectively (Antwi-Boasiako *et al.*, 2011). Bamboo is used in many countries as fodder for ruminant livestock (Asaolu *et al.*, 2009; Halvorson *et al.*, 2011) and has a huge potential to economically empower individuals and communities worldwide (INBAR, 2019). However, information regarding the utilisation of *B. vulgaris* as rabbit feed is scanty. The prospects of exploring *B. vulgaris* leaf meal as part of concentrate diets for rabbits remain unexplored. Since the production of rabbits has been demonstrated to be an effective means of assuaging animal protein deficiency (Ajala and Balogun, 2004), this experiment sought to assess the effects of incorporating *B. vulgaris* leaf meal in the grower rabbit diet. The study specifically sought to ascertain the impact of feeding different levels of *B. vulgaris* leaf meal on growth performance and production economics. It also sought to evaluate the effects of the different levels on apparent nutrient digestibility and carcass characteristics.

Materials and Methods

Experimental site

The work was undertaken at the Department of Animal Science (DAS), Kwame Nkrumah University of Science and Technology (KNUST), Kumasi Ghana. The average monthly temperature ranges from 26.1°C to 28.9°C. There is a bimodal rainfall pattern for the area, with a mean annual total of 1500 mm (Weather Spark, 2022).

Harvesting and processing of bamboo leaves

Fresh *Bambusa vulgaris* leaves were plucked from mature trees at the Department of Horticulture, KNUST. Identification and authentication of the bamboo plant were done at the Herbarium of the Department of Herbal Medicine, KNUST. A voucher specimen with the reference number KNUST/HM1/2021/L024 was stored in the Department's herbarium. The harvested leaves were then air-dried in a well-ventilated barn for fourteen days until they turned crispy but retained the greenish hue. *B. vulgaris* Leaf Meal (BVLM) was prepared by separating the leaves from the stalk after they had air-dried and then milled in a hammer mill with a 2 mm sieve size. Samples of the leaf meal were analysed in triplicate at the laboratory for their proximate and mineral (calcium and phosphorus) composition based on the methods of the Association of Official Analytical Chemists (AOAC, 1990). The technique described by Goering and Van Soest (1970) was used to determine neutral and acid-detergent fibre fractions. Cellulose content was calculated by deducting acid detergent lignin from the acid detergent fibre, and hemicellulose content was determined by subtracting acid detergent fibre from the neutral detergent fibre.

Feed ingredients, diets and experimental design

All feed ingredients except millet mash residue (wheat bran, soya bean meal, vitamin premix, dicalcium phosphate and common salt) were bought from a feed shop. Millet mash, the residue left when a mixture of millet dough and water is sieved during the preparation of millet porridge, was bought in the wet state from local porridge sellers in Kumasi. It was subsequently dried in the sun for 7 days and bagged for use. Five diets were formulated: the control diet (BVLM 0%) had no BVLM. The four other diets designated BVLM 5%, BVLM 10%, BVLM 15% and BVLM 20% had 5%, 10%, 15% and 20% BVLM, respectively. The grower rabbits were assigned to five groups of six animals per treatment. Subsequently, in a Completely Randomized Design (CRD), the treatment groups were allocated the five formulated diets resulting in six replicates per treatment.

Experimental animals and management

Thirty (30) grower rabbits of mixed breeds (crosses from New Zealand White and Californian breeds) weighing 980g to 1000g and aged 8 weeks were involved in the study. They were kept individually in two-tiered cages made from wood but with welded-mesh floors. The rabbits were allowed *ad libitum* access to feed and water for 10 weeks after they had been adapted for a week. All rabbits were dewormed with Piperamentic (The Arab Pesticides and Veterinary Drugs, Jordan) before the start of the trial and repeated after every four weeks. Coccidiosis was regularly controlled with Britacox (Special T Products Limited, United Kingdom), which was also administered at the start and repeated after every four weeks during the study.

Animal care and welfare

All required standard operating procedures defined by the Animal Research Ethics Committee (AREC, 2018) of the Quality Assurance and Planning Unit, KNUST, were adhered to.

Growth study and economics of production

Separate earthenware feeders and drinkers were used to serve feed and water for each rabbit in the morning (08.00 hours). The rabbits were fed at 10 % of their respective body weights. Intake of feed on daily basis, live body weight changes, and feed conversion ratio (FCR) were the performance parameters measured. Representative samples of all formulated diets were taken for proximate and detergent fibre analyses following AOAC (1990) and Goering and Van Soest (1970) methods, respectively. For each dietary treatment, the feed cost per kilogram diet was multiplied by the feed conversion ratio to obtain the feed cost per kilogram live weight gain for the economic appraisal of the diets.

Digestibility study

In the tenth and final week of the study, an apparent nutrient digestibility study was included. It involved the collection of the daily totals of faeces from each rabbit. Proximate and detergent fibre analyses using the methods of AOAC (1990) and Goering and Van Soest (1970), respectively, were carried out on dried representative samples of the faeces. Apparent nutrient digestibility coefficients were calculated by subtracting nutrients excreted from nutrient intake and dividing by nutrient intake and expressing the result as a percentage (Maynard *et al.*, 1979; Perez *et al.*, 1995).

Evaluation of carcass characteristics

Three rabbits were chosen randomly from each treatment, starved of feed and water for a full day and humanely slaughtered upon the termination of the study. Differences between live slaughter weights and hot carcass weights were used to estimate blood weight. To evaluate the carcasses, they were defurred using flame and then eviscerated. The dressing percentage was calculated by dividing the hot-dressed carcass weight by the slaughter weight and multiplying by 100 (Gugolek *et al.*, 2011). Additionally, weights of the liver, kidney, heart, and lungs, as well as full and empty weights of the gastrointestinal tract and caecum, were measured (Adeosun and Iyeghe-Erakpotobor, 2012; Jiwuba and Ogbuewu, 2019).

Statistical analysis

All data collected from the different aspects of the study (feeding trial, digestibility and carcass yield evaluation) were analyzed as a CRD and subjected to Analysis of Variance (ANOVA) using Minitab Version 19.1. (Minitab, 2019). The means were separated by Tukey's pairwise comparison. The probability level for declaration of significance was set at 5%.

Results and Discussion

Chemical composition of air-dried BVLM

Analysed chemical components of BVLM are presented in Table 1. The results showed BVLM to be dry (DM; 93.6%), highly fibrous (NDF; 57.3%) and moderate in ash (13.4%) and CP (16.2%) contents, making it a suitable feed for rabbits. The CP value for *B. vulgaris* for the present study was higher relative to those recounted by Andriarimalala *et al.* (2019) and Ayeni *et al.* (2018) but lower than what was specified by Ikhimioya *et al.* (2007). The current ash content also related well with those of Andriarimalala *et al.* (2019) but was higher compared to the range recounted earlier by Ikhimioya *et al.* (2007) and Ayeni *et al.* (2018).

Table 1. Chemical composition and metabolisable energy content of air-dried BVLM.

Parameter	Percentage
Dry matter (DM)	93.60
Crude protein (CP)	16.20
Ash	13.40
Crude fat (CF)	5.20
Nitrogen-free extracts (NFE)	18.90
Crude fibre	40.90
Neutral detergent fibre (NDF)	57.30
Acid detergent fibre (ADF)	37.30
Acid detergent lignin (ADL)	1.28
Hemicellulose	20.00
Cellulose	36.02
Phosphorus	0.21
Calcium	0.72
*Metabolisable energy (Kcal/kg)	1663.31

**Estimated according to Pauzenga (1985): ME (kcal/kg) = (35 x percentage crude protein) + (81.8 x per cent ether extract) + (35.5 x percentage nitrogen-free extract)*

The current *B. vulgaris* value for crude fibre was higher than what Andriarimalala *et al.* (2019) reported but well within the range detailed by Bhandari *et al.* (2015). The present values for NDF (57.3%) and ADF (37.3%) were; however, lower when compared to the range of values related by Andriarimalala *et al.* (2019). The disparities detected in the chemical components may be attributable to the maturity stage of the bamboo, conditions of weather, edaphic factors, agronomic practices, leaf processing and analysis methods (Fuglie, 1999). *B. vulgaris* is, however, regarded as the fodder of good grade given the criteria by Upreti and Shrestha (2006) that forages with CP less than 8 %, ADF higher than 45 % and NDF more than 65 % are regarded to be of low grade.

Calcium and phosphorus are two essential minerals whose bone metabolism efficiency is interdependent (McDowell, 1976). The calcium and phosphorus contents (0.72% and 0.21%, respectively) were higher than the 0.032% and 0.013% reported for *B. vulgaris* by Ayeni *et al.* (2018). Nonetheless, the present levels were lower relative to those recounted for *B. arundinaria* by Idowu *et al.* (2013). The observed variations in mineral levels might be attributable to differing varieties, harvest seasons and maturity stages of the leaves. Compared to the levels of calcium (0.22%) and phosphorus (0.37%) recommended for growing rabbits by Chapin and Smith (1967), the current calcium level was way higher, but the phosphorus content was lower in BVLM.

Inclusion levels of ingredients and the chemical composition of formulated diets

Levels of inclusion of BVLM and the analysed nutrient composition of all experimental diets are shown in Table 2. The chemical components of the diets showed slight variability due to the varied levels of BVLM and soya bean meal. The control diet had the highest CP (21.8%), probably due to the inclusion of the highest level of soya bean meal.

Table 2. Percentage inclusion levels of dietary ingredients in experimental diets and their analysed chemical components.

	Treatments				
Ingredients	BVLM 0%	BVLM 5%	BVLM 10%	BVLM 15%	BVLM 20%
Millet mash residue	39.00	35.00	31.00	27.00	23.00
Rice bran	20.00	20.00	20.00	20.00	20.00
Soya bean meal	19.00	18.00	17.00	16.00	15.00
Wheat bran	20.00	20.00	20.00	20.00	20.00
B. vulgaris leaf meal	--	5.00	10.00	15.00	20.00
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00
Vitamin premix[1]	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Analysed composition (%)					
Dry matter	86.33	87.20	87.80	88.00	88.40
Crude protein	21.80	21.40	20.80	20.20	19.90
Crude fat	12.00	12.50	12.90	13.10	13.40
Ash	4.70	6.60	7.30	7.90	8.70
Carbohydrate	40.30	38.10	37.50	36.30	35.20
Crude fibre	7.50	8.60	9.30	10.50	11.20
Neutral detergent fibre	35.45	36.50	37.80	38.30	39.50
Acid detergent fibre	16.20	17.00	17.50	17.90	18.20
*Metabolisable energy (Kcal/kg)	3174.65	3124.05	3114.47	3067.23	3042.22

[1]Vitamin-mineral premix: contains the following/kg diet: vitamin A - 8000 IU; vitamin D – 3000 IU; vitamin E – 8 IU; vitamin K- 2 mg; vitamin B1- 1 mg; vitamin B 2 – 2.5 mg; vitamin B 12 – 15 mcg; niacin – 10 mg; panthothenic – 5 mg; antioxidant – 6 mg; folic acid – 0.5 mg; choline –150 mg; iron -20 mg; manganese – 80 mg; copper – 8 mg; zinc – 50 mg; cobalt – 0.225 mg; iodine – 2 mg; selenium – 0.1 mg.

**Estimated according to Pauzenga (1985): ME (kcal/kg) = (35 x percentage crude protein) + (81.8 x per cent ether extract) + (35.5 x percentage nitrogen-free extract)*

The crude fat content was also higher in the control than in the BVLM-based diets. Crude fibre contents were, however, superior in the BVLM-based diets relative to the control, apparently due to the inclusion of the BVLM. Fibre contents of the various diets were lower than 14-18% on dry matter basis recommended by Gidenne and Lebas (2002). The generally low levels of crude fibre (7.5-11.2%) were most likely attributable to the low levels of BVLM included in the feeds. Estimated Metabolizable energy levels of the experimental diets were all higher than those reported by Njidda and Isidahomen (2010) but lower than those stated by Osman *et al.* (2020). All the formulated diets, however, generally met the minimum nutrient requirement for rabbits published by Maertens (1992).

Growth performance of rabbits fed the formulated diets

Growth performance of grower rabbits on the diets formulated is shown in Table 3. Initial live body weights of grower rabbits were similar (P>0.05). The results revealed that treatment differences did not influence live weight changes, average daily feed intake, feed conversion ratio, or feed cost/kg gain (P>0.05). The absence of significant effects (P>0.05) in performance parameters measured among the various treatments showed that BVLM could serve as a suitable alternate feed source in feeding rabbits. The trend of similarity regarding intake of feed and average daily gain across the various treatments observed were in accordance with the findings of Oloruntola *et al.* (2018) but at variance with the report of Jiwuba and Ogbuewu (2019), who observed variances when soya bean meal was replaced with *Moringa oleifera* leaf meal.

Table 3. Productive performance of grower rabbits fed the experimental diets.

Parameter	Treatment					SEM	P value
	BVLM 0%	BVLM 5%	BVLM 10%	BVLM 15%	BVLM 20%		
Initial weight (g)	1000.00	997.00	1000.00	1000.00	998.00	13.200	0.100
Final weight (g)	1848.00	1841.20	1834.60	1830.20	1805.60	15.000	0.205
Total weight gain (g)	846.00	844.20	834.60	830.20	807.60	8.620	0.509
Average daily gain (g)	12.10	12.10	12.00	11.90	11.50	0.123	0.509
Average daily feed intake (g)	65.00	64.50	63.50	62.90	63.20	0.698	0.180
Feed conversion ratio	5.40	5.40	5.30	5.30	5.50	0.070	0.400
Feed cost /kg (Gh¢)	1.84	1.80	1.77	1.74	1.71	--	--
Feed cost/kg gain (Gh¢)	9.90	9.70	9.40	9.20	9.40	0.133	0.390

[a,b,c,] *Mean values with different superscripts on the same row differ significantly (P<0.05).*

The present ADG values were higher relative to those recounted by Osman *et al.* (2020) but lower compared to the reports of Jiwuba and Ogbuewu (2019) and Oloruntola *et al.* (2018). FCR was also similar (P>0.05) for all treatments imposed, a trend that corroborates the observations of Amata and Bratte (2008) and Osman *et al.* (2022) when *Gliricidia* leaf meal and Paper mulberry leaf meal, respectively, were incorporated into the diets of rabbits. The current values for FCR were lower relative to those obtained by Oloruntola *et al.* (2018) and Jiwuba and Ogbuewu (2019) but well within range of values related by Osman *et al.* (2022) and Iyayi and Odueso (2003).

Feed cost per kilogram and feed cost per kilogram gain decreased linearly with an increase in the inclusion level of BVLM. This trend was attributed to the low cost of BVLM, which is proof of the economic gains of adding BVLM to the diet. The decrease in feed cost observed with the dietary addition of BVLM also agreed with Ogundipe *et al.* (2014), who raised awareness regarding the importance of reducing feed cost to supply meat and other animal products at fair prices.

Effects of feeding bamboo leaf meals on nutrient digestibility

A comparison of the apparent nutrient digestibility coefficients of the various diets is provided in Table 4. The results showed significant (P<0.05) differences in digestibility coefficients for CP, crude fat and ash due to treatment effects. Digestibility coefficients for all other nutrients remained unaffected (P>0.05) by the treatments imposed.

Table 4. Apparent nutrient digestibility of grower rabbits fed the formulated diets.

Parameter	Treatments					SEM	P value
	BVLM 0%	BVLM 5%	BVLM 10%	BVLM 15%	BVLM 20%		
Dry matter	62.17	63.07	62.97	62.20	60.87	0.319	0.966
Crude protein	66.50[a]	67.00[a]	66.67[a]	65.67[a]	61.00[b]	0.721	0.028
Crude fibre	61.38	63.16	64.53	65.83	67.16	0.773	0.738
Crude fat	71.61[a]	69.96[ab]	67.33[bc]	66.45[bc]	64.78[c]	0.710	0.001
Ash	29.45[c]	34.44[bc]	39.28[ab]	42.02[ab]	43.24[a]	1.48	0.002
NDF	40.33	44.96	45.96	46.16	47.30	0.928	0.376
ADF	30.33	37.00	38.00	39.33	40.33	1.300	0.562

[a,b,c,] *Mean values with different superscripts on the same row differ significantly (P<0.05).*

CP digestibility declined when the level of inclusion of BVLM was increased to 20%, probably due to the relatively lowest level of soya bean meal in BVLM 20%. The lowest CP digestibility in BVLM 20% could also be associated with tannins in bamboo leaves, as reported by Akinmoladun (2022). The CP digestibility coefficients were comparable to those of Iyeghe-Erakpotobor *et al.* (2006) but lower than that of Bamikole *et al.* (2005). Digestibility coefficients for crude fibre obtained were lower relative to those recounted by Bamikole *et al.* (2005), probably because of the swift passage of ingested feed through the gut (Gidenne, 2000). However, the current values were higher than those related by Iyayi and Odueso (2003) and Iyeghe-Erakpotobor *et al.* (2006). Crude fat digestibility declined linearly with increased dietary inclusion of BVLM. The current digestibility coefficients were all lower than those recounted by Eustace *et al.* (2003) and Oso *et al.* (2006) but comparable to those of Bamikole *et al.* (2005). Contrary to the digestibility of crude fat, ash digestibility rather increased linearly when the level of dietary inclusion of BVLM was increased up to 20%, probably due to the high amount of ash in BVLM. However, the present digestibility coefficients were all lower than those published by Ajayi *et al.* (2007) and Bamikole *et al.* (2005).

Effects of feeding bamboo leaf meals on carcass characteristics of grower rabbits.

Slaughter weight, carcass, and organ characteristics of grower rabbits on the formulated diets are provided in Table 5. The data showed that with the exception of dressing percentage and empty caecum weight, which was significantly influenced ($P<0.05$) by the treatments imposed, the other parameters remained unaffected ($P>0.05$). The dressing percentage decreased significantly ($P<0.05$) when the level of inclusion of BVLM was increased to 20%. This trend contradicted the reports of Omole *et al.* (2007) and Amata (2010) when rabbits were fed *Stylosanthes guianensis/Lablab purpureus* and Gliricidia leaf meal respectively. The current values for dressing percentage were within the range of values in the report of Akinmoladun *et al.* (2018) but higher than those recounted by Adeosun and Iyeghe-Erakpotobor (2012).

Table 5. Carcass characteristics of grower rabbits fed the formulated diets.

	Treatments						
Parameter	BVLM 0%	BVLM 5%	BVLM 10%	BVLM 15%	BVLM 20%	SEM	P value
Slaughter weight (g)	1800.00	1796	1798.00	1795.00	1796.00	17.20	1.000
Hot carcass weight (g)	1756.50	1752.00	1755.00	1752.67	1754.67	17.10	1.000
Blood weight (g)	43.50	44.00	43.00	42.33	41.33	0.424	0.090
Dressed weight (g)	1194.46	1184.33	1178.28	1159.02	1144.67	11.00	0.338
Dressing percentage	66.37[a]	66.00[a]	65.53[ab]	64.57[ab]	63.73[b]	0.305	0.017
Full GIT weight (g)	235.83	225.17	225.33	232.67	225.33	4.860	0.145
Empty GIT weight (g)	133.67	130.63	131.00	139.83	144.83	5.290	0.251
Liver weight (g)	49.00	49.50	48.50	45.67	45.67	0.951	0.398
Kidney weight (g)	9.60	9.73	9.57	9.60	9.53	0.126	0.086
Heart weight (g)	3.40	3.50	3.40	3.80	3.80	0.072	0.225
Lung weight (g)	11.70	12.20	12.33	11.50	11.17	0.182	0.929
Caecum + content (g)	105.50	112.00	132.17	125.83	130.00	4.080	0.383
Empty caecum (g)	39.00[b]	39.00[b]	40.83[ab]	41.17[ab]	41.67[a]	0.380	0.032

[abc] *Means along the same row with different superscripts are significantly different (P<0.05).*

In feeding experiments, the weightiness of internal organs (heart, kidney and liver) is typically utilized to determine whether dietary treatments exert harmful effects on animals (Ahamefule *et al.*, 2006). The addition of BVLM did not appear to exert any adverse effect on the internal organs, as the weights across the treatments imposed were similar. This current trend corroborates the results of Oloruntola *et al.* (2015) but contradicts those of Akinmoladun *et al.* (2018), who detected differences in the weights of the organs mentioned above. Weights of empty caecum improved linearly when the level of BVLM inclusion was augmented from 5% to 20%, probably due to the associated increment in fibre levels. This trend followed the works of Hoover and Heitman (1972) and Chao and Li (2008), who observed increased caecum weight when dietary fibre levels were increased.

Conclusion

The current study has shown that BVLM could be incorporated into the feed of grower rabbits up to 20 % without negatively affecting intake of feed, weight gain and FCR. BVLM could be utilized to lower the costs of feed per kilogram and per kilogram weight gain in grower rabbit diets. In addition, BVLM can be utilized up to 15% in grower rabbit diets without reducing dressing percentage and nutrient digestibility. Indeed, levels of BVLM inclusion in up to 20% of the diet enhanced ash digestibility. Finally, BVLM could be utilized in up to 20% of the diet of grower rabbits with no adverse effects on weights and functions of internal organs.

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