EFFECTS OF THE DIETARY INCLUSION OF VARYING LEVELS OF PAPER MULBERRY (*BROUSSONETIA PAPYRIFERA*) LEAF MEAL ON GROWTH PERFORMANCE, NUTRIENTS DIGESTIBILITY AND CARCASS CHARACTERISTICS OF GROWER RABBITS

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ABSTRACT

A ten-week feeding trial was conducted using 25 grower rabbits in a completely randomised design to evaluate effects of the inclusion of varying levels of paper mulberry leaf meal (PMLM) on growth performance, nutrients digestibility and carcass characteristics. The rabbits were of mixed breeds and sexes, aged 8 weeks and weighing between 1000 – 1350 g. PMLM was incorporated into five diets designated T0, T1, T2, T3 and T4 at 0, 5, 10, 15 and 20 % levels of inclusion. Feed intake and live weight changes were monitored throughout the study. A digestibility study was carried out during the sixth week. At the end of the feeding trial, two rabbits per treatment were randomly selected and humanely slaughtered. Hot carcass weight, blood weight, dressed weight, weights of gastrointestinal tract, internal organs and caecum were taken. Dressing percentage was determined by dividing the hot dressed carcass weight by the slaughter weight and multiplied by hundred. Existing market prices for feed ingredients were used for the economic appraisal of feeds. Results did not show significant differences (p>0.05) in live weight changes. However, feed cost/kg and feed cost/kg gain declined with increase in level of PMLM. Digestibility coefficients were similar for all nutrients across the treatments except for ash which improved with increase in level of PMLM. PMLM inclusion also improved dressing percentage without deleterious effects on internal organs. It was concluded that dietary inclusion of PMLM up to 20 % could be used in rabbits to reduce feed cost/kg gain.

Keywords: Growth performance, Digestibility, Carcass, Paper mulberry leaf meal, Rabbits

INTRODUCTION

Rapid increase in human and livestock populations has brought about the need for increased food and feed needs in developing countries (Odunsi *et al.,* 2002) which have triggered the search for new feed resources that have the capacity to yield the same output as conventional feeds and at a cheaper cost. It is in the light of this that Gueye and Branckaert (2002) have called for the need to recognise and use locally available feed resources to create healthy and productive diets for livestock. The use of plants in different forms as alternatives to the relatively expensive and scarce conventional feed resources in feeding livestock has thus become popular in the tropics (Oloruntola *et al.,* 2015). This is apparently because plants and their parts could serve as an indispensable source of protein, phytobiotics, antioxidants (Dhama *et al.,* 2015), vitamins and oxycarotenoids (Jiwuba *et al.,* 2017) particularly in monogastric nutrition. Leaf meals are produced by air-drying and milling plant leaves for incorporation into animal diets to wholly or partially replace the relatively costly and scarce ingredients. The dietary inclusion of leaf meals has been reported to be capable of reducing feed cost and for that matter the cost of animal protein (Oloruntola *et al.,* 2018).

One plant whose leaves have a huge potential as livestock feed but have been under-utilised in Ghana is paper mulberry (*Broussonetia papyrifera* (Linn.) Vint, Rosales: Moraceae). Internationally, paper mulberry is identified as an invasive weed in over a dozen countries (Swearingen *et al.,* 2010) including Pakistan, Argentina and Uganda. In West Africa, Kyereh *et al.* (2014) reported that since paper mulberry was introduced to Ghana in 1969, it has become second only to Siam weed (*Chromolaena odorata* (L.) R. M. King and H. Rob., Asterales: Asteraceae) as an invasive species found mainly in disturbed forests and other open sites. In many communities in Ghana where the spread cannot be controlled, several uses have been found for it. The stem is used as firewood and for making charcoal. The bark is used in strips as binding ropes for mud houses and sometimes weaved into mesh used in erosion prevention. In many areas, the leaves are fed to sheep and goats (Sunderland and Ndoye, 2004).

Given the fact that prices of the conventional protein sources (soya bean meal and fish meal) continue to skyrocket, the need for alternate protein sources that could yield the same results at a cheaper cost cannot be overemphasised. Paper mulberry leaves have the prospect to be used as an alternative cheap source of protein given the chemical composition.

The aerial parts of paper mulberry have been found by Qureshi *et al.* (2014) to contain bioactive toxic principles. Flavonoids (mainly quercetin, isoglycyrrhizin and carotenoids) and alkaloids are the main active ingredients in paper mulberry leaves (Ma *et al*., 2009; Pang *et al.,* 2014). Paper mulberry has been reported to contain over 40 flavonoids and terpenes that result in its antioxidant, anti-inflammatory and antineoplastic properties (Ko *et al.,* 1997; Feng *et al.* 2008). The presence of a very long list of phytochemicals including broussonin A, broussonin B, kazinol F, broussochalcone A, among others has been reported in paper mulberry (Shende *et al*., 2021). Paper mulberry contains 24.1 % crude protein, 44.71 % neutral detergent fibre, 23.9 % acid detergent fibre, 2.92 % ether extract and 11.67 % ash (Hao *et al.,* 2020). The calcium and phosphorus contents, according to the authors were 2.65 and 0.30 % respectively. Hua *et al.* (2020) reported that paper mulberry is increasingly used as high-quality feed for ruminants because of its high nutritional value (>23 % crude protein, 4.3 % ether extract and 1.9 % of calcium on dry matter basis). Obour *et al.* (2017) reported a crude protein content of 20.52 and 27.17 % respectively for the dry and wet seasons in Ghana. The contents of neutral detergent fibre according to the authors were 34.76 % for the dry season and 32.14 % for the wet season, while acid detergent fibre ranged from 19.86 % in the dry season to 31.87 % in the wet season. The leaves of paper mulberry have reportedly been used as a feedstuff for animals due to its high crude protein content (Hua *et al.,* 2020; Sheng *et al.,* 2021).

Supplementing Napier grass with paper mulberry in sheep led to increases in total feed intake and live weight gain (Osman *et al.,* 2018). Singh *et al.* (1997) evaluated the use of paper mulberry as a sole roughage diet in pelleted forms for rabbits and reported depression in body weight relative to the control diet due to poor palatability. Inthapanya and Preston (2009) also evaluated the effects of supplementation with sweet potato and paddy rice in rabbits on a basal diet of water spinach or paper mulberry. In their study, water spinach performed better than paper mulberry as the basal diet for rabbits. The afore-mentioned reports are indicative of the fact that, paper mulberry, though a good dietary ingredient has not performed too well as a sole diet for rabbits with and without supplementation. This study therefore sought to evaluate the effects of incorporating varying levels of paper mulberry leaf meal as partial replacement for soya bean meal in the diet of grower rabbits. Specifically, the study sought to determine: (i) the effects of feeding varying levels of paper mulberry leaf meal on the growth performance and economics of production of grower rabbits, (ii) the effects of the incorporation of paper mulberry leaf meal on apparent nutrients digestibility and (iii) the effects of incorporating the paper mulberry leaf meal on carcass characteristics and organ weights of grower rabbits.

MATERIALS AND METHODS

Experimental Site: The study was conducted at the Animal Science Department of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. The department is located in the south-eastern part of Kumasi. The annual monthly temperatures of the area vary between 26.1 and 28.9°C. High temperatures occur during the months of November to April with maximum temperatures occurring between February and March, while the lowest temperature is experienced in July. Rainfall in the area is bimodal with an annual mean of 1500 mm (Weather Spark, 2022).

Harvesting and Processing of Paper Mulberry Leaf Meal: Fresh leaves of paper mulberry were harvested from mature trees at the Department of Animal Science, KNUST. Sample of the leaf was identified (Llamas, 2003) and authenticated at the Department of Herbal Medicine, KNUST. Voucher specimens were kept at the Department's herbarium with voucher specimen number KNUST/HM1/2022/L002. The harvested leaves were then detached from the stems and air-dried in a well-ventilated shed for 1 – 2 weeks till they were crispy to touch while maintaining their greenish colouration. After air drying, the leaves were milled using a hammer mill of sieve size of 2 mm to produce the paper mulberry leaf meal (PMLM).

Toxicity and Phytochemical Assay of Paper Mulberry Leaf Meal: The toxicity and phytochemical assay of paper mulberry leaf meal was adopted from the study of Qureshi *et al.* (2014).

Feed Ingredients and Experimental Diets: Millet mash residue (obtained by sun-drying the residue left when a mixture of millet dough or flour and water is sieved during the preparation of millet porridge) was procured from local porridge sellers in Kumasi, while soya bean meal (SBM), wheat bran, dicalcium phosphate and vitamin premix were purchased from a commercial feed supplier.

Five diets were formulated. Diet 1, which was designated as T0 served as the control diet and contained soya bean meal as the main protein source with no PMLM. The four other diets designated as T1, T2, T3 and T4 contained 5, 10, 15 and 20 % PMLM respectively. All formulated diets and water were fed to the rabbits in the different treatment groups *ad libitum* for 10 weeks.

Proximate Composition: Representative samples of the PMLM and the experimental diets were assayed for their proximate composition (AOAC, 2005) at the Nutrition Laboratory of the Department of Animal Science, KNUST. The NDF and the ADF fractions of PMLM were determined following the technique described by Goering and Van Soest (1970). The leaf meal was also analysed for calcium and phosphorus at the Crop and Soil Sciences Laboratory of the Faculty of Agriculture, KNUST.

Experimental Animals and Management: Twenty five (25) rabbits of mixed breeds (from New Zealand White and Californian breeds) and sexes were used for the study. The rabbits were about 8 weeks of age and weighed between 1000 – 1350 g. The animals were housed individually in two-tiered wooden cages with welded-mesh floors. Each animal was provided with earthenware feeder and drinker specifically designed to reduce spillage. They were assigned to five groups of five animals per treatment. The five treatment groups were then assigned the five experimental diets in a Completely Randomized Design (CRD). Each treatment was replicated five times. Each rabbit was fed the assigned diet for 10 weeks after one week adjustment period. Prior to the commencement of the experiment, each animal was dewormed using Piperazine (Dorpharma B.V. Limited, The Netherlands). Coccidiosis was routinely controlled using Britacox (Special T Products Limited, United Kingdom).

Animal Care and Welfare: All necessary standard operating procedures outlined by the Animal Research Ethics Committee (AREC, 2018) of the Quality Assurance and Planning Unit of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana were followed.

Growth Study and Economics of Production: Each rabbit was offered the experimental feed and water in separate earthenware feeders at 08.00 hours in the morning. Each rabbit's daily feed intake was 10 % of its body weight. All animals were weighed at commencement of the experiment before allotting them to the various treatments. Growth performance parameters measured were average feed intake, live weight changes and feed conversion ratio. Feed cost and feed cost per kilogramme weight gain were also calculated for the determination of the economics of production.

Digestibility Study: This study was carried out during the 6th week of the feeding trial and involved feeding the rabbits with known quantities of feed. Total faeces voided were collected daily and oven dried to determine moisture content. Representative samples of dried faeces were taken for proximate analysis using AOAC (2005) methods. The digestibility values for dry matter (DM), crude protein (CP), crude fibre (CF), crude fat, ash, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were calculated as nutrient intake minus nutrient excreted divided by nutrient intake multiplied by hundred (Perez *et al.,* 1995).

Evaluation of Carcass Characteristics: Two rabbits per treatment were randomly selected, starved of feed and water for 24 hours and humanely slaughtered at the end of the feeding trial. Blood weight was determined by the difference between slaughter weight and hot carcass weight. The carcasses were defurred using flame and eviscerated to evaluate their carcasses. Dressing percentage was determined by dividing the hot dressed carcass weight by the slaughter weight and multiplied by hundred according to the procedure of Gugolek *et al.* (2011). Weights of gastrointestinal tract (full and empty), liver, kidney, lung, heart and caecum (full and empty) were measured as described by Adeosun and Iyeghe-Erakpotobor (2012) and Jiwuba and Ogbuewu (2019).

Economics of Production: Prevailing market prices for the feed ingredients (Table 1) were used for the economic appraisal of the feeds which was based on the feed cost per kg diet and feed cost per kg weight gain. Feed cost per kg live weight gain was calculated as a product of the feed cost per kg diet and feed conversion ratio for individual dietary treatments. The cost of processing the leaf meal was included as the price of the leaf meal since the leaves were freely available.

Table 1: Feed ingredients and their prevailing prices per kilogramme

Ingredients	Price per kilogramme (Gh¢)
Millet mash residue	1.00
Soya bean meal	4.30
Wheat bran	1.40
Paper mulberry leaf meal	1.00
Vitamin premix	15.00
Dicalcium phosphate	5.00
Salt	5.00

Statistical Analysis: The data collected from the feeding trial, digestibility study and carcass yield evaluations were subjected to Analysis of Variance (ANOVA) using Minitab Version 16. The means were separated by Tukey's post-hoc test. The probability level of significance was set at 5 %.

RESULTS AND DISCUSSION

Toxicity and Phytochemicals of Paper Mulberry Leaf Meal: Paper mulberry leaf crude extract was found to be not toxic with 40

% lethality at 1000 ppm (Qureshi *et al.,* 2014), thus safe for utilization in animal diet. Rich phytochemical constituent that includes alkaloids, flavonoids, coumarins, glycosides and phenols has been reported crude extract of paper mulberry leaf (Qureshi *et al.,* 2014).

Chemical Composition of Air-Dried PMLM: Results of the proximate composition of PMLM are shown in Table 2.

Table 2: Chemical composition of paper mulberry (*Broussonetia papyrifera*) leaf meal

Chemical composition	Values
Dry matter (g/kg)	875.00
Crude protein (g/kgDM)	195.00
Crude fibre (g/kgDM)	146.00
Ash (g/kgDM)	138.60
Crude fat (g/kgDM)	65.50
Acid detergent fibre (g/kgDM)	341.50
Neutral detergent fibre (g/kgDM)	432.00
Hemicellulose (g/kgDM)	90.50
Calcium (%)	2.96
Phosphorus (%)	0.40
*Metabolizable energy (Kcal/Kg)	2389.44

**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)*

Values for dry matter, crude protein, ash and ether extract obtained in the current study were lower than those reported by Osman *et al.* (2018). However, values for acid detergent fibre, neutral detergent fiber and hemicellulose were comparable to those of Osman *et al.* (2018). The disparities in proximate composition noted may be attributed to the age at harvesting, climatic conditions, edaphic factors, as well as methods of processing and analysis of leaf samples (Osman *et al.,* 2020).

In comparison with other leaf meals that have reportedly been used in rabbit nutrition, values for crude protein, crude fibre, ash and crude fat in the current study were higher than the 15.60, 13.77, 11.58 and 1.41 % respectively reported by Amata and Bratte (2008) for *Gliricidia* (Fabales: Fabaceae) leaf meal. Paper mulberry also had a higher crude protein, ash and crude fat content than those (17, 6.5 and 2.0 % respectively) reported for Ackee leaf meal by Osman *et al.* (2020). Compared to the crude protein content (28.20 %) of *Moringa oleifera* Lam. (Brassicales: Moringaceae) leaf meal reported by Tesfaye *et al.* (2013), the crude protein (19.5 %) for paper mulberry was lower. However, paper mulberry had a higher ash content (13.86 %) than *Moringa* leaf meal (11.90 %) and the crude fat contents were similar in both leaf meals (Tesfaye *et al.,* 2013). Similarly, the crude protein content of paper mulberry in the current study was slightly lower than the 20.26 % for *Leucaena leucocephala* (Lam.) de Wit (Fabales: Fabaceae) leaf meal, but the ash and crude fat contents of paper mulberry were both higher than those of *L. leucocephala* leaf meal (Tesfaye *et al.,* 2013).

Calcium content of paper mulberry (2.96 %) in this study was higher than the 0.98 % recorded for Ackee leaf meal (Osman *et al.,* 2020) but lower than the 8.86 % recorded for *Moringa* leaf meal (Nuhu, 2010). However, the phosphorus content of 0.40 % for paper mulberry obtained in this study was higher than the 0.33 % for *Moringa* leaf meal (Nuhu, 2010) and 0.30 % for Ackee leaf meal (Osman *et al.,* 2020).

PMLM Inclusion Levels and Chemical Contents of Experimental Diets: Percentage inclusion levels of PMLM and analysed nutrient composition of the five formulated diets are presented in Table 3. Analysed chemical components of the experimental diets were slightly variable but the nutrients in all experimental diets met the minimum requirements for rabbits (Maertens, 1992). The control diet (T0) and T4 with 20 % PMLM had similar crude protein contents which were the lowest.

Crude fibre, neutral detergent fibre and acid detergent fibre contents of the leaf meal-based diets increased linearly with increase in level of inclusion from 5 to 20 % attributable to the crude fibre content of the leaf meal. A similar trend of increase in crude fibre content was observed by Osman *et al.* (2020) when graded levels of ackee leaf meal were added to the diet. The ash contents of leaf meal-based diets were also higher than the leaf meal-free control diet due to the high ash content of PMLM.

Table 3: Percentage inclusion levels of dietary ingredients in experimental diets and their analysed chemical compositions

Ingredients	Dietary treatments				
	T0 (0 % PMLM)	T1 (5 % PMLM)	T2 (10 % PMLM)	T3 (15 % PMLM)	T4 (20 % PMLM)
Millet mash residue	59	55	51	47	43
Soya bean meal	19	18	17	16	15
Wheat bran	20	20	20	20	20
Paper mulberry leaf meal	0	5	10	15	20
Dicalcium phosphate	1	1	1	1	1
Vitamin premix[1]	0.5	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100
Analysed composition (%)					
Dry matter	89.8	87.9	86.1	88.5	88.8
Crude protein	22.7	23.3	24.2	24.3	22.3
Crude fibre	7.35	8.2	8.6	9.4	10.1
Crude fat	11.9	11.3	11.7	12.2	13.5
Ash	4.5	7.2	7.1	8.1	8.3
Carbohydrate	43.4	37.9	34.5	34.5	34.6
Neutral detergent fibre	33.2	36.0	37.3	37.9	44.0
Acid detergent fibre	12.6	14.4	14.8	14.8	14.9
***Metabolisable energy (Kcal/kg)**	3307.3	3085.3	3030.6	3083.9	3077.6

*[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)*

In an earlier study, Singh *et al.* (1997) reported paper mulberry to be very rich in minerals.Similarly crude fat content increased linearly from 5 % inclusion level in T1 to the 20 % inclusion level in T4, but those of T1 and T2 were lower than that of the leaf meal-free control diet. The increases may be attributable to the high crude fat content of paper mulberry leaf meal which has been earlier buttressed by Obour *et al.* (2017).

Productive Performance of Rabbits Fed the Experimental Diets: The productive performance of rabbits fed the various diets indicated that the initial body weights of the rabbits were similar ($p>0.05$) (Table 4). The final weight, total weight gain, average daily gain, daily feed intake and feed conversion ratio were not affected by dietary treatments. The similarity in the afore-mentioned performance parameters between the control group and those fed the PMLM-based diets was an indication of the suitability of PMLM as an alternative feed resource for grower rabbits. The observed absence of differences in feed intake and average daily gain was consistent with the report of Oloruntola *et al.* (2018) when they fed *Gliricidia* leaf meal and multi-enzyme but in contrast with the findings of Jiwuba and Ogbuewu (2019) who reported differences when *M. oleifera* leaf meal was used to replace soya bean meal.

Furthermore, the present ADG values of 10.90 – 11.90 g/d were higher than the 8.93 – 10.57 g/d obtained by Osman *et al.* (2020) but lower than the 16.71 – 21.90 g/d reported by Jiwuba and Ogbuewu (2019) and the 31.13 – 34.03 g/d reported by Oloruntola *et al.* (2018).

Feed conversion ratio (FCR) was not influenced ($p>0.05$) by dietary treatments. This finding was similar to the observation made by Amata and Bratte (2008) who reported no differences in feed conversion ratio when soya bean meal was partially replaced with *Gliricidia*

Table 4: Productive performance of grower rabbits fed the experimental diets

Parameter	Dietary treatments				
	T0 (0 % PMLM)	T1 (5 % PMLM)	T2 (10 % PMLM)	T3 (15 % PMLM)	T4 (20 % PMLM)
Initial weight (g)	1126.0 ± 104.3^{a}	1134.0 ± 88.2^{b}	1130.0 ± 109.5^{ab}	1126.0 ± 85.3^{a}	1128.0 ± 122.1^{a}
Final weight (g)	1891.2 ± 184.9^{a}	1911.6 ± 96.1^{ab}	1958.6 ± 103.7^{ab}	1983.2 ± 264.0^{b}	1962.2 ± 93.0^{ab}
Total weight gain (g)	765.2 ± 116.0^{a}	777.6 ± 42.1^{a}	828.6 ± 39.4^{ab}	857.2 ± 214.7^{b}	834.2 ± 54.5^{ab}
Average daily gain (g)	10.9 ± 1.66^{a}	11.1 ± 0.60^{ab}	11.9 ± 0.56^{ab}	12.2 ± 3.07^{b}	11.9 ± 0.78^{ab}
Daily feed intake (g)	67.5 ± 2.02^{b}	67.1 ± 2.08^{b}	65.1 ± 1.81^{ab}	67.2 ± 1.80^{b}	63.5 ± 2.23^{a}
FCR	6.3 ± 0.78^{b}	6.1 ± 0.78^{b}	5.7 ± 0.24^{ab}	5.5 ± 1.32^{a}	5.3 ± 0.40^{a}
Feed cost/kg (Gh¢)	1.84^{b}	1.80^{ab}	1.77^{ab}	1.74^{a}	1.71^{a}
Feed cost/kg gain (Gh¢)	11.5 ± 1.44^{c}	10.9 ± 0.57^{b}	10.2 ± 0.42^{b}	9.6 ± 2.34^{ab}	9.1 ± 0.69^{a}

[a,b,c], Mean values with different superscripts on the same row differ significantly (p<0.05), FCR: Feed conversion ratio

leaf meal. FCR values obtained in this study (5.30 – 6.30) were higher than the 2.39 – 2.53 reported by Oloruntola *et al.* (2018) and 4.00 – 4.74 reported by Jiwuba and Ogbuewu (2019).

The inclusion of PMLM in the diet did not increase the unit cost of the feed. In fact, both feed cost/kg and feed cost/kg weight gain declined progressively with increase in inclusion level of PMLM. The generally lower feed cost/kg weight gain was due to the low cost of the PMLM which has proven the financial benefit of inclusion of the leaf meal. Adeniji *et al.* (2011) observed a similar trend of reduction in cost of feed when *M. oleifera* leaf meal was fed. The significant reduction in feed cost/kg weight gain achieved with the inclusion of the leaf meal was in agreement with the report of Ogunsipe *et al.* (2014) who highlighted the need to lower the cost of feed in order to produce meat and animal products that are affordable.

Effects of Feeding PMLM on Nutrients Digestibility: The comparison of the digestibility coefficients of PMLM-based diets with those of the PMLM-free (control) diet revealed that treatment differences did not affect ($p>0.05$) digestibility coefficients for dry matter, crude protein, crude fibre, neutral detergent fibre and acid detergent fibre (Table 5).

The present dry matter digestibility values (61.70 – 63.50 %) were lower than the 67.55 – 74.94, 75.67 – 82.33 and 78.26 – 83.51 % reported by Eustace and Oluwakemi (2003), Bamikole *et al.* (2005) and Ajayi *et al.* (2007) respectively. The present values were however within the range of 59.89 – 66.33 % reported by Osman *et al.* (2020) and higher than the 52.3 – 57.07 % obtained by Dougnon *et al.* (2012).

Crude protein digestibility was similar across the treatments which was indicative of similar efficiency in crude protein utilization. The present digestibility values of 66.50 - 69.00 % were within the ranges of 65.1 – 87.8 % and 59 – 74 % reported by Nuhu (2010) and Iyeghe-Erakpotobor *et al.* (2005) respectively but lower than the 76.33 – 84.00 % recorded by Bamikole *et al.* (2005)

Compared to the crude fibre digestibility values of 79.67 – 88.67 % reported by Bamikole *et al.* (2005), the digestibility coefficients for crude fibre in the current study were low. This low utilization of the fibrous fraction of the feed could be due to the rapid passage of the feed through the gastrointestinal tract as reported by Gidenne (2000). The present values were however comparable and within the range of 63.85 – 70.23 % reported by Osman *et al.* (2020) but higher than the 33.37 – 48.53 % and the 43.0 – 55.0 % reported by Iyayi and Odueso (2003) and Iyeghe-Erakpotobor *et al.* (2005) respectively.

Differences ($p<0.05$) in digestibility coefficients for crude fat and ash were present and attributable to treatment effects.

Table 5: Apparent nutrients digestibility of grower rabbits fed paper mulberry leaf meal based diets

Parameter	Dietary treatments				
	T0 (0 % PMLM)	T1 (5 % PMLM)	T2 (10 % PMLM)	T3 (15 % PMLM)	T4 (20 % PMLM)
Dry matter	61.70 ± 1.23	61.70 ± 1.42	62.60 ± 1.50	63.90 ± 0.42	63.50 ± 0.42
Crude protein	66.50 ± 0.87	66.00 ± 4.00	66.70 ± 3.51	69.00 ± 2.00	67.70 ± 1.15
Crude fibre	62.00 ± 4.32	68.20 ± 4.95	61.50 ± 4.05	61.50 ± 1.86	61.20 ± 2.18
Crude fat	71.60 ± 1.49[b]	74.30 ± 1.87[b]	62.00 ± 4.98[a]	69.10 ± 1.45[ab]	69.10 ± 2.91[ab]
Ash	30.80 ± 1.33[a]	36.80 ± 4.89[ab]	41.60 ± 1.63[bc]	44.00 ± 0.97[c]	44.40 ± 3.64[c]
NDF	41.70 ± 0.63	49.30 ± 3.16	50.20 ± 4.32	47.50 ± 6.99	47.20 ± 6.21
ADF	32.00 ± 2.65	39.70 ± 2.52	39.70 ± 4.73	40.00 ± 5.57	40.00 ± 4.58

[abc] Means along the same row with different superscript are significantly different ($p<0.05$) PMLM: Paper mulberry leaf meal, NDF: Neutral detergent fibre, ADF: Acid detergent fibre

Crude fat digestibility was lowest for T2 but comparable to those of T3 and T4. Values in the current study were all lower than the 83.07 – 90.66 % reported by Eustace and Oluwakemi (2003) and the 80.01 – 81.90 % by Oso *et al.* (2006) but were within the range of 55.65 – 86.0 % reported by Bamikole *et al.* (2005).

The PMLM-based diets generally had better ash digestibility than the control. Ash digestibility increased linearly as dietary inclusion of PMLM increased from 5 to 20 %. This may be attributable to the high content of ash in PMLM. All values in the current study were however lower than the 52.0 – 62.67 and 75.11 – 86.43 % reported by Bamikole *et al.* (2005) and Ajayi *et al.* (2007) respectively.

Digestibility coefficients for neutral detergent fibre and acid detergent fibre were not influenced ($p>0.05$) by the dietary treatments even though the PMLM-based diets recorded slightly higher values than the control. This trend may be due to the presence of the anti-nutritive factor (lignin) in paper mulberry (Obour *et al*., 2017; Sheng *et al*., 2021) that may have prevented the corresponding increase in acid detergent fibre and neutral detergent fibre digestibility. The findings of this study was in contrast with the report of Safwat *et al.* (2015) who observed a better digestibility coefficient for the control diet relative to leaf meal-based diets.

Carcass Characteristics of Grower Rabbits Fed the Experimental Diets: Carcass and organ characteristics of grower rabbits fed the experimental diets revealed that except for dressing percentage and weights of empty and full caecum which were affected ($p<0.05$) by treatment effects, all other carcass parameters measured were similar ($p>0.05$) (Table 6).

Dressing percentage was significantly ($p<0.05$) affected by the treatments imposed. The values were higher in the leaf meal-based diets than the control. Among the leaf meal-based diets, T2, T3 and T4 with 10, 15 and 20 % respectively did better than T1 with only 5 % inclusion level. This observation was in contrast with the finding of Omole *et al.* (2007) who observed that dressing percentage of rabbits fed *Stylosanthes guianensis* (Aubl.) Sw. (Fabales: Fabaceae) and *Lablab purpureus* (L.) Sweet (Fabales: Fabaceae) forage were similar. Amata (2010) also reported a similar trend of absence of differences in carcass characteristics when gliricidia leaf meal was fed to rabbits. Dressing percentage in the current study of 63.80 – 68.30 % were comparable to the 58.40 – 67.21 and 60.38 – 66.63 % reported by Akinmoladun *et al.* (2018) and Nuhu (2010) respectively but much higher than the 49.4 – 56.43% reported by Adeosun and Iyeghe-Erakpotobor (2012).

Weight of full caecum for the control and T1 were higher than those of the other leaf meal-based diets. Values obtained in the current study (112.00 – 132.00 g) were higher than those (65.67 – 80.00 and 65.48 – 88.15 g) reported by Nuhu (2010) and Osman *et al.* (2020) respectively. Weight of empty caecum declined when PMLM was increased to 15 and 20 % as shown in Table 6.

Table 6: Carcass characteristics of grower rabbits fed paper mulberry leaf meal based diets

Parameter	Dietary treatments				
	T0 (0 % PMLM)	T1 (5 % PMLM)	T2 (10 % PMLM)	T3 (15 % PMLM)	T4 (20 % PMLM)
Slaughter weight (g)	1978.30 ± 57.52	1978.70 ± 114.25	1974.67 ± 15.28	1978.30 ± 40.10	1977.30 ± 20.53
Hot carcass weight (g)	1935.80 ± 58.02	1930.50 ± 116.26	1932.00 ± 17.00	1931.30 ± 37.11	1934.30 ± 21.50
Blood weight (g)	42.50 ± 0.50	48.20 ± 2.02	42.70 ± 3.51	47.00 ± 3.00	43.00 ± 1.00
Dressed weight (g)	1263.00 ± 48.00	1319.70 ± 84.51	1329.10 ± 5.24	1351.50 ± 24.28	1346.20 ± 11.14
Dressing percentage	63.80 ± 0.57[a]	66.70 ± 0.44[b]	67.30 ± 0.70[b]	68.30 ± 0.54[c]	68.10 ± 0.20[c]
Full GIT weight (g)	329.50 ± 10.04	314.50 ± 13.50	322.00 ± 17.00	288.70 ± 59.07	288.70 ± 59.07
Empty GIT weight (g)	134.70 ± 32.13	114.30 ± 3.70	131.00 ± 27.00	139.80 ± 14.68	139.80 ± 14.68
Liver weight (g)	51.00 ± 1.00	50.80 ± 1.04	51.20 ± 2.75	46.70 ± 4.04	47.00 ± 4.36
Kidney weight (g)	9.50 ± 0.50	9.60 ± 0.64	9.20 ± 0.85	9.40 ± 1.22	9.20 ± 0.20
Heart weight (g)	3.50 ± 0.50	3.00 ± 0.05	3.50 ± 0.50	3.90 ± 0.10	3.90 ± 0.10
Lung weight (g)	10.90 ± 0.10	11.60 ± 1.35	12.20 ± 0.76	10.80 ± 0.76	11.50 ± 0.50
Caecum + content (g)	132.00 ± 9.85[c]	125.80 ± 5.20[b]	112.00 ± 4.50[a]	112.00 ± 3.00[a]	112.00 ± 3.00[a]
Weight of empty caecum (g)	41.50 ± 1.50[ab]	43.00 ± 1.00[b]	41.50 ± 0.50[ab]	39.00 ± 1.00[a]	39.00 ± 1.00[a]

[abc] *Means along the same row with different superscript are significantly different (p<0.05)*

Values across all treatments (39.00 – 43.00 g) were also higher than 17.33 – 24.67 and 21.0 – 27.89 g reported by Nuhu (2010) and Osman *et al.* (2020) respectively. The weight of internal organs like the liver and kidney are normally used in feeding trials to determine whether particular feed ingredients have had toxic effects on animals (Ahamefule *et al.,* 2006). There is usually an increase in the metabolic rate of these organs which would lead to abnormalities in their weights in an attempt to reduce or detoxify anti-nutritive factors or toxins in feed ingredients (Fails and Magee, 2018). So the similarity of weights of internal organs across the various treatments in the current study suggested the inclusion of PMLM did not have any deleterious effect on the internal organs. The present values recorded for the heart (3.0 – 3.9 g) and kidneys (9.2 – 9.6g) were comparable to the 2.41 – 3.5 g and 10.82 – 12.76 g reported by Adeosun and Iyeghe-Erakpotobor (2012) respectively. The values also compared well with those reported by Jiwuba and Ogbuewu (2019) which were 2.98 – 3.54 g for heart and 7.14 – 11.66 g for kidney. However values recorded for liver (46.7 – 51.2 g) and lungs (10.8 – 12.2 g) were higher than those (28.67 – 30.87g and 8.12 – 9.18g) recorded by Adeosun and Iyeghe-Erakpotobor (2012).

Conclusions: The following conclusions are drawn from the results of the current study: (i) PMLM could be included up to 20 % as a partial replacement for soya bean meal in the diet of grower rabbits without negatively affecting feed intake, average daily gain and feed conversion ratio, (ii) PMLM could be used to reduce feed cost/kg and feed cost per kg weight gain in the diet of grower rabbits, (iii) PMLM could be used up to 20 % in the diet of grower rabbits without lowering nutrients digestibility. Inclusion levels of 10 to 20 % PMLM in the diet improved ash digestibility, (iv) the inclusion of PMLM up to 20 % of the diet improved the dressing percentage of the carcass and (v) Finally, PMLM could be used up to 20 % of the diet of grower rabbits without any deleterious effects on the weights and metabolism of internal organs.

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