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Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass

Abstract

Background and Aim: The availability of grass as a source of fibrous feed is often scarce for ruminants in Indonesia during the dry season, and agricultural byproducts have been widely used as substitutes for grass. This study was aimed to determine the effect of agricultural byproducts to substitute Napier grass on the productivity and carcass characteristics in lambs.

Materials and Methods: Twenty-four male lambs aged about 3 months with an initial body weight of 13.26 $\pm$ 1.29 kg (CV = 9.73%) were allocated into a completely randomized design with 4 treatments and 6 replications. The treatments applied were 4 kinds of Napier substitution grass with agricultural wastes in the diets, namely NG = 100% Napier grass; CC = 50% Napier grass and 50% corn cobs; BG = 50% Napier grass and 50% bagasse, and PS = 50% Napier grass and 50% peanut shells. The diets were pelleted and consisted of 40% fibrous feed and 60% concentrate feed. They were formulated to contain 10.36-11.65% crude protein (CP) and 55.47-57.31% total digestible nutrients (TDN). Parameters observed included dry matter intake (DMI), dry matter digestibility (DMD), body weight gain (BWG), feed conversion ratio (FCR), feed cost per gain (FC/G), and carcass characteristics. Data obtained were analyzed by analysis of variance, and Duncan's Multiple Range test was applied if there were differences among the treatments.

Results: The results showed that the lamb fed diet PS had the highest ($p<0.05$) DMI (781g/d) among the treatments, which were not significantly different ($p>0.05$) from each other (averaged 721 g/d). Diet PS was the highest and diet BG was the lowest in digestibility ($p<0.05$), while diets NG and CC were in between. Bodyweight gain of the lamb fed diet PS (92.5 g/d) was the highest ($p<0.05$), followed by diet NG and diet CC

(76.5 and 68.2 g/d, respectively), and diet BG was in the lowest (54.4 g/d). The FCR of the lamb fed diet PS (9.13) was the lowest (p<0.05) and that fed diet BG was the lowest (13.53), while those fed diet NG and diet CC were in between (9.73 and 11.22, respectively). The FC/G of diet PS (IDR 23,541/ kg) was the lowest compared to other diets. There were no significant differences (p>0.05) among the diets in carcass and meat characteristics. The averages of slaughter weight, carcass weight, and carcass percentage were 20.03 kg, 8.02 kg, and 40.0%, respectively. The average meat bone ratio was 3.67.

Conclusion: It was concluded that agricultural wastes could be used to Napier grass in the diet of lambs without a negative effect on the production.

Keywords: agricultural waste, carcass, lamb, meat, productivity.

Introduction

In some countries such as Indonesia, agricultural byproducts have been widely used for ruminants during the dry season when the grass is limited. The use of agricultural waste as a source of fiber for ruminants can reduce the feed prices, keep the environment friendly, and the feed materials are sustainably available. Some of the agricultural waste for ruminants are corn cobs [1,2,3], bagasse [4,5,6,7], and peanut shells [8]. Wachirapakorn et al. [1] used ground corn cobs as a fiber source in cows ration, while [2] used for goat ration, and [3] applied for lamb diet. Babiker et al. [5] used bagasse for beef cattle, Silva et al. [4]; Filho et al. [6] and Galvani et al. [7] used it for lamb.

Agricultural byproducts are usually categorized as low-quality roughages, because of their high crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents. Corn cobs contain 10.2% of crude fiber, 38.0-79.9% NDF, and 16-40% ADF [2,3]. Bagasse contains 84.6% of NDF and 53.1% of ADF [7]. Peanut shells contain 43.9-80.5% of crude fiber, 27.6-87% of NDF, 13.1-76.2% of ADF and 5.8-45.2% of lignin [9]. For the aforementioned reasons, these by-products have been processed into many forms such as ammoniated bagasse, bagasse treated with calcium oxide [6], ground maize cobs [1], maize cob silage [3], etc. Wachirapakom et al. [1] reported that ground corn cobs were better than rice straw, and they can be used as a single roughage source. The treatments of agricultural byproducts as a roughage source have positive effects on ruminants, including decrease methane emission in lambs [3] as well as improve nutrient intake and milk yield in lactating dairy crossbred cows [1].

Complete feed or total mixed ration (TMR) is the best way to blend concentrate and roughage from locally agricultural byproducts to make a cheap and balance ration [10]. Furthermore, blended feed material in TMR can improve the palatability of feed [11, 10, 12], and hence unconventional feeds can be added to reduce the price of the rations [10]. In TMR, forage and concentrate ratio can be formulated to meet the animals' need for health and production [12]. In addition, Lin [12] stated that the same amount of supply of protein and carbohydrates in TMR can maximize the fermentation activity of ruminal microbes and stabilize the rumen pH.

Pelleting is a further process of TMR that can increase feed intake and digestion [10]. Karimizadeh et al. [13] reported that dry matter intake (DMI) of lambs fed pelleted TMR was higher than those of lamb fed mash TMR (1.2 g/d vs 1.1 g/d). In addition, Islam et al. [14] also reported that pelleted TMR increased crude fiber digestibility compared to mash form of TMR. Likewise, Ishaq et al. [15] found that when lambs were fed pelleted diets there was an increase in DMI around 17% compared to loose hay diets (1.9 kg/d vs 1.6 kg/d) and the average daily gain (ADG) was also higher (0.24 kg/d vs 0.08 g/d). Based on the fact that there are abundantly available agricultural byproducts to substitute grass and also considering that pelleting may be the best way to utilize the waste materials, this study was set up to investigate the use of agricultural byproduct as a component of pelleted feed for lambs to increase their productivity and reduce feed cost.

Materials and Methods

The experiment was conducted at the Research Farm of Meat and Dairy Production Laboratory, Department of Animal Science, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia.

Ethical approval

Using Animal and Scientific Procedures in this study has been approved by the Animal Ethics Committee in the Faculty of Animal and Agricultural Science, Diponegoro University, Indonesia.

Animals, experimental design, and treatments

The study used 24 male lambs of 3 months of age and 13.26 $\pm$ 1.29 kg body weight (CV = 9.73%). They were allocated into a completely randomized design [16] with 4 treatments and 6 replications. The diets contained three different agricultural byproducts (i.e., corn cobs, bagasse, and peanut shells) to substitute Napier grass as fiber source feed. The concentrate consisted of rice bran, cassava waste product, soybean meal, molasses, and minerals. The diets consisted of 40% fibrous feedstuff and 60% concentrate and formulated to contain 10.36-11.65% crude protein (CP) and 55.47-57.31% total digestible nutrients (Table 1). The diets were offered to the animals in form of a pellet. The treatments implemented were substitution of Napier grass by agricultural wastes, namely: NG = 100% Napier grass with no agricultural waste; CC = 50% Napier grass and 50% corn cobs; BG = 50% Napier grass and 50% bagasse, and PS = 50% Napier grass and 50% peanut shells.

Observed variables, research activities, and procedures

The variables observed included the lamb productivity and carcass characteristics, i.e. dry matter intake (DMI), organic matter intake (OMI), dry matter digestibility (DMD), organic matter digestibility (OMD), body weight gain (BWG), feed conversion ratio (FCR) and feed cost per gain, carcass productivity and carcass composition (bones, meat, and fat) productivity, and meat bone ratio. The research activities consisted of 5 stages: preparation (3 weeks), adaptation period (3 weeks), preliminary period (1 week), treatment period (12 weeks), and slaughtering process. The lambs were allowed to access diets and water that were provided ad libitum. The lambs weighed once a week. During week 3 of the treatment period, feces were collected for 7 days to calculate feed digestibility [18]. The daily feces were collected, weighed, and sampled using the procedure of Darlis et al. [19]. After 12 weeks of the treatment period, the lambs fasted for 12 hours with free access to freshwater. Then, they were slaughtered and the carcasses were weighed, separated for bone, fat, and meat according to Pratiwi et al. [20], but in this study, kidneys were included in the carcasses.

Statistical analysis

The data obtained were analyzed using analysis of variance, except that the feed cost per gain, which was analyzed descriptively. Duncan's Multiple Range test was applied if there were differences among the treatments [16].

Results

Lamb's productivity

The effect of Napier grass substitution by agricultural byproducts on lambs' productivity is presented in Table 2. The DMI and OMI of the lamb fed diet PS was significantly higher ($p<0.05$) than the others, although DMI in the percentage of body weight was not significantly different ($p>0.05$) among the treatments. The crude protein intake (CPI) of lambs fed diet PS and NG was higher ($p<0.05$) than those of CC and BG lambs. However, the CPI of the lambs fed diet PS and diet NG was not significantly different ($p>0.05$). The crude fiber intake (CFI) of the lamb fed diet NG was the lowest. The TDN intake of the lamb fed diet NG and diet BG were lower than those fed diet PS.

However, the TDN intake of lambs fed diet CC was not significantly different ($p>0.05$) from those fed diets NG, BG, and PS.

The DMD and OMD of diet PS were higher ($p<0.05$) than those of diet CC and diet BG, but they were not significantly different ($p>0.05$) from those of diet NG. Meanwhile, there was no significant difference ($p>0.05$) among diet NG, CC, and BG in DMD and OMD. While diet BG was the lowest among diets ($p<0.05$), diet CC and diet BG, but not significantly different ($p>0.05$) from that of diet NG and PS. The DMD and OMD of the NG group were the same as ($p>0.05$) those of CC, BG, and PS groups. Digested DMI and OMI of the PS group was the highest ($p<0.05$).

Bodyweight gain of the lamb fed diet PS was higher ($p<0.05$) than that fed diet CC and BG, but not significantly different ($p>0.05$) from that fed diet NG. The lamb fed diet NG had higher ($p<0.05$) BWG than that fed diet BG. However, there was no significant difference ($p>0.05$) in BWG between the lambs fed diet NG and diet CC, and between the lambs fed diet CC and diet BG (Table 2). Consequently, these results followed by FCR of the lamb diet PS being the lowest and that of BG being the highest ($p<0.05$).

The results of BWG and FCR, in turn, influenced feed cost per gain (FC/G). The lamb fed diet PS had the lowest FC/G, followed by those fed diet NG, CC, and BG.

Lamb carcass' characteristics

Characteristics of lamb carcass as affected by grass substitution with agricultural wastes are presented in Table 3. All of the lamb carcass characteristics were not significantly different ($p>0.05$) among the treatments. The average slaughter weight of 20.03 kg produced 8.02 kg carcass weight and 4.50 kg meat. The average carcass bone weight was The meat-bone ratio was 3.67 on average.

Discussion

Feed Intake, digestibility, body weight gain, feed conversion ratio, and economic implications

The feed intake and digestibility influenced the productivity of lambs. The lamb fed diet PS had the highest DMI, OMI, and TDN intake. These could be attributed to the high DMD and OMD of diet PS. The high DMI and DMD of diet PS led to high DDMI, which in turn caused the lamb fed diet PS to have the highest BWG and lowest FCR, and cheapest feed cost per gain. The lamb fed diet containing bagasse had the lowest BWG, while BWG of the lamb fed diet NG was similar to those fed diet CC and diet PS. This result was in agreement with the finding of Santos et al. [21] that BWG was affected by DMI.

The high content of NDF and ADF (Table 1) in the diet containing agricultural byproducts did not significantly decrease the lamb productivity. Usually, the higher content of NDF and ADF caused lower feed intake [21]. It was speculated peanut shells and corn cobs were palatable to the lamb so that the inclusion of these feedstuffs did not reduce DMI. Another possibility was that all of the feed ingredients were ground, then offered to the animal in pellet form; as Khan et al. [22] stated that grinding and pelleting feeds break down the cell wall, reduce particle size, increase feed density, increase rumen passage rate, and increase DMI. The inclusion of concentrate into the diet improved nutrient digestibility of low-quality crop residues and increase the animal’s growth rate and meat production [23,24], and reduce feed cost per gain compared to conventional feeding system [24]. Karimizadeh et al. [13] reported that the digestibility of pelleted complete feed was higher than that of mash complete feed.

Carcass characteristics

The substitution of Napier grass by agricultural wastes did not affect slaughter weight, carcass production, meat production, meat-bone ration, and subcutaneous fat thickness in lambs. These were attributed to the fact that the slaughter weights of the lambs of different diets were similar.

This indicated that corn cobs, bagasse, and peanut shells could be used to substitute Napier grass without a negative effect on the production. Similar slaughter weights produced similar carcass weights and dressing percentages, as Sabbioni et al. [25] noted that carcass weight was affected by the slaughter weight. The carcass weights obtained in this study were similar to the report of Setyaningrum et al. [26] that Indonesia thin-tailed sheep weighing 17.5-18.8 kg produced 7.7-8.5 kg carcass. Other studies reported that the higher carcass weights of lambs varied from 15.3 kg to 26.1 kg coming from the slaughter weight of 34.3 kg to 54.1 kg [21,27,28,29,30]. Forwood et al. [30] reported that the heavier live weight produced the higher carcass weight and dressing percentage.

Dressing percentages in this study (40.03%) were similar to those reported by Setyaningrum et al. [26] in thin-tailed sheep. Previous studies reported that dressing percentages of lambs in different breeds varied from 39% to 51% [26,25,21,29,30]. A study by Valizadeh et al. [31] showed that the heavier the bodyweight of the lamb the higher its carcass percentage.

Generally, consumers prefer meat with less fat as noted by Ripoll and Panea [32]. Carcass fat percentage in this study (17.61%) was similar to the report of Santos et al. [21], i.e. 15-18%, and Obeidat et al. [27], i.e. 16.6-20.1%. Lambs with lighter bodyweight than that of mutton contain less carcass fat trimming, as Sabbioni et al. [25] reported that fat trimmings in lamb were 13.04-17.31%, while those in mutton were 15.96-19.06%. Therefore, consumers believed that light lamb produces healthier meat [32]. In fact, Ekiz et al. [33] reported that the lean fat ratio of lambs with low, medium, and high weight groups (26 kg, 30 kg, 35 kg) was similar (3.93-4.25) having total fat content of 15.24-16.81%.

Meat bone ratio is important to discuss because it is related to the edible portion of the carcass. The meat bone ratio in this study (3.67) was higher than that in Awassi lambs fed layer litter up to 300 g/kg that was about 2.95-3.10 [27], Cornigliese lambs (2.22 to 3.09), and mutton (3.25 to 3.52) [25]. However, the lean meat bone ratio in this study (2.84) was lower than that reported by Ekiz et al. [33], being 3.13-3.48.

Conclusion

The conclusion of this research that agricultural wastes, namely corn cobs, bagasse, and peanut shell, can be used to substitute grass as a component of the diet for lambs. The use of peanut shells to substitute Napier grass increased lamb's productivity. The characteristics of carcass and carcass components were relatively the same. The use of agricultural wastes as substitutes for grass is depending on the availability and price of the stuff.

Authors' Contributions

All authors planned and conducted the study, carried out the study, participated in the drafting, and wrote the manuscript. All authors corrected the manuscript and approved the final manuscript.

Competing Interests

The authors declare that they have no competing interests.

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Table-1: Feed composition and nutritional content of the diets

Feed composition/ nutritional content	**NG**	**CC**	**BG**	**PS**
Feed composition (%)				
Napier grass	40.00	20.00	20.00	20.00
Corn cobs	0.00	20.00	0.00	0.00
Bagasse	0.00	0.00	20.00	0.00
Peanut shell	0.00	0.00	0.00	20.00
Rice bran	34.05	34.05	34.05	34.05
Cassava waste products	5.00	5.00	5.00	5.00
Soybean meal	12.95	12.95	12.95	12.95
Molasses	6.00	6.00	6.00	6.00
Mineral mix	2.00	2.00	2.00	2.00
Nutritional content (%)				
Dry matter	92.20	92.42	92.14	92.17
Ash	9.75	8.85	8.46	9.96
Organic matter (OM)	90.25	91.15	91.54	90.04
Crude protein (CP)	11.65	10.73	10.36	10.41
Ether extract (EE)	5.55	6.08	5.19	5.23
Crude fiber (CF)	31.43	33.16	34.81	37.46
Nitrogen free extract (NFE)	41.62	41.18	41.18	36.94
Total digestible nutrients (TDN)[5]	56.48	57.31	55.47	55.77
Neutral detergent fiber (NDF)	55.83	57.61	54.47	56.76
Acid detergent fiber (ADF)	27.38	29.63	31.20	32.15

Feed composition/ nutritional content	NG	CC	BG	PS
Price (IDR/kg)	2,352	2,352	2,331	2,377

NG:100% Napier grass, CC: 50% Napier grass and 50% corn cobs; BG: 50% Napier grass and 50% bagasse, PS: 50% Napier grass and 50% peanut shells, TDN was calculated from the formula TDN = digested CP + (2.25 x digested EE) + digested CF + digested NFE [17].

Table-2: Productivity of lambs fed diets with different sources of fiber

Variables	NG	CC	BG	PS
Dry matter intake (g/d)	724^{a}	722^{a}	718^{a}	781^{b}
Dry matter intake (% BW)	4.42	4.44	4.50	4.73
Organic matter intake (g/d)	654^{a}	658^{a}	657^{a}	704^{b}
Crude protein intake (g/d)	84^{b}	76^{a}	74^{a}	81^{b}
Crude fiber intake (g/d)	228^{a}	240^{b}	250^{b}	293^{c}
TDN intake (g/d)	410^{a}	416^{ab}	398^{a}	435^{b}
Dry matter digestibility (%)	51.9^{ab}	51.4^{a}	50.9^{a}	53.0^{b}
Digestible dry matter intake (g/d)	376^{b}	372^{ab}	365^{a}	414^{c}
Organic matter digestibility (%)	55.9^{ab}	53.9^{a}	52.8^{a}	62.1^{b}
Digestible organic matter intake (g/d)	367^{a}	355^{a}	347^{a}	437^{b}
Body weight gain (g/d)	77.5^{bc}	68.2^{ab}	54.4^{a}	92.5^{c}
Feed conversion ratio	9.7^{a}	11.2^{ab}	13.5^{b}	9.1^{a}
Feed cost per gain (IDR/kg)	24,835	28,554	34,234	23,541

^{a,b,c} within a row, means without a common uppercase superscript differ ($p<0.05$).

NG: 100% Napier grass, CC: 50% Napier grass and 50% corn cobs; BG: 50% Napier grass and 50% bagasse, PS: 50% Napier grass and 50% peanut shells

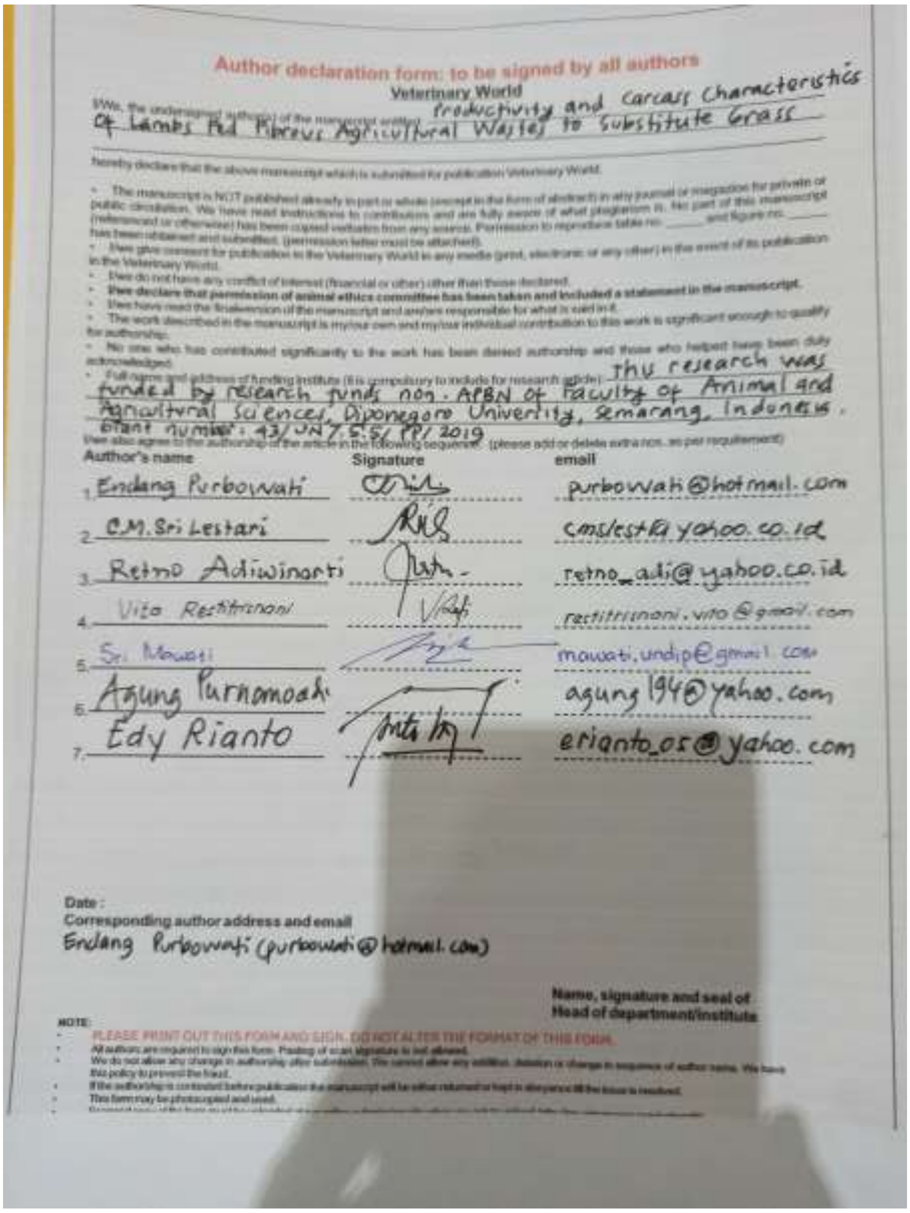
Table-3. Carcass production and characteristics of lambs fed diets with different sources of fiber

Variables	**NG**	**CC**	**BG**	**PS**	**Average**
Slaughter weight (kg)	20.22	19.82	19.26	20.84	20.03
Carcass weight (kg)	8.40	7.88	7.46	8.34	8.02
Dressing percentage (%)	41.5	39.9	38.7	40.1	40.0
Carcass components					
Meat weight (g)	4,79	4,53	4,21	4,45	4,50
Meat percentage (%)	57.1	57.6	56.2	53.3	56.0
Bone weight (g)	1,755	1,663	1,672	1,868	1,740
Bone percentage (%)	21.1	21.2	22.6	22.5	21.9
Fat weight (g)	1,466	1,321	1,253	1,654	1,423
Fat percentage (%)	17.3	16.5	16.9	19.8	17.6
Connective tissue weight (g)	385	367	321	368	360
Connective tissue percentage (%)	4.6	4.7	4.3	4.4	4.5
Distribution of carcass fat					
Subcutaneous fat weight (g)	836	695	723	979	808
Subcutaneous fat percentage (%)	57.1	50.5	57.5	59.2	56.1
Intermuscular fat weight (g)	487	485	395	463	457
Intermuscular fat percentage (%)	33.0	39.0	31.7	28.5	33.1
Kidney fat weight (g)	91	92	90	127	100
Kidney fat percentage (%)	6.5	6.7	7.1	7.4	6.9
Pelvic fat weight (g)	51	49	46	84	58
Pelvic fat percentage (%)	3.5	3.8	3.6	4.9	3.9

Variables	NG	CC	BG	PS	Average
Meat bone ratio					
Meat bone ratio	3.86	3.78	3.47	3.59	3.67
Lean meat bone ratio	3.00	2.98	2.72	2.65	2.84

NG: Napier grass, CC: 50% Napier grass and 50% corn cobs, BG: 50% Napier grass and 50% bagasse, PS: 50% Napier grass and 50% peanut shells.

AUTHORS DECLARATION



Author declaration form: to be signed by all authors

Veterinary World

I/We, the undersigned author(s) of the manuscript entitled Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass

hereby declare that the above manuscript which is submitted for publication Veterinary World.

- The manuscript is NOT published already in part or whole (except in the form of abstract) in any journal or magazine for private or public circulation. We have read instructions to contributors and are fully aware of what plagiarism is. No part of this manuscript (referenced or otherwise) has been copied verbatim from any source. Permission to reproduce table no. _____ and figure no. _____ has been obtained and submitted. (permission letter must be attached).
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- I/we do not have any conflict of interest (financial or other) other than those declared.
- **I/we declare that permission of animal ethics committee has been taken and included a statement in the manuscript.**
- I/we have read the final version of the manuscript and am/are responsible for what is said in it.
- The work described in the manuscript is my/our own and my/our individual contribution to this work is significant enough to qualify for authorship.
- No one who has contributed significantly to the work has been denied authorship and those who helped have been duly acknowledged.
- Full name and address of funding institute (it is compulsory to include for research article): This research was funded by research funds non-APBN of Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia. Grant number: 43/UN7.5.5/PP/2019

I/we also agree to the authorship of the article in the following sequence: (please add or delete extra nos. as per requirement)

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Name, signature and seal of Head of department/institute

NOTE:

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2. BUKTI PENGIRIMAN MAKALAH SUDAH DITERIMA (16/2/2021)

NE Noreply eJManager <noreply@ejmanager.com>
To: You
Tue 2/16/

Dear Endang Purbowati,

Your submission entitled **Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass** (Manuscript Nu
VETWORLD-2021-02-100) has been received by **Veterinary World**.

You could follow status of your manuscript by login to your author account at www.ejmanager.com.

Thank you for submitting your work to our journal.

Best regards,

Editor
Veterinary World
http://www.veterinaryworld.org

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3. PAPER ACCEPTED WITH MINOR REVISION (18/4/2021)

NE Noreply eJManager <noreply@ejmanager.com>
To: You
Sun 4/18/

Dear Endang Purbowati,

Your manuscript entitled \"Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Sul
Grass\" (Ms.Nr. VETWORLD-2021-02-100) was reviewed by reviewers of the Veterinary World. As initial decision, yo
manuscript was found interesting but some revisions have to be made before it can reach a publishable value. Plea
comments given at bottom.

You should send your revised manuscript via the online system of ScopeMed on https://ejmanager.com/my/vetwo

Sincerely yours,

Dr. Anjum Sherasiya
Editor-Veterinary World
Star, Gulshan Park,
NH-8A, Chandrapur Road, Wankaner 363621
Dist. Morbi (Gujarat) INDIA

ARTICLE REVISION LETTER FOR AUTHORS

Letter

Article Title: Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass

Letter Subject: Article Revision Letter for Authors - (VETWORLD-2021-02-100)

Letter:
Dear Endang Purbowati,

Your manuscript entitled "Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass" (Ms.Nr. VETWORLD-2021-02-100) was reviewed by reviewers of the Veterinary World. As initial decision, your manuscript was found interesting but some revisions have to be made before it can reach a publishable value. Please refer comments given at bottom.

You should send your revised manuscript via the online system of ScopeMed on https://ejmanager.com/my/vetworld/.

Sincerely yours,

Dr. Anjum Sherasiya
Editor-Veterinary World
Star, Gulshan Park,
NH-8A, Chandrapur Road, Wankaner 363621
Dist. Morbi (Gujarat) INDIA

COMMENTS for Authors:

EDITORIAL COMMENTS:

- Highlight all corrections/additions in red color font in revised manuscript.
- Please answer all the comments below point-by-point in an accompanying response letter to your revised submission and include your responses at appropriate paragraphs in the revised word file.
- Include all authors name, affiliation, ORCID and email address in revised Word file as per format and style of Veterinary World. Please check latest article from www.veterinaryworld.org for format of this section.
- All reference no. in the text must be in continuous no. as per style of Veterinary World and amend the reference section accordingly if you have not done it.
- Please divide the introduction into 3 paragraphs if you have already not done. Introduction must be divided into 3 paragraphs i.e., 1. introduction 2. significance of the study and 3. aim of the study.
- Include authors' contributions (refer just below the conclusion section in latest article from www.veterinaryworld.org for format of this section) if you have not added.
- Include Acknowledgements along with source of fund for this study if you have not included.
- All journal names in references must be as per standard journal abbreviation.
- If you will not revise strictly as per suggestion then there will be chance of rejection. So, revise carefully. If you have any query then please email to Editor-in-Chief.

=> Reviewer # 1

Manuscript Veterinary World 2-1613461220, entitled “Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass”

Recommendation: The above paper is not suitable for publication in its present form.

General comment

The article provides useful information about the productivity and carcass characteristics of lambs fed fibrous agricultural wastes as grass replacer. Although the experiment is appropriately designed and implemented, there are some points that should be corrected:

Specific comments

L11-12: “The treatment applied was substitution of Napier grass by agricultural wastes, namely…”
L21: “…the lambs fed with the PS diet had…”
L22-23: “…treatments; the other groups (NF, CC and BG) had similar DMI (averaged…”
L23-26: “PS diet had the highest and BG diet the lowest digestibility (p<0.05), while NG and CC diets had intermediate values. Bodyweight gain of the lambs fed the PS diet (92.5 g/d) was the highest (p<0.05), followed by NG and CC diets (76.5 and 68.2 g/d, respectively), and BG diet was associated with the lowest body weight gain (54.4 g/d).”
L26-29: “The FCR in the lambs fed with the PS diet (9.13) was the lowest (p<0.05), but similar to that of NG treatment, and FCR in BG treatment was the highest (13.53), while those fed with the CC had intermediate values (11.22). The FC/G of PS diet (IDR 23,541/ kg)…”
L33-34: “…could be used as an alternative to Napier grass at the level of 50% in the diet of lambs without a negative effect on the production performance and carcass traits.”
L39-40: What do you mean by “environmental friendly”?
L41-43: “…peanut shells [8]. Ground corn cobs have been used as a fiber source in cows [1], goats [2] and lambs [3]. Babiker et al. [5] used bagasse for beef cattle, while Silva…”
L45-46: “due to” instead of “because of”
L53: Better in what way?
L55: “…as well as an improvement in nutrient…”
L58: “balanced”
L61-62: “…need for obtaining the desired health status and production performance [12].”
L63: “offered as” instead of “in”
L67: Please delete “of lamb”
L74: “designed” instead of “set up”
L81: “Handling of” instead of “Using”
L85: “of age with an average body weight of 13.26 + 1.29 kg…”
L97: “The examined variables included…”
L100-101: “…carcass traits, carcass composition (bones, meat, and fat) and meat to bone ratio. The experimental period consisted…”
L109: “…but in the present study, kidneys…”
L112: “apart from” instead of “except that”
L118-119: “…of the lambs fed with the PS diets were significantly higher (p<0.05) than that of the other treatments, although…”
L121: “…of lambs fed the PS and NG diets was higher (p<0.05) than that of CC…”
L122: “…lambs fed with the PS and NG diets was not…”
L123-124: “…of the lambs fed with the NG diet was the lowest. The TDN intake of the lambs fed with the NG and BG diets were lower than those fed with the PS diet.”
L125: “…fed the CC diet was…”
L126: “…fed the NG, BG, and PS diets.”
L127-128: “…of PS diet…than those of CC and BG diets, but…of NG diet.”
L129: “…among NG, CC and BG diets in DMD and OMD values.”
L130-132: Please delete (repetition)
L133: “Digestible DMI and OMI of the PS group had the highest value (p<0.05).”
L134-141 and throughout the text: Please remove “diet” after treatment (PS, BG, NG or CC) as in the previous comments.
L143: “…affected due to grass substitution by agricultural…”
L144: “All the lamb…”
L147: A number is missing.
L152: “These findings could…”
L161: “It was speculated that peanut…”
L162: “…cobs were palatable and as a result the inclusion of these feedstuffs did not reduce DMI in lambs.”
L163: “…were ground and then offered…”
L164: “…form. Khan et al…”
L174-175: “These findings were attributed to the fact that the slaughter weights of the lambs fed with different…”
L176: “The above results” instead of “This”
L177-179: “…weights were associated with similar carcass weights and dressing percentages, as already pointed out by Sabbioni et al. [25]. The carcass…”
L180: “where” instead of “that”
L181-182: Please delete “the higher”
L182: “originating” instead of “coming”

L195: “believe”
L199: “…is an important parameter because…”
L205: “…research is that…”
L208: “of carcass traits were not affected by agricultural wastes. The use of…”
L209-210: “…and price of these unconventional feedstuffs.”

=> Reviewer # 2

Numerous corrections regarding English should be made to make it acceptable.

Editor's comment:
Get professional copyediting from ENAGO or Editage [keep all corrections in track changes (language as well as editorial and reviewers) and paste the certificate in the revised word file] or ask Veterinary World in answer letter for copyediting service (with extra payment) as your manuscript needs extensive copyediting.

Letter Sent Date: Apr 18, 2021

4. BUKTI RESUBMIT MAKALAH SETELAH PERBAIKAN (23/4/2021)

NE Noreply eJManager <noreply@ejmanager.com>
To: You
Fri 4/23/

Dear Endang Purbowati,

Your REVISED ARTICLE entitled **Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass** (Mns No:VETWORLD-2021-02-100) has been received by **Veterinary World**.

You could follow status of your manuscript by login to your author account at www.ejmanager.com.

Thank you for submitting your REVISED version of your article.

Best regards,

Editor
Veterinary World
http://www.veterinaryworld.org

ARTICLE REVISION LETTER FOR EDITOR

Article Title: Productivity and Carcass Characteristics of Lambs Fed Fibrous Agricultural Wastes to Substitute Grass

Letter Subject: Article Revision Letter for Editor - (VETWORLD-2021-02-100)

Letter:

Dear Dr. Anjum Sherasiya
Editor-Veterinary World

Thank you for your suggestions for improving my paper. Here is the list of revisions that we made.

Sincerely yours,

Endang Purbowati (EP), C.M. Sri Lestari (CMSL), Retno Adiwinarti (RA), Vita Restitrisnani (VR), Sri Mawati (SM), Agung Purnomoadi (AP) and Edy Rianto (ER)
Department of Animal Sciences,
Faculty of Animal and Agricultural Sciences,
Diponegoro University.
Campus Drh. Soejono Koesoemowardojo, Tembalang, Semarang, 50275, Indonesia

Table of list editorial comments

Editor Suggestions	Respond
Highlight all corrections/additions in red color font in revised manuscript.	Thank you for your suggestions. I have marked the corrections/additions in red color font.
Include all authors name, affiliation, ORCID and email address in revised Word file as per format and style of Veterinary World. Please check latest article from www.veterinaryworld.org for format of this section	Thank you for your suggestions. I have put that all in the revised paper 1. Endang Purbowati (ORCID: 0000-0003-1696-5133; email address: purbowati@hotmail.com), 2. C.M. Sri Lestari (ORCID: 0000-0002-0952-9686; email address: cmslest@yahoo.co.id), 3. Retno Adiwinarti (ORCID: 0000-0003-0638-4220; email address: retno_adi@yahoo.co.id), 4. Vita Restitrisnani (0000-0001-9114-5763; email address: restitrisnani.vita@gmail.com), 5. Sri Mawati (ORCID: 0000-0001-8346-1766; email address: mawati.undip@gmail.com), 6. Agung Purnomoadi (ORCID: 0000-0002-5902-0394; email address: agung194@yahoo.com) and 7. Edy Rianto (ORCID: 0000-0003-0736-6649; email address: erianto_05@yahoo.com)
All reference no. in the text must be in continuous no. as per style of Veterinary World and amend the reference section accordingly if you have not done it.	I have made the references based on the style of Veterinary World.

Editor Suggestions	Respond
Please divide the introduction into 3 paragraphs if you have already not done. Introduction must be divided into 3 paragraphs i.e., 1. introduction 2. significance of the study and 3. aim of the study.	Thank you for your suggesstions. I have made the introduction into 3 paragraphs, and the content of each paragraph is revised based on editor suggestions
Include authors' contributions (refer just below the conclusion section in latest article from www.veterinaryworld.org for format of this section) if you have not added.	Thank you, I have added the authors' contributions.
Include Acknowledgements along with source of fund for this study if you have not included.	Thank you for your suggestions. I have added.
All journal names in references must be as per standard journal abbreviation.	Thank you for your suggestions. I have checked the standard abbreviation and revised the manuscript.

Table of list reviewer comments

Line	Reviewer Suggestions	Rensponds
Reviewer #1		
Recommendation	The above paper is not suitable for publication in its present form	Thank you, I have made some revisions based on the suggestion from editors and reviewers.
General comment	The article provides useful information about the productivity and carcass characteristics of lambs fed fibrous agricultural wastes as grass replacer. Although the experiment is appropriately designed and implemented, there are some points that should be corrected:	Thank you, I have made some revisions based on the suggestion from editors and reviewers.
Specific comments		
L11-12	"The treatment applied was a substitution of Napier grass by agricultural wastes, namely…"	Thank you for your suggestions. I have revised it. (L22-23)
L21	"…the lambs fed with the PS diet had…"	Thank you for your suggestions. I have revised it. (L33)
L22-23	"…treatments; the other groups (NF, CC and BG) had similar DMI (averaged…"	Thank you for your suggestions. I have revised it. (L34-35)
L23-26	"PS diet had the highest and BG diet the	Thank you for your suggestions. I have

Line	Reviewer Suggestions	Rensponds
	lowest digestibility (p<0.05), while NG and CC diets had intermediate values. Bodyweight gain of the lambs fed the PS diet (92.5 g/d) was the highest (p<0.05), followed by NG and CC diets (76.5 and 68.2 g/d, respectively), and BG diet was associated with the lowest body weight gain (54.4 g/d)."	revised it. (L35-38)
L26-29	"The FCR in the lambs fed with the PS diet (9.13) was the lowest (p<0.05), but similar to that of NG treatment, and FCR in BG treatment was the highest (13.53), while those fed with the CC had intermediate values (11.22). The FC/G of PS diet (IDR 23,541/ kg)…"	Thank you for your suggestions. I have revised it. (L39-41)
L33-34	"…could be used as an alternative to Napier grass at the level of 50% in the diet of lambs without a negative effect on the production performance and carcass traits."	Thank you for your suggestions. I have revised it. (L46-48)
L39-40	What do you mean by "environmental friendly"?	Thank you for your suggestions. I have revised it. (L54)
L41-43	"…peanut shells [8]. Ground corn cobs have been used as a fiber source in cows [1], goats [2] and lambs [3]. Babiker et al. [5] used bagasse for beef cattle, while Silva…"	Thank you for your suggestions. I have revised it. (L56-57)
L45-46	"due to" instead of "because of"	Thank you for your suggestions. I have revised it. (L59)
L53	Better in what way?	Thank you for your suggestions. I have revised it. (L66-L68)
L55	"…as well as an improvement in nutrient…"	Thank you for your suggestions. I have revised it. (L70)
L58	"balanced"	Thank you for your suggestions. I have revised it. (L73)
L61-62	"…need for obtaining the desired health status and production performance [12]."	Thank you for your suggestions. I have revised it. (L76-77)
L63	"offered as" instead of "in"	Thank you for your suggestions. I have revised it. (L78)
L67	Please delete "of lamb"	Thank you for your suggestions. I have revised it. (L82)
L74	"designed" instead of "set up"	Thank you for your suggestions. I have revised it. (L89)
L81	"Handling of" instead of "Using"	Thank you for your suggestions. I have revised it. (L97)
L85	"of age with an average body weight of 13.26 + 1.29 kg…"	Thank you for your suggestions. I have revised it. (L101)
L97	"The examined variables included…"	Thank you for your suggestions. I have

Line	Reviewer Suggestions	Rensponds
		revised it. (L114)
L100-101	"…carcass traits, carcass composition (bones, meat, and fat) and meat to bone ratio. The experimental period consisted…"	Thank you for your suggestions. I have revised it. (117-118)
L109	"…but in the present study, kidneys…"	Thank you for your suggestions. I have revised it. (L127)
L112	"apart from" instead of "except that"	Thank you for your suggestions. I have revised it. (L129)
L118-119	"…of the lambs fed with the PS diets were significantly higher ($p<0.05$) than that of the other treatments, although…"	Thank you for your suggestions. I have revised it. (L135-136)
L121	"…of lambs fed the PS and NG diets was higher ($p<0.05$) than that of CC…"	Thank you for your suggestions. I have revised it. (L138-139)
L122	"…lambs fed with the PS and NG diets was not…"	Thank you for your suggestions. I have revised it. (L139)
L123-124	"…of the lambs fed with the NG diet was the lowest. The TDN intake of the lambs fed with the NG and BG diets were lower than those fed with the PS diet."	Thank you for your suggestions. I have revised it.(L140-142)
L125	"…fed the CC diet was…"	Thank you for your suggestions. I have revised it. (L142)
L126	"…fed the NG, BG, and PS diets."	Thank you for your suggestions. I have revised it. (L143)
L127-128	"…of PS diet…than those of CC and BG diets, but…of NG diet."	Thank you for your suggestions. I have revised it. (L144-145)
L129	"…among NG, CC and BG diets in DMD and OMD values."	Thank you for your suggestions. I have revised it. (L146-147)
L130-132	Please delete (repetition)	Thank you for your suggestions. I have revised it.
L133	"Digestible DMI and OMI of the PS group had the highest value ($p<0.05$)."	Thank you for your suggestions. I have revised it. (L147-148)
L134-141	and throughout the text: Please remove "diet" after treatment (PS, BG, NG or CC) as in the previous comments	Thank you for your suggestions. I have revised it. (L149-156)
L143	"…affected due to grass substitution by agricultural…"	Thank you for your suggestions. I have revised it. (L158)
L144	"All the lamb…"	Thank you for your suggestions. I have revised it. (L159)
L147	A number is missing.	Thank you for your suggestions. I have revised it. (L162)
L152	"These findings could…"	Thank you for your suggestions. I have revised it. (L167)
L161	"It was speculated that peanut…"	Thank you for your suggestions. I have revised it. (L176)
L162	"…cobs were palatable and as a result the inclusion of these feedstuffs did not	Thank you for your suggestions. I have revised it. (L177-178)

Line	Reviewer Suggestions	Rensponds
	reduce DMI in lambs.”	
L163	“…were ground and then offered…”	Thank you for your suggestions. I have revised it. (L179)
L164	“…form. Khan et al…”	Thank you for your suggestions. I have revised it. (179)
L174-175	“These findings were attributed to the fact that the slaughter weights of the lambs fed with different…”	Thank you for your suggestions. I have revised it. (189-190)
L176	“The above results” instead of “This”	Thank you for your suggestions. I have revised it. (L191)
L177-179	“…weights were associated with similar carcass weights and dressing percentages, as already pointed out by Sabbioni et al. [25]. The carcass…”	Thank you for your suggestions. I have revised it. (L193-194)
L180	“where” instead of “that”	Thank you for your suggestions. I have revised it. (L196)
L181-182	Please delete “the higher”	Thank you for your suggestions. I have revised it. (L197)
L182	“originating” instead of “coming”	Thank you for your suggestions. I have revised it. (198)
L195	“believe”	Thank you for your suggestions. I have revised it. (L211)
L199	“…is an important parameter because…”	Thank you for your suggestions. I have revised it. (L215)
L205	“…research is that…”	Thank you for your suggestions. I have revised it. (L221)
L208	“of carcass traits were not affected by agricultural wastes. The use of…”	Thank you for your suggestions. I have revised it. (L224)
L209-210	“…and price of these unconventional feedstuffs.”	Thank you for your suggestions. I have revised it. (L226)
Reviewer #2	Numerous corrections regarding English should be made to make it acceptable	Thank you for your suggestions. I have revised it.
Editor's comment	Get professional copyediting from ENAGO or Editage [keep all corrections in track changes (language as well as editorial and reviewers) and paste the certificate in the revised word file] or ask Veterinary World in answer letter for copyediting service (with extra payment) as your manuscript needs extensive copyediting.	Thank you for your suggestions. According to it, for the copy editing service we choose to be carried out by the veterinary world, and we are willing to bear the extra payment.

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Editor-Veterinary World
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Dist. Morbi (Gujarat) INDIA
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7. LETTER OF ACCEPTANCE (1/5/2021)

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I am attaching herewith the acceptance letter of your article.

Best Regards,

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By E-mail

Ref No. VW/Accept/152/2021 Date: 29-04-2021

To,
Endang Purbowati
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Diponegoro University,
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Tembalang, Semarang, 50275,
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Acceptance of article for publication in Veterinary World

Dear Dr.

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Productivity and carcass characteristics of lambs fed fibrous agricultural wastes to substitute grass - Endang Purbowati, C. M. Sri Lestari, Retno Adiwinarti, Vita Restitrisnani, Sri Mawati, Agung Purnomoadi and Edy Rianto

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RESEARCH ARTICLE

Productivity and carcass characteristics of lambs fed fibrous agricultural wastes to substitute grass

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Abstract

Background and Aim: Grass is often scarce for ruminants during the dry season in Indonesia, thus agricultural by-products are widely used as a substitutes for grass. This study aimed to determine the effect of replacing Napier grass (NG) with agricultural by-products on the productivity and carcass characteristics of lambs.

Materials and Methods: Twenty-four 3-month-old male lambs with initial body weights of 13.26±1.29 kg (coefficient of variation=9.73%) were allocated into a completely randomized design with four treatments and six replications. The treatments included: NG=100% NG; corn cob (CC)=50% NG and 50% CCs; bagasse (BG)=50% NG and 50% BG; and peanut shells (PSs)=50% NG and 50% PSs. All treatment diets were pelleted and consisted of 40% fibrous feed and 60% concentrate feed, and contained 10.36-11.65% crude protein and 55.47-57.31% total digestible nutrients. Parameters observed included dry matter intake (DMI), dry matter digestibility, body weight gain (BWG), feed conversion ratio (FCR), feed cost per gain (FC/G), and carcass characteristics.

Results: Lambs fed the PS diet had the highest ($p<0.05$) DMI (781 g/d). The other groups (NF, CC, and BG) had similar DMI (averaged 721 g/d). The digestibility was highest in the PS diet and the lowest in the BG diet ($p<0.05$). The PS-fed lambs had the highest BWG (92.5 g/d; $p<0.05$) followed by NG and CC (76.5 and 68.2 g/d, respectively). The BG diet had the lowest BWG (54.4 g/d). The FCR of the PS diet was 9.13, which was similar to NG. The FCR of the BG diet was the highest (13.53), and the CC diet had an intermediate value (11.22). The FC/G of the PS diet (IDR 23,541/kg) was the lowest compared to the other diets. There were no significant differences ($p>0.05$) in the carcass and meat characteristics of any diet. The averages of slaughter weight, carcass weight, and carcass percentage were 20.03 kg, 8.02 kg, and 40.0%, respectively. The average meat-bone ratio was 3.67.

Conclusion: It was concluded that agricultural wastes could be used as an alternative to NG at the level of 50% in the diet of lambs without a negative effect on production performance and carcass traits.

Keywords: agricultural waste, carcass, lamb, meat, productivity.

<H1>Introduction

Agricultural by-products are widely used for ruminant feed when grass is limited during the dry season in some countries. The use of agricultural waste as a source of fiber for ruminants can reduce feed prices and improve environmental sustainability using feed materials that are sustainably available. Examples of agricultural waste include corn cobs (CCs) [1-3], bagasse (BG) [4-7], and peanut shells (PSs) [8]. Ground CCs have been used as a fiber source in cows [1], goats [2], and lamb [3]. Babiker *et al*. [5] used BG for beef cattle, while Silva *et al*. [4], Filho *et al*. [6], and Galvani *et al*. [7] used it for lambs.

Agricultural by-products are usually categorized as low-quality roughages, due to their high crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents. CCs contain 10.2% crude fiber, 38.0-79.9% NDF, and 16-40% ADF [2,3]. BG contains 84.6% NDF and 53.1% ADF [7]. PSs contain 43.9%-80.5% crude fiber, 27.6-87% NDF, 13.1-76.2% ADF, and 5.8-45.2% lignin [9]. These by-products have been processed into many dietary forms, such as ammoniated BG, BG treated with calcium oxide [6], ground maize cobs [1], and maize cob silage [3]. Wachirapakom *et al*. [1] used ground CCs as a single roughage source and found that ground CCs result in better dry matter intake (DMI) and milk yields compared to rice straw when used as a source of fiber in dairy cow diets. Treated agricultural by-products have additional positive effects on ruminants when used as a roughage source, including decreased methane emission in lambs [3] and improved nutrient intake and milk yield in lactating dairy, crossbred cows [1]. Complete feed or total mixed ration (TMR) is the ideal method to blend concentrate and roughage from local agricultural by-products to make a cheap and balanced ration [10]. Blended feed material in TMR can improve feed palatability [10-12], which allows unconventional feeds to be added that further reduce the price of the ration [10]. The forage and concentrate ratio in TMR can be formulated to meet the animals' nutritional requirements for the desired health status and production performance [12]. For example, Lin [12] found that equal amounts of proteins and carbohydrates in TMR maximize the fermentation activity of ruminal microbes and stabilize rumen pH. The further processing of TMR into pellets increases feed intake and digestion [10]. Karimizadeh *et al*. [13] reported that the DMI of lambs fed pelleted TMR was higher than those fed mash TMR (1.2 g/d vs. 1.1 g/d, respectively). Islam *et al*. [14] also reported that pelleted TMR increased crude fiber digestibility compared to mash TMR. Ishaq *et al*. [15] found that lambs fed pelleted diets had an increased DMI of around 17% compared to those fed loose hay diets (1.9 kg/d vs. 1.6 kg/d, respectively), with a higher average daily gain (ADG; 0.24 kg/d vs. 0.08 g/d, respectively).

This study investigated the use of agricultural by-products as a component of pelleted lamb feed to increase productivity and reduce feed costs (FC), since agricultural by-products are abundantly available to substitute grass and may be best utilized as pellets.

<H1>**Materials and Methods**

<H2>**Ethical approval**

The animal handling and scientific procedures in this study were approved by the Animal Ethics Committee from the Faculty of Animal and Agricultural Science, Diponegoro University, Indonesia.

<H2>**Study period and location**

Commented [H1]: Please mention exact month and year in which study was conducted.

The experiment was conducted at the Research Farm of Meat and Dairy Production Laboratory, Department of Animal Science, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia.

<H2>**Animals, experimental design, and treatments**

The study used 24, 3-month-old male lambs with an average body weight of 13.26±1.29 kg (coefficient of variation=9.73%). The lambs were allocated into a completely randomized design [16] with four treatments and six replications. The diets contained three different agricultural by-products (i.e., CCs, BG, and PSs) as a fiber source to substitute Napier grass (NG). The concentrate consisted of rice bran, cassava waste product, soybean meal, molasses, and minerals. The diets consisted of 40% fibrous feedstuffs and 60% concentrate, and were formulated to contain 10.36-11.65% crude protein and 55.47-57.31% total digestible nutrients

(TDN) (Table-1) [17]. The diets were offered to the animals in pellet form. The treatments included NG=100% NG (with no agricultural wastes); CC=50% NG and 50% CCs; BG=50% NG and 50% BG; and PS=50% NG and 50% PSs.

<H2>Observed variables, research activities, and procedures

The examined variables included lamb productivity and carcass characteristics (i.e., DMI, organic matter intake (OMI), dry matter digestibility (DMD), organic matter digestibility (OMD), body weight gain (BWG), feed conversion ratio (FCR), FC per gain (FC/G), carcass traits, carcass composition (bones, meat, and fat), and meat-bone ratio). The experimental period consisted of five stages: Preparation (3 weeks), adaptation (3 weeks), the preliminary period (1 week), the treatment period (12 weeks), and slaughtering. The lambs were provided the diets and water *ad libitum* and were weighed once a week. Feces were collected for 7 days during week 3 of the treatment period to calculate feed digestibility [18]. The feces were collected daily, weighed, and sampled using the procedure of Darlis *et al*. [19]. After the 12-week treatment period, the lambs were fasted for 12 h with free access to fresh water, then were slaughtered. The carcasses were weighed and separated for bone, fat, and meat according to Pratiwi *et al*. [20]; however, in this study, the kidneys were included in the carcasses.

<H2>Statistical analysis

The data obtained were analyzed using analysis of variance, apart from the FC/G, which was analyzed descriptively. Duncan's multiple range test was applied when there were differences among the treatments [16].

<H1>Results

<H2>Lamb's productivity

The effect of NG substitution by agricultural by-products on lamb productivity is presented in Table-2. The DMI and OMI of the lambs fed the PS diet were significantly higher ($p<0.05$) than the other diets, although the DMI in the percentage of body weight was not significantly different ($p>0.05$) among the treatments. The crude protein intake (CPI) of lambs fed the PS and NG diets was higher ($p<0.05$) than that of the CC- and BG-fed lambs. The CPI of the lambs fed the PS and NG diets was not significantly different ($p>0.05$). The crude fiber intake (CFI) of the lambs fed the NG diet was the lowest. The TDN intake of the lambs fed the NG and BG diets was lower than that of those fed the PS diet. The TDN intake of the lambs fed the CC diet was not significantly different ($p>0.05$) from those fed the NG, BG, and PS diets.

The DMD and OMD of the PS diet were higher ($p<0.05$) than those of the CC and BG diets, but were not significantly different ($p>0.05$) from those of the NG diet. There was no significant difference ($p>0.05$) in DMD and OMD for the NG, CC, and BG diets. The digestible DMI and OMI in the PS group had the highest value ($p<0.05$).

The bodyweight gain of the lambs fed the PS diet was higher ($p<0.05$) than those fed the CC and BG diets, but was not significantly different ($p>0.05$) from those fed the NG diet. The lambs fed the NG diet had higher ($p<0.05$) BWG than those fed the BG diet; however, there was no significant difference ($p>0.05$) in BWG between the lambs fed the NG and CC diets, or between the lambs fed the CC and BG diets (Table-2). Consequently, the FCR was lowest in the PS-fed lambs and highest in the BG-fed lambs ($p<0.05$). The BWG and FCR results influenced the FC/G. The lambs fed the PS diet had the lowest FC/G, followed by those fed the NG, CC, and BG diets, respectively.

<H2>Lamb carcass characteristics

The effect of NG substitution by agricultural wastes on lamb carcass characteristics is presented in Table-3. No significant differences ($p>0.05$) were found between the different treatments for any of the measured lamb carcass characteristics. The average slaughter weight was 20.03 kg, which produced 8.02 kg carcass weight and 4.50 kg meat. The average carcass bone weight was 1.74 kg. The meat-bone ratio was 3.67 on average.

<H1>Discussion

<H2>Feed intake, digestibility, BWG, FCR, and economic implications

The feed intake and digestibility influenced lamb productivity. The PS-fed lambs had the highest DMI, OMI, and TDN intake values. These findings could be attributed to the high DMD and OMD of the PS diet. The high DMI and DMD of the PS diet led to high DDMI, which, in turn, caused the lambs fed the PS diet to have the highest BWG and lowest FCR, with the cheapest FC/G. The lambs fed the diet containing BG had the lowest BWG. The BWG of the lambs fed the NG diet was similar to those fed the CC and PS diets. These results agree with Santos *et al*. [21] who found that BWG was affected by DMI.

The high NDF and ADF contents (Table-1) in the agricultural by-product diets did not significantly decrease lamb productivity. Usually, the higher NDF and ADF contents cause lower feed intake [21]. We speculate that the PSs and CCs were more palatable in this study, since the inclusion of these feedstuffs did not reduce DMI in the lambs. Another explanation may be that the ingredients were all ground, then offered to the animal in pelleted form. Khan *et al*. [22] stated that grinding and pelleting feeds break down cell walls, reduce particle sizes, increase feed density, increase rumen passage rates, and increase DMI. The inclusion of concentrate in the diet improved the nutrient digestibility of the low-quality crop residues, increased growth rate and meat production [23,24], and reduced FC/G compared to conventional feeding systems [24]. Karimizadeh *et al*. [13] reported that the digestibility of pelleted complete feed was higher than that of mash complete feed.

<H2>Carcass characteristics

The substitution of NG by agricultural wastes did not affect slaughter weight, carcass production, meat production, meat-bone ratio, or subcutaneous fat thickness in lambs. These findings were attributed to the fact that the slaughter weights of the lambs fed with different diets were similar.

The above results indicate that CCs, BG, and PSs could be used to substitute NG without a negative effect on production. Similar slaughter weights were associated with similar carcass weights and dressing percentages, as already pointed out by Sabbioni *et al*. [25]. The carcass weight was affected by the slaughter weight. The carcass weights obtained in this study were similar to those reported by Setyaningrum *et al*. [26], where Indonesia thin-tailed sheep weighing 17.5-18.8 kg produced 7.7-8.5 kg carcasses. Other studies reported that lamb carcass weights varied from 15.3 kg to 26.1 kg when originating from a slaughter weight of

34.3 kg-54.1 kg [21,27-30]. Forwood *et al*. [30] reported that heavier live weights produced higher carcass weights and dressing percentages. Dressing percentages in this study (40.03%) were similar to those reported by Setyaningrum *et al*. [26] in thin-tailed sheep. The previous studies reported that the dressing percentages of different lamb breed varied from 39% to 51% [21,25,26,29,30]. Valizadeh *et al*. [31] showed that the heavier the bodyweight of the lamb the higher its carcass percentage.

In general, consumers prefer meat with less fat [32]. Carcass fat percentage in this study (17.61%) was similar to those reported by Santos *et al*. [21] (i.e., 15-18%) and Obeidat *et al*. [27] (i.e., 16.6-20.1%). Lambs with a lighter bodyweight than mutton contain less carcass fat trimming, as reported by Sabbioni *et al*. [25] who found that lamb fat trimmings were 13.04-17.31%, whereas those in mutton were 15.96-19.06%. Thus, consumers believe that the lighter lambs produce healthier meat [32]. In fact, Ekiz *et al*. [33] reported that the lean fat ratios of low, medium, and high weight groups (26 kg, 30 kg, and 35 kg) of lambs were similar (3.93-4.25) with a total fat content of 15.24%-16.81%.

Meat-bone ratio is an important parameter because it is related to the edible portion of the carcass. The meat-bone ratio in this study (3.67) was higher than that in Awassi lambs fed up to 300 g/kg layer litter (2.95-3.10) [27], Cornigliese lambs (2.22-3.09), and mutton (3.25-

3.52) [25]. The lean meat-bone ratio in this study (2.84) was lower than that reported by Ekiz *et al.* [33] (3.13-3.48).

<H1>Conclusion

The conclusion of this research is that agricultural wastes, namely, CCs, BG, and PS, can be used to substitute grass as a component of lamb diets. The use of PSs to substitute NG increased lamb productivity. Carcass trait characteristics were not affected by agricultural wastes. The use of agricultural wastes as substitutes for grass depends on the availability and price of these unconventional feedstuffs.

<H1>Authors' Contributions

EP and AP designed the study, interpreted the data, and drafted the manuscript. ER, RA, CMSL, and SM were involved in designing the study also contributed to the preparation and critical checking of this manuscript. RA and VR were contributed to statistical analysis and manuscript preparation. All authors read and approved the final manuscript.

<H1>Acknowledgments

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<H1>Competing Interests

The authors declare that they have no competing interests.

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Table-1: Feed composition and nutritional content of the diets.

Feed composition/nutritional content	NG	CC	BG	PS
Feed composition (%)				
Napier grass	40.00	20.00	20.00	20.00
Corn cobs	0.00	20.00	0.00	0.00
Bagasse	0.00	0.00	20.00	0.00
Peanut shell	0.00	0.00	0.00	20.00
Rice bran	34.05	34.05	34.05	34.05
Cassava waste products	5.00	5.00	5.00	5.00
Soybean meal	12.95	12.95	12.95	12.95
Molasses	6.00	6.00	6.00	6.00
Mineral mix	2.00	2.00	2.00	2.00
Nutritional content (%)				

Dry matter	92.20	92.42	92.14	92.17
Ash	9.75	8.85	8.46	9.96
OM	90.25	91.15	91.54	90.04
CP	11.65	10.73	10.36	10.41
EE	5.55	6.08	5.19	5.23
CF	31.43	33.16	34.81	37.46
NFE	41.62	41.18	41.18	36.94
TDN[5]	56.48	57.31	55.47	55.77
NDF	55.83	57.61	54.47	56.76
ADF	27.38	29.63	31.20	32.15
Price (IDR/kg)	2,352	2,352	2,331	2,377

NG=100% Napier grass, CC=50% Napier grass and 50% corn cobs; BG=50% Napier grass and 50% bagasse, PS=50% Napier grass and 50% peanut shells, TDN was calculated from the formula TDN=digested CP+(2.25×digested EE)+digested CF+digested NFE [17]. OM=Organic matter, CP=Crude protein, EE=Ether extract, CF=Crude fiber, NFE=Nitrogen-free extract, TDN=Total digestible nutrients,

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NDF=Neutral detergent fiber, ADF=Acid detergent fiber

Table-2: Productivity of lambs fed diets with different sources of fiber.

Variables	NG	CC	BG	PS
Dry matter intake (g/days)	724^{a}	722^{a}	718^{a}	781^{b}
Dry matter intake (% BW)	4.42	4.44	4.50	4.73
Organic matter intake (g/days)	654^{a}	658^{a}	657^{a}	704^{b}
Crude protein intake (g/days)	84^{b}	76^{a}	74^{a}	81^{b}
Crude fiber intake (g/days)	228^{a}	240^{b}	250^{b}	293^{c}
TDN intake (g/days)	410^{a}	416^{ab}	398^{a}	435^{b}
Dry matter digestibility (%)	51.9^{ab}	51.4^{a}	50.9^{a}	53.0^{b}
Digestible dry matter intake (g/days)	376^{b}	372^{ab}	365^{a}	414^{c}
Organic matter digestibility (%)	55.9^{ab}	53.9^{a}	52.8^{a}	62.1^{b}
Digestible organic matter intake (g/days)	367^{a}	355^{a}	347^{a}	437^{b}
Body weight gain (g/days)	77.5^{bc}	68.2^{ab}	54.4^{a}	92.5^{c}

Feed conversion ratio	9.7[a]	11.2[ab]	13.5[b]	9.1[a]
Feed cost per gain (IDR/kg)	24,835	28,554	34,234	23,541

[a,b,c]Within a row, means without a common uppercase superscript differ ($p<0.05$). NG=100% Napier grass, CC=50% Napier grass and 50% corn cobs; BG=50% Napier grass and 50% bagasse, PS=50% Napier grass and 50% peanut shells. BW=Body weight

Table-3: Carcass production and characteristics of lambs fed diets with different sources of fiber.

Variables	**NG**	**CC**	**BG**	**PS**	**Average**
Slaughter weight (kg)	20.22	19.82	19.26	20.84	20.03
Carcass weight (kg)	8.40	7.88	7.46	8.34	8.02
Dressing percentage (%)	41.5	39.9	38.7	40.1	40.0
Carcass components					
Meat weight (g)	4,79	4,53	4,21	4,45	4,50
Meat percentage (%)	57.1	57.6	56.2	53.3	56.0
Bone weight (g)	1.755	1.663	1.672	1.868	1.740
Bone percentage (%)	21.1	21.2	22.6	22.5	21.9
Fat weight (g)	1.466	1.321	1.253	1.654	1.423
Fat percentage (%)	17.3	16.5	16.9	19.8	17.6
Connective tissue weight	385	367	321	368	360

(g)					
Connective tissue percentage (%)	4.6	4.7	4.3	4.4	4.5
Distribution of carcass fat					
Subcutaneous fat weight (g)	836	695	723	979	808
Subcutaneous fat percentage (%)	57.1	50.5	57.5	59.2	56.1
Intermuscular fat weight (g)	487	485	395	463	457
Intermuscular fat percentage (%)	33.0	39.0	31.7	28.5	33.1
Kidney fat weight (g)	91	92	90	127	100
Kidney fat percentage (%)	6.5	6.7	7.1	7.4	6.9
Pelvic fat weight (g)	51	49	46	84	58
Pelvic fat percentage (%)	3.5	3.8	3.6	4.9	3.9

Meat-bone ratio					
Meat-bone ratio	3.86	3.78	3.47	3.59	3.67
Lean meat-bone ratio	3.00	2.98	2.72	2.65	2.84
NG=Napier grass, CC=50% Napier grass and 50% corn cobs, BG=50% Napier grass and 50% bagasse, PS=50% Napier grass and 50% peanut shells.					

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RESEARCH ARTICLE

Productivity and carcass characteristics of lambs fed fibrous agricultural wastes to substitute grass

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Abstract

Background and Aim: Grass is often scarce for ruminants during the dry season in Indonesia, thus agricultural by-products are widely used as a substitutes for grass. This study aimed to determine the effect of replacing Napier grass (NG) with agricultural by-products on the productivity and carcass characteristics of lambs.

Materials and Methods: Twenty-four 3-month-old male lambs with initial body weights of 13.26±1.29 kg (coefficient of variation=9.73%) were allocated into a completely randomized design with four treatments and six replications. The treatments included: NG=100% NG; corn cobs (CCs)=50% NG and 50% CCs; bagasse (BG)=50% NG and 50% BG; and peanut shells (PSs)=50% NG and 50% PSs. All treatment diets were pelleted and consisted of 40% fibrous feed and 60% concentrate feed, and contained 10.36-11.65% crude protein and 55.47-57.31% total digestible nutrients. Parameters observed included dry matter intake (DMI), dry matter digestibility, body weight gain (BWG), feed conversion ratio (FCR), feed cost per gain (FC/G), and carcass characteristics.

Results: : Lambs fed the PS diet had the highest (p<0.05) DMI (781 g/d). The other groups (NF, CC, and BG) had similar DMI (averaged 721 g/d). The digestibility was highest in the PS diet and the lowest in the BG diet (p<0.05). The PS-fed lambs had the highest BWG (92.5 g/d; p<0.05) followed by NG and CC (76.5 and 68.2 g/d, respectively). The BG diet had the lowest BWG (54.4 g/d). The FCR of the PS diet was 9.13, which was similar to NG. The FCR of the BG diet was the highest (13.53), and the CC diet had an intermediate value (11.22). The FC/G of the PS diet (IDR 23,541/kg) was the lowest compared to the other diets. There were no significant differences (p>0.05) in the carcass and meat characteristics of any diet. The averages of slaughter weight, carcass weight, and carcass percentage were 20.03 kg, 8.02 kg, and 40.0%, respectively. The average meat-bone ratio was 3.67. Lambs fed the PSs diet had the highest ($p < 0.05$) DMI (781 g/d), digestibility, and body weight gain (92.5 g/d; $p < 0.05$). The FCR of the PSs diet (9.13) was similar to NG. The FC/G of the PSs diet (IDR 23,541/kg) was the lowest of all diets. The BG diet had the lowest ($p < 0.05$) digestibility, body weight gain (54.4 g/d), and the highest (13.53) FCR. No significant differences ($p > 0.05$) were found in the carcass or meat characteristics of any diets. The averages of slaughter weight, carcass weight, and carcass percentage were 20.03 kg, 8.02 kg, and 40.0%, respectively. The average meat bone ratio was 3.67.

Conclusion: It was concluded that agricultural wastes could be used as an alternative to NG at the level of 50% in the diet of lambs without a negative effect on production performance and carcass traits.

Keywords: agricultural waste, carcass, lamb, meat, productivity. bagasse, corn cobs, digestibility, feed efficiency, meat-bone ratio, peanut shells.

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<H1>Introduction

Agricultural by-products are widely used for ruminant feed when grass is limited during the dry season in some countries. The use of agricultural waste as a source of fiber for ruminants can reduce feed prices and improve environmental sustainability using feed materials that are sustainably available. Examples of agricultural waste include corn cobs (CCs) [1-3], bagasse (BG) [4-7], and peanut shells (PSs) [8]. Ground CCs have been used as a fiber source in cows [1], goats [2], and lamb [3]. Babiker *et al*. [5] used BG for beef cattle, while Silva *et al*. [4], Filho *et al*. [6], and Galvani *et al*. [7] used it for lambs. Eshag *et al*. [8] used ground PSs for lambs to reduce feed cost.

Agricultural by-products are usually categorized as low-quality roughages, due to their high crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents. CCs contain 10.2% crude fiber, 38.0-79.9% NDF, and 16-40% ADF [2,3]. BG contains 84.6% NDF and 53.1% ADF [7]. PSs contain 43.9%-80.5% crude fiber, 27.6-87% NDF, 13.1-76.2% ADF, and 5.8-45.2% lignin [9]. These by-products have been processed into many dietary forms, such as ammoniated BG, BG treated with calcium oxide [6], ground maize cobs [1], and maize cob silage [3]. Wachirapakom *et al*. [1] used ground CCs as a single roughage source and found that ground CCs result in better dry matter intake (DMI) and milk yields compared to rice straw when used as a source of fiber in dairy cow diets. Treated agricultural by-products have additional positive effects on ruminants when used as a roughage source, including decreased methane emission in lambs [3] and improved nutrient intake and milk yield in lactating dairy, crossbred cows [1]. Complete feed or total mixed ration (TMR) is the ideal method to blend concentrate and roughage from local agricultural by-products to make a cheap and balanced ration [10]. Blended feed material in TMR can improve feed palatability [10-12], which allows unconventional feeds to be added that further reduce the price of the ration [10]. The forage and concentrate ratio in TMR can be formulated to meet the animals' nutritional requirements for the desired health status and production performance [12]. For example, Lin [12] found that equal amounts of proteins and carbohydrates in TMR maximize the fermentation activity of ruminal microbes and stabilize rumen pH. The further processing of TMR into pellets increases feed intake and digestion [10]. Karimizadeh *et al*. [13] reported that the DMI of lambs fed pelleted TMR was higher than those fed mash TMR (1.2 g/d vs. 1.1 g/d, respectively). Islam *et al*. [14] also reported that pelleted TMR increased crude fiber digestibility compared to mash TMR. Ishaq *et al*. [15] found that lambs fed pelleted diets had an increased DMI of around 17% compared to those fed loose hay diets (1.9 kg/d vs. 1.6 kg/d, respectively), with a higher average daily gain (ADG; 0.24 kg/d vs. 0.08 g/d, respectively).

This study investigated the use of agricultural by-products as a component of pelleted lamb feed to increase productivity and reduce feed costs (FC), since agricultural by-products are abundantly available to substitute grass and may be best utilized as pellets.

<H1>Materials and Methods

<H2>Ethical approval

The animal handling and scientific procedures in this study were approved by the Animal Ethics Committee from the Faculty of Animal and Agricultural Science, Diponegoro University, Indonesia.

<H2>Study period and location

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The experiment was conducted at the Research Farm of Meat and Dairy Production Laboratory, Department of Animal Science, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia, from July to December 2019.

<H2>Animals, experimental design, and treatments

The study used 24, 3-month-old male lambs with an average body weight of 13.26±1.29 kg (coefficient of variation=9.73%). The lambs were allocated into a completely randomized design [16] with four treatments and six replications. The diets contained three different agricultural by-products (i.e., CCs, BG, and PSs) as a fiber source to substitute Napier grass (NG). The concentrate consisted of rice bran, cassava waste product, soybean meal, molasses, and minerals. The diets consisted of 40% fibrous feedstuffs and 60% concentrate, and were formulated to contain 10.36-11.65% crude protein and 55.47-57.31% total digestible nutrients (TDN) (Table-1) [17]. The diets were offered to the animals in pellet form. The treatments included NG=100% NG (with no agricultural wastes); CCs=50% NG and 50% CCs; BG=50% NG and 50% BG; and PSs=50% NG and 50% PSs.

<H2>Observed variables, research activities, and procedures

The examined variables included lamb productivity and carcass characteristics (i.e., DMI, organic matter intake (OMI), dry matter digestibility (DMD), organic matter digestibility (OMD), body weight gain (BWG), feed conversion ratio (FCR), FC per gain (FC/G), carcass traits, carcass composition (bones, meat, and fat), and meat-bone ratio). The experimental period consisted of five stages: Preparation (3 weeks), adaptation (3 weeks), the preliminary period (1 week), the treatment period (12 weeks), and slaughtering. The lambs were provided the diets and water *ad libitum* and were weighed once a week. Feces were collected for 7 days during week 3 of the treatment period to calculate feed digestibility [18]. The feces were collected daily, weighed, and sampled using the procedure of Darlis *et al*. [19]. After the 12-week treatment period, the lambs were fasted for 12 h with free access to fresh water, then were slaughtered. The carcasses were weighed and separated for bone, fat, and meat according to Pratiwi *et al*. [20]; however, in this study, the kidneys were included in the carcasses.

<H2>Statistical analysis

The data obtained were analyzed using analysis of variance, apart from the FC/G, which was analyzed descriptively. Duncan's multiple range test was applied when there were differences among the treatments [16]. The level of significance was based on $p<0.05$.

<H1>Results

<H2>Lamb's productivity

The effect of NG substitution by agricultural by-products on lamb productivity is presented in Table-2. The DMI and OMI of the lambs fed the PSs diet were significantly higher ($p<0.05$) than the other diets, although the DMI in the percentage of body weight was not significantly different ($p>0.05$) among the treatments. The crude protein intake (CPI) of lambs fed the PSs and NG diets was higher ($p<0.05$) than that of the CCs- and BG-fed lambs. The CPI of the lambs fed the PSs and NG diets was not significantly different ($p>0.05$). The crude fiber intake (CFI) of the lambs fed the NG diet was the lowest. The TDN intake of the lambs fed the NG and BG diets was lower than that of those fed the PSs diet. The TDN intake of the lambs fed the CCs diet was not significantly different ($p>0.05$) from those fed the NG, BG, and PSs diets.

The DMD and OMD of the PSs diet were higher ($p<0.05$) than those of the CCs and BG diets, but were not significantly different ($p>0.05$) from those of the NG diet. There was no significant difference ($p>0.05$) in DMD and OMD for the NG, CCs, and BG diets. The digestible DMI and OMI in the PSs group had the highest value ($p<0.05$).

The bodyweight gain of the lambs fed the PSs diet was higher ($p<0.05$) than those fed the CCs and BG diets, but was not significantly different ($p>0.05$) from those fed the NG diet. The lambs fed the NG diet had higher ($p<0.05$) BWG than those fed the BG diet; however, there was no significant difference ($p>0.05$) in BWG between the lambs fed the NG and CCs diets, or between the lambs fed the CCs and BG diets (Table-2). Consequently, the FCR was lowest in the PSs-fed lambs and highest in the BG-fed lambs ($p<0.05$). The BWG and FCR results influenced the FC/G. The lambs fed the PSs diet had the lowest FC/G, followed by those fed the NG, CCs, and BG diets, respectively.

<H2>Lamb carcass characteristics

The effect of NG substitution by agricultural wastes on lamb carcass characteristics is presented in Table-3. No significant differences (p>0.05) were found between the different treatments for any of the measured lamb carcass characteristics. The average slaughter weight was 20.03 kg, which produced 8.02 kg carcass weight and 4.50 kg meat. The average carcass bone weight was 1.74 kg. The meat-bone ratio was 3.67 on average.

<H1>Discussion

<H2>Feed intake, digestibility, BWG, FCR, and economic implications

The feed intake and digestibility influenced lamb productivity. The PSs-fed lambs had the highest DMI, OMI, and TDN intake values. These findings could be attributed to the high DMD and OMD of the PSs diet. The high DMI and DMD of the PSs diet led to high DDMI, which, in turn, caused the lambs fed the PSs diet to have the highest BWG and lowest FCR, with the cheapest FC/G. The lambs fed the diet containing BG had the lowest BWG. The BWG of the lambs fed the NG diet was similar to those fed the CCs and PSs diets. These results agree with Santos *et al*. [21] who found that BWG was affected by DMI.

The high NDF and ADF contents (Table-1) in the agricultural by-product diets did not significantly decrease lamb productivity. Usually, the higher NDF and ADF contents cause lower feed intake [21]. We speculate that the PSs and CCs were more palatable in this study, since the inclusion of these feedstuffs did not reduce DMI in the lambs. Another explanation may be that the ingredients were all ground, then offered to the animal in pelleted form. Khan *et al*. [22] stated that grinding and pelleting feeds break down cell walls, reduce particle sizes, increase feed density, increase rumen passage rates, and increase DMI. The inclusion of concentrate in the diet improved the nutrient digestibility of the low-quality crop residues, increased growth rate and meat production [23,24], and reduced FC/G compared to conventional feeding systems [24]. Karimizadeh *et al*. [13] reported that the digestibility of pelleted complete feed was higher than that of mash complete feed.

<H2>Carcass characteristics

The substitution of NG by agricultural wastes did not affect slaughter weight, carcass production, meat production, meat-bone ratio, or subcutaneous fat thickness in lambs. These findings were attributed to the fact that the slaughter weights of the lambs fed with different diets were similar.

The above results indicate that CCs, BG, and PSs could be used to substitute NG without a negative effect on production. Similar slaughter weights were associated with similar carcass weights and dressing percentages, as already pointed out by Sabbioni *et al.* [25]. The carcass weight was affected by the slaughter weight. The carcass weights obtained in this study were similar to those reported by Setyaningrum *et al*. [26], where Indonesia thin-tailed sheep weighing 17.5-18.8 kg produced 7.7-8.5 kg carcasses. Other studies reported that lamb carcass weights varied from 15.3 kg to 26.1 kg when originating from a slaughter weight of 34.3 kg-54.1 kg [21,27-30]. Forwood *et al*. [30] reported that heavier live weights produced higher carcass weights and dressing percentages. Dressing percentages in this study (40.03%) were similar to those reported by Setyaningrum *et al*. [26] in thin-tailed sheep. The previous studies reported that the dressing percentages of different lamb breed varied from 39% to 51% [21,25,26,29,30]. Valizadeh *et al*. [31] showed that the heavier the bodyweight of the lamb the higher its carcass percentage.

In general, consumers prefer meat with less fat [32]. Carcass fat percentage in this study (17.61%) was similar to those reported by Santos *et al*. [21] (i.e., 15-18%) and Obeidat *et al*. [27] (i.e., 16.6-20.1%). Lambs with a lighter bodyweight than mutton contain less carcass fat trimming, as reported by Sabbioni *et al*. [25] who found that lamb fat trimmings were 13.04-17.31%, whereas those in mutton were 15.96-19.06%. Thus, consumers believe that the lighter lambs produce healthier meat [32]. In fact, Ekiz *et al*. [33] reported that the lean fat ratios of low, medium, and high weight groups (26 kg, 30 kg, and 35 kg) of lambs were similar (3.93-4.25) with a total fat content of 15.24%-16.81%.

Meat-bone ratio is an important parameter because it is related to the edible portion of the carcass. The meat-bone ratio in this study (3.67) was higher than that in Awassi lambs fed up to 300 g/kg layer litter (2.95-3.10) [27], Cornigliese lambs (2.22-3.09), and mutton (3.25-3.52) [25]. The lean meat-bone ratio in this study (2.84) was lower than that reported by Ekiz *et al.* [33] (3.13-3.48).

<H1>Conclusion

The conclusion of this research is that agricultural wastes, namely, CCs, BG, and PS, can be used to substitute grass as a component of lamb diets at the level of 50% without a negative effect on production performance and carcass traits. The use of PSs to substitute NG increased lamb productivity. Carcass trait characteristics were not affected by agricultural wastes. ~~The use of agricultural wastes as substitutes for grass depends on the availability and price of these unconventional feedstuffs.~~

<H1>Authors' Contributions

EP and AP designed the study, interpreted the data, and drafted the manuscript. ER, RA, CMSL, and SM were involved in designing the study also contributed to the preparation and critical checking of this manuscript. RA and VR were contributed to statistical analysis and manuscript preparation. All authors read and approved the final manuscript.

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<H1>**Competing Interests**

The authors declare that they have no competing interests.

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Table-1: Feed composition and nutritional content of the diets.

Feed composition/nutritional content	**NG**	**CCs**	**BG**	**PSs**
Feed composition (%)				
Napier grass	40.00	20.00	20.00	20.00
Corn cobs	0.00	20.00	0.00	0.00
Bagasse	0.00	0.00	20.00	0.00
Peanut shell	0.00	0.00	0.00	20.00
Rice bran	34.05	34.05	34.05	34.05
Cassava waste products	5.00	5.00	5.00	5.00
Soybean meal	12.95	12.95	12.95	12.95
Molasses	6.00	6.00	6.00	6.00
Mineral mix	2.00	2.00	2.00	2.00
Nutritional content (%)				

Dry matter	92.20	92.42	92.14	92.17
Ash	9.75	8.85	8.46	9.96
OM	90.25	91.15	91.54	90.04
CP	11.65	10.73	10.36	10.41
EE	5.55	6.08	5.19	5.23
CF	31.43	33.16	34.81	37.46
NFE	41.62	41.18	41.18	36.94
TDN[§]	56.48	57.31	55.47	55.77
NDF	55.83	57.61	54.47	56.76
ADF	27.38	29.63	31.20	32.15
Price (IDR/kg)	2,352	2,352	2,331	2,377

NG=100% Napier grass, CCs=50% Napier grass and 50% corn cobs; BG=50% Napier grass and 50% bagasse, PSs=50% Napier grass and 50% peanut shells, TDN was calculated from the formula TDN=digested CP+(2.25×digested EE)+digested CF+digested NFE [17]. OM=Organic matter, CP=Crude protein, EE=Ether extract, CF=Crude fiber, NFE=Nitrogen-free extract, TDN=Total digestible nutrients,

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NDF=Neutral detergent fiber, ADF=Acid detergent fiber

Table-2: Productivity of lambs fed diets with different sources of fiber.				
Variables	**NG**	**CCs**	**BG**	**PSs**
Dry matter intake (g/days)	724[a]	722[a]	718[a]	781[b]
Dry matter intake (% BW)	4.42	4.44	4.50	4.73
Organic matter intake (g/days)	654[a]	658[a]	657[a]	704[b]
Crude protein intake (g/days)	84[b]	76[a]	74[a]	81[b]
Crude fiber intake (g/days)	228[a]	240[b]	250[b]	293[c]
TDN intake (g/days)	410[a]	416[ab]	398[a]	435[b]
Dry matter digestibility (%)	51.9[ab]	51.4[a]	50.9[a]	53.0[b]
Digestible dry matter intake (g/days)	376[b]	372[ab]	365[a]	414[c]
Organic matter digestibility (%)	55.9[ab]	53.9[a]	52.8[a]	62.1[b]
Digestible organic matter intake (g/days)	367[a]	355[a]	347[a]	437[b]
Body weight gain (g/days)	77.5[bc]	68.2[ab]	54.4[a]	92.5[c]

Feed conversion ratio	9.7[a]	11.2[ab]	13.5[b]	9.1[a]
Feed cost per gain (IDR/kg)	24,835	28,554	34,234	23,541

[a,b,c]Within a row, means without a common uppercase superscript differ (p<0.05). NG=100% Napier grass, CCs=50% Napier grass and 50% corn cobs; BG=50% Napier grass and 50% bagasse, PSs=50% Napier grass and 50% peanut shells. BW=Body weight

Table-3: Carcass production and characteristics of lambs fed diets with different sources of fiber.

Variables	**NG**	**CCs**	**BG**	**PSs**	**Average**
Slaughter weight (kg)	20.22	19.82	19.26	20.84	20.03
Carcass weight (kg)	8.40	7.88	7.46	8.34	8.02
Dressing percentage (%)	41.5	39.9	38.7	40.1	40.0
Carcass components					
Meat weight (g)	4,79	4,53	4,21	4,45	4,50
Meat percentage (%)	57.1	57.6	56.2	53.3	56.0
Bone weight (g)	1.755	1.663	1.672	1.868	1.740
Bone percentage (%)	21.1	21.2	22.6	22.5	21.9
Fat weight (g)	1.466	1.321	1.253	1.654	1.423
Fat percentage (%)	17.3	16.5	16.9	19.8	17.6
Connective tissue weight	385	367	321	368	360

(g)					
Connective tissue percentage (%)	4.6	4.7	4.3	4.4	4.5
Distribution of carcass fat					
Subcutaneous fat weight (g)	836	695	723	979	808
Subcutaneous fat percentage (%)	57.1	50.5	57.5	59.2	56.1
Intermuscular fat weight (g)	487	485	395	463	457
Intermuscular fat percentage (%)	33.0	39.0	31.7	28.5	33.1
Kidney fat weight (g)	91	92	90	127	100
Kidney fat percentage (%)	6.5	6.7	7.1	7.4	6.9
Pelvic fat weight (g)	51	49	46	84	58
Pelvic fat percentage (%)	3.5	3.8	3.6	4.9	3.9

Meat-bone ratio					
Meat-bone ratio	3.86	3.78	3.47	3.59	3.67
Lean meat-bone ratio	3.00	2.98	2.72	2.65	2.84
NG=Napier grass, CCs=50% Napier grass and 50% corn cobs, BG=50% Napier grass and 50% bagasse, PSs=50% Napier grass and 50% peanut shells.					

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RESEARCH ARTICLE
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Productivity and carcass characteristics of lambs fed fibrous agricultural wastes to substitute grass

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Abstract

Background and Aim: Grass is often scarce for ruminants during the dry season in Indonesia; thus agricultural by-products are widely used as a substitute for grass. This study aimed to determine the effect of replacing Napier grass (NG) with agricultural by-products on the productivity and carcass characteristics of lambs.

Materials and Methods: Twenty-four 3-month-old male lambs with initial body weights of 13.26±1.29 kg (coefficient of variation=9.73%) were allocated into a completely randomized design with four treatments and six replications. The treatments included: NG=100% NG; corn cobs (CCs)=50% NG and 50% CCs; bagasse (BG)=50% NG and 50% BG; and peanut shells (PSs)=50% NG and 50% PSs. All treatment diets were pelleted and consisted of 40% fibrous feed and 60% concentrate feed, and contained 10.36-11.65% crude protein and 55.47-57.31% total digestible nutrients. Parameters observed included dry matter intake (DMI), dry matter digestibility, body weight gain (BWG), feed conversion ratio (FCR), feed cost per gain (FC/G), and carcass characteristics.

Results: Lambs fed the PSs diet had the highest ($p<0.05$) DMI (781 g/d), digestibility, and body weight gain (92.5 g/d; $p<0.05$). The FCR of the PSs diet (9.13) was similar to NG. The FC/G of the PSs diet (IDR 23,541/kg) was the lowest of all diets. The BG diet had the lowest ($p<0.05$) digestibility, body weight gain (54.4 g/d), and the highest (13.53) FCR. No significant differences ($p>0.05$) were found in the carcass or meat characteristics of any diets. The averages of slaughter weight, carcass weight, and carcass percentage were 20.03 kg, 8.02 kg, and 40.0%, respectively. The average meat bone ratio was 3.67.

Conclusion: It was concluded that agricultural wastes could be used as an alternative to NG at the level of 50% in the diet of lambs without a negative effect on production performance and carcass traits.

Keywords: bagasse, corn cobs, digestibility, feed efficiency, meat-bone ratio, peanut shells.

Introduction

Agricultural by-products are widely used for ruminant feed when grass is limited during the dry season in some countries. The use of agricultural waste as a source of fiber for ruminants can reduce feed prices and improve environmental sustainability using feed materials that are sustainably available. Examples of agricultural waste include corn cobs (CCs) [1-3], bagasse (BG) [4-7], and peanut shells (PSs) [8]. Ground CCs have been used as a fiber source in cows [1], goats [2], and lambs [3]. Babiker *et al*. [5] used BG for beef cattle, while Silva *et al*. [4], Filho *et al*. [6], and Galvani *et al*. [7] used it for lambs. Eshag *et al*. [8] used ground PSs for lambs to reduce feed cost.

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Agricultural by-products are usually categorized as low-quality roughages due to their high crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents. CCs contain 10.2% crude fiber, 38.0-79.9% NDF, and 16-40% ADF [2,3]. BG contains 84.6% NDF and 53.1% ADF [7]. PSs contain 43.9%-80.5% crude fiber, 27.6-87% NDF, 13.1-76.2% ADF, and 5.8-45.2% lignin [9]. These by-products have been processed into many dietary forms, such as ammoniated BG, BG treated with calcium oxide [6], ground maize cobs [1], and maize cob silage [3]. Wachirapakom *et al*. [1] used ground CCs as a single roughage source and found that ground CCs result in better dry matter intake (DMI) and milk yields compared to rice straw when used as a source of fiber in dairy cow diets. Treated agricultural by-products have additional positive effects on ruminants when used as a roughage source, including decreased methane emission in lambs [3] and improved nutrient intake and milk yield in lactating dairy, crossbred cows [1]. Complete feed or total mixed ration (TMR) is the ideal method to blend concentrate and roughage from local agricultural by-products to make a cheap and balanced ration [10]. Blended feed material in TMR can improve feed palatability [10-12], which allows unconventional feeds to be added that further reduce the price of the ration [10]. The forage and concentrate ratio in TMR can be formulated to meet the animals' nutritional requirements for the desired health status and production performance [12]. For example, Lin [12] found that equal amounts of proteins and carbohydrates in TMR maximize the fermentation activity of ruminal microbes and stabilize rumen pH. The further processing of TMR into pellets increases feed intake and digestion [10]. Karimizadeh *et al*. [13] reported that the DMI of lambs fed pelleted TMR was higher than those fed mash TMR (1.2 g/d vs. 1.1 g/d, respectively). Islam *et al*. [14] also reported that pelleted TMR increased crude fiber digestibility compared to mash TMR. Ishaq *et al*. [15] found that lambs fed pelleted diets had an increased DMI of around 17% compared to those fed loose hay diets (1.9 kg/d vs. 1.6 kg/d, respectively), with a higher average daily gain (ADG; 0.24 kg/d vs. 0.08 g/d, respectively).

This study investigated the use of agricultural by-products as a component of pelleted lamb feed to increase productivity and reduce feed costs (FC), since agricultural by-products are abundantly available to substitute grass and may be best utilized as pellets.

Materials and Methods

Ethical approval

The animal handling and scientific procedures in this study were approved by the Animal Ethics Committee from the Faculty of Animal and Agricultural Science, Diponegoro University, Indonesia.

Study period and location

The study was conducted from July to December 2019 at the Research Farm of Meat and Dairy Production Laboratory, Department of Animal Science, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia.

Animals, experimental design, and treatments

The study used 24, 3-month-old male lambs with an average body weight of 13.26±1.29 kg (coefficient of variation=9.73%). The lambs were allocated into a completely randomized design [16] with four treatments and six replications. The diets contained three different agricultural by-products (i.e., CCs, BG, and PSs) as a fiber source to substitute Napier grass (NG). The concentrate consisted of rice bran, cassava waste product, soybean meal, molasses, and minerals. The diets consisted of 40% fibrous feedstuffs and 60% concentrate, and were formulated to contain 10.36-11.65% crude protein and 55.47-57.31% total digestible nutrients (TDN) (Table-1) [17]. The diets were offered to the animals in pellet form. The treatments included NG=100% NG (with no agricultural wastes); CCs=50% NG and 50% CCs; BG=50% NG and 50% BG; and PSs=50% NG and 50% PSs.

Table-1: Feed composition and nutritional content of the diets.

Feed composition/ nutritional content	NG	CCs	BG	PSs
Feed composition (%)				
Napier grass	40.00	20.00	20.00	20.00
Corn cobs	0.00	20.00	0.00	0.00
Bagasse	0.00	0.00	20.00	0.00
Peanut shell	0.00	0.00	0.00	20.00
Rice bran	34.05	34.05	34.05	34.05
Cassava waste products	5.00	5.00	5.00	5.00
Soybean meal	12.95	12.95	12.95	12.95
Molasses	6.00	6.00	6.00	6.00
Mineral mix	2.00	2.00	2.00	2.00
Nutritional content (%)				
Dry matter	92.20	92.42	92.14	92.17
Ash	9.75	8.85	8.46	9.96
OM	90.25	91.15	91.54	90.04
CP	11.65	10.73	10.36	10.41
EE	5.55	6.08	5.19	5.23
CF	31.43	33.16	34.81	37.46
NFE	41.62	41.18	41.18	36.94
TDN	56.48	57.31	55.47	55.77
NDF	55.83	57.61	54.47	56.76
ADF	27.38	29.63	31.20	32.15
Price (IDR/kg)	2,352	2,352	2,331	2,377

NG=100% Napier grass, CCs=50% Napier grass and 50% corn cobs; BG=50% Napier grass and 50% bagasse, PSs=50% Napier grass and 50% peanut shells, TDN was calculated from the formula TDN=digested CP+(2.25×digested EE)+digested CF+digested NFE [17]. OM=Organic matter, CP=Crude protein, EE=Ether extract, CF=Crude fiber, NFE=Nitrogen-free extract, TDN=Total digestible nutrients, NDF=Neutral detergent fiber, ADF=Acid detergent fiber

Observed variables, research activities, and procedures

The examined variables included lamb productivity and carcass characteristics (i.e., DMI, organic matter intake (OMI), dry matter digestibility (DMD), organic matter digestibility (OMD), body weight gain (BWG), feed conversion ratio (FCR), FC per gain (FC/G), carcass traits, carcass composition (bones, meat, and fat), and meat-bone ratio). The experimental period consisted of five stages: Preparation (3 weeks), adaptation (3 weeks), the preliminary period (1 week), the treatment period (12 weeks), and slaughtering. The lambs were provided the diets and water *ad libitum* and were weighed once a week. Feces were collected for 7 days during week 3 of the treatment period to calculate feed digestibility [18]. The feces were collected daily, weighed, and sampled using the procedure of Darlis *et al*. [19]. After the 12-week treatment period, the lambs were fasted for 12 h with free access to freshwater, and then slaughtered. The carcasses were weighed and separated for bone, fat, and meat according to Pratiwi *et al*. [20]; however, in this study, the kidneys were included in the carcasses.

Statistical analysis

The data obtained were analyzed using analysis of variance, apart from the FC/G, which was analyzed descriptively. Duncan's multiple range test was applied when there were differences among the treatments [16]. The level of significance was based on p<0.05.

Results

Lamb's productivity

The effect of NG substitution by agricultural by-products on lamb productivity is presented in Table-2. The DMI and OMI of the lambs fed the PSs diet were significantly higher (p<0.05) than the other diets, although the DMI in the percentage of body weight was not significantly different (p>0.05) among the treatments. The crude protein intake (CPI) of lambs fed the PSs and NG diets was higher (p<0.05) than that of the CCs- and BG-fed lambs. The CPI of the lambs fed the PSs and NG diets was not significantly different (p>0.05). The crude fiber intake (CFI) of the lambs fed the NG diet was the lowest. The TDN intake of the lambs fed the NG and BG diets was lower than that of those fed the PSs diet. The TDN intake of the lambs fed the CCs diet was not significantly different (p>0.05) from those fed the NG, BG, and PSs diets.

The DMD and OMD of the PSs diet were higher (p<0.05) than those of the CCs and BG diets, but were not significantly different (p>0.05) from those of the NG diet. There was no significant difference (p>0.05) in DMD and OMD for the NG, CCs, and BG diets. The digestible DMI and OMI in the PSs group had the highest value (p<0.05).

The BWG of the lambs fed the PSs diet was higher (p<0.05) than those fed the CCs and BG diets, but was not significantly different (p>0.05) from those fed the NG diet. The lambs fed the NG diet had higher (p<0.05) BWG than those fed the BG diet; however, there was no significant difference (p>0.05) in BWG between the lambs fed the NG and CCs diets, or between the lambs fed the CCs and BG diets (Table-2). Consequently, the FCR was lowest in the PSs-fed lambs and highest in the BG-fed lambs (p<0.05). The BWG and FCR results influenced the FC/G. The lambs fed the PSs diet had the lowest FC/G, followed by those fed the NG, CCs, and BG diets, respectively.

Lamb carcass characteristics

The effect of NG substitution by agricultural wastes on lamb carcass characteristics is presented in Table-3. No significant differences (p>0.05) were found between the different treatments for any of the measured lamb carcass characteristics. The average slaughter weight was 20.03 kg, which produced 8.02 kg carcass weight and 4.50 kg meat. The average carcass bone weight was 1.74 kg. The meat-bone ratio was 3.67 on average.

Discussion

Feed intake, digestibility, BWG, FCR, and economic implications

The feed intake and digestibility influenced lamb productivity. The PSs-fed lambs had the highest DMI, OMI, and TDN intake values. These findings could be attributed to the high DMD and OMD of the PSs diet. The high DMI and DMD of the PSs diet led to high DDMI, which, in turn, caused the lambs fed the PSs diet to have the highest BWG and lowest FCR, with

Table-2: Productivity of lambs fed diets with different sources of fiber.

Variables	NG	CCs	BG	PSs
Dry matter intake (g/days)	724^{a}	722^{a}	718^{a}	781^{b}
Dry matter intake (% BW)	4.42	4.44	4.50	4.73
Organic matter intake (g/days)	654^{a}	658^{a}	657^{a}	704^{b}
Crude protein intake(g/days)	84^{b}	76^{a}	74^{a}	81^{b}
Crude fiber intake (g/days)	228^{a}	240^{b}	250^{b}	293^{c}
TDN intake (g/days)	410^{a}	416^{ab}	398^{a}	435^{b}
Dry matter digestibility (%)	51.9^{ab}	51.4^{a}	50.9^{a}	53.0^{b}
Digestible dry matter intake (g/days)	376^{b}	372^{ab}	365^{a}	414^{c}
Organic matter digestibility (%)	55.9^{ab}	53.9^{a}	52.8^{a}	62.1^{b}
Digestible organic matter intake (g/days)	367^{a}	355^{a}	347^{a}	437^{b}
Body weight gain (g/days)	77.5^{bc}	68.2^{ab}	54.4^{a}	92.5^{c}
Feed conversion ratio	9.7^{a}	11.2^{ab}	13.5^{b}	9.1^{a}
Feed cost per gain (IDR/kg)	24,835	28,554	34,234	23,541

^{a,b,c}Within a row, means without a common uppercase superscript differ (p<0.05). NG=100% Napier grass, CCs=50% Napier grass and 50% corn cobs; BG=50% Napier grass and 50% bagasse, PSs=50% Napier grass and 50% peanut shells. BW=Body weight

Table-3: Carcass production and characteristics of lambs fed diets with different sources of fiber.

Variables	NG	CCs	BG	PSs	Average
Slaughter weight (kg)	20.22	19.82	19.26	20.84	20.03
Carcass weight (kg)	8.40	7.88	7.46	8.34	8.02
Dressing percentage (%)	41.5	39.9	38.7	40.1	40.0
Carcass components					
Meat weight (g)	4,79	4,53	4,21	4,45	4,50
Meat percentage (%)	57.1	57.6	56.2	53.3	56.0
Bone weight (g)	1.755	1.663	1.672	1.868	1.740
Bone percentage (%)	21.1	21.2	22.6	22.5	21.9
Fat weight (g)	1.466	1.321	1.253	1.654	1.423
Fat percentage (%)	17.3	16.5	16.9	19.8	17.6
Connective tissue weight (g)	385	367	321	368	360
Connective tissue percentage (%)	4.6	4.7	4.3	4.4	4.5
Distribution of carcass fat					
Subcutaneous fat weight (g)	836	695	723	979	808
Subcutaneous fat percentage (%)	57.1	50.5	57.5	59.2	56.1
Intermuscular fat weight (g)	487	485	395	463	457
Intermuscular fat percentage (%)	33.0	39.0	31.7	28.5	33.1
Kidney fat weight (g)	91	92	90	127	100
Kidney fat percentage (%)	6.5	6.7	7.1	7.4	6.9
Pelvic fat weight (g)	51	49	46	84	58
Pelvic fat percentage (%)	3.5	3.8	3.6	4.9	3.9
Meat-bone ratio					
Meat-bone ratio	3.86	3.78	3.47	3.59	3.67
Lean meat-bone ratio	3.00	2.98	2.72	2.65	2.84

NG=Napier grass, CCs=50% Napier grass and 50% corn cobs, BG=50% Napier grass and 50% bagasse, PSs=50% Napier grass and 50% peanut shells the cheapest FC/G. The lambs fed the diet containing BG had the lowest BWG. The BWG of the lambs fed the NG diet was similar to those fed the CCs and PSs diets. These results agree with Santos *et al*. [21] who found that BWG was affected by DMI.

The high NDF and ADF contents (Table-1) in the agricultural by-product diets did not significantly decrease lamb productivity. Usually, the higher NDF and ADF contents cause lower feed intake [21]. We speculate that the PSs and CCs were more palatable in this study, since the inclusion of these feedstuffs did not reduce DMI in the lambs. Another explanation may be that the ingredients were all ground, then offered to the animal in pelleted form. Khan *et al*. [22] stated that grinding and pelleting feeds break down cell walls, reduce particle sizes, increase feed density, increase rumen passage rates, and increase DMI. The inclusion of concentrate in the diet improved the nutrient digestibility of the low-quality crop residues, increased growth rate and meat production [23,24], and reduced FC/G compared to conventional feeding systems [24]. Karimizadeh *et al*. [13] reported that the digestibility of pelleted complete feed was higher than that of mash complete feed.

Carcass characteristics

The substitution of NG by agricultural wastes did not affect slaughter weight, carcass production, meat production, meat-bone ratio, or subcutaneous fat thickness in lambs. These findings were attributed to the fact that the slaughter weights of the lambs fed with different diets were similar.

The above results indicate that CCs, BG, and PSs could be used to substitute NG without a negative effect on production. Similar slaughter weights were associated with similar carcass weights and dressing percentages, as already pointed out by Sabbioni *et al*. [25]. The carcass weight was affected by the slaughter weight. The carcass weights obtained in this study were similar to those reported by Setyaningrum *et al*. [26], where Indonesian thin-tailed sheep weighing 17.5-18.8 kg produced 7.7-8.5 kg carcasses. Other studies reported that lamb carcass weights varied from 15.3 kg to 26.1 kg when originating from a slaughter weight of 34.3 kg-54.1 kg [21,27-30]. Forwood *et al*. [30] reported that heavier live weights produced higher carcass weights and dressing percentages. Dressing percentages in this study (40.03%) were similar to those reported by Setyaningrum *et al*. [26] in thin-tailed sheep. The previous studies reported that the dressing percentages of different lamb breeds varied from 39% to 51% [21,25,26,29,30]. Valizadeh *et al*. [31] showed that the heavier the body weight of the lamb, the higher its carcass percentage.

In general, consumers prefer meat with less fat [32]. Carcass fat percentage in this study (17.61%) was similar to those reported by Santos *et al*. [21] (i.e., 15-18%) and Obeidat *et al*. [27] (i.e., 16.6-20.1%). Lambs with lighter body weight than mutton contain less carcass fat trimming, as reported by Sabbioni *et al*. [25] who found that lamb fat trimmings were 13.04-17.31%, whereas those in mutton were 15.96-19.06%. Thus, consumers believe that lighter lambs produce healthier meat [32]. In fact, Ekiz *et al*. [33] reported that the lean fat ratios of low, medium, and high weight groups (26 kg, 30 kg, and 35 kg) of lambs were similar (3.93-4.25) with a total fat content of 15.24%-16.81%.

Meat-bone ratio is an important parameter because it is related to the edible portion of the carcass. The meat-bone ratio in this study (3.67) was higher than that in Awassi lambs fed up to 300 g/kg layer litter (2.95-3.10) [27], Cornigliese lambs (2.22-3.09), and mutton (3.25-3.52) [25]. The lean meat-bone ratio in this study (2.84) was lower than that reported by Ekiz *et al.* [33] (3.13-3.48).

Conclusion

It can be concluded that agricultural wastes, namely, CCs, BG, and PS, can be used to substitute grass as a component of lamb diets at the level of 50% without a negative effect on production performance and carcass traits. The use of PSs to substitute NG increased lamb productivity. Carcass trait characteristics were not affected by agricultural wastes.

Authors' Contributions

EP and AP: Designed the study, interpreted the data, and drafted the manuscript. ER, RA, CMSL, and SM: Participated in study design and contributed to the preparation and critical review of this manuscript. RA and VR: Did statistical analysis and drafted the manuscript. All authors read and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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