p-ISSN 2615-787X e-ISSN 2615-790X
Accredited by Directorate General of Higher Education, Research, and Technology, Republic of Indonesia, No. 225/E/KPT/2022

Tropical Animal Science Journal, March 2024, 47(1):87-96
DOI: https://doi.org/10.5398/tasj.2024.47.1.87
Available online at https://journal.ipb.ac.id/index.php/tasj

Productivity, Carcass Traits, and Meat Quality of Local Lambs Fed with *Carica pubescens* Seeds Meal

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(Received 24-07-2023; Revised 01-12-2023; Accepted 04-12-2023)

ABSTRACT

This study aimed to determine the effect of substituting agricultural by-products of *Carica pubescens* seeds meal with some concentrates on productivity, carcass characteristics, and meat quality of local lambs. Eighteen male thin-tailed lambs with an average initial body weight of 10.68 ± 1.3 kg (3-4 months old) were treated with a completely randomized design for ten weeks. The feed ingredients were *C. pubescens*, Pakchong grass (PG), and concentrate (K). Feed ingredients were prepared into complete feed with a balance of forage and concentrate 40:60% with three treatments, namely: T1= 40% PG + 55% K + 5% *C. pubescens*; T2= 40% PG + 47.5% K + 12.5% *C. pubescens*; and T3= 40% RG + 40% K + 20% *C. pubescens*. The use of 20% *C. pubescens*-treated lambs was statistically different ($p<0.05$) regarding the increasing BWG (115.60 g/day), CPI (104.96 g/day), FCR (6.40), slaughter weight (19.62 kg), carcass weight (7.83 kg), meat weight (4.49 kg), and fat weight (1.66 kg). The treatment with 12.5% *C. pubescens* resulted in significantly different increasing tenderness ($p<0.05$) in *longissimus dorsi* and *biceps femoris* muscle pain (2.79 kgf/cm^2) and (3.36 kgf/cm^2), respectively. The inclusion level of *C. pubescens* seeds up 20% resulted in higher body weight gain, crude protein intake, feed cost ratio, slaughter weight, carcass weight, and meat weight.

Keywords: carcass; Carica pubescens; lambs; meat; productivity

INTRODUCTION

The sheep farming industry's rapid development has implications for feed ingredient demand. The continuous availability of quality feed throughout the year is essential in the young sheep fattening industry. A sustainable livestock industry must pay attention to increasing productivity by using existing resources (Yulistiani *et al.*, 2017; Purbowati *et al.*, 2021). Nearly all agro-industrial wastes are already used to make comprehensive commercial feeds. The young sheep-fattening sector will experience supply problems without further research on alternative ingredients. Although many feed ingredients in the country have been exploited, the need for this feed has yet to be fulfilled. Consequently, further research is necessary to investigate unconventional ingredients that are expected to replace commercial feed ingredients potentially.

Carica pubescens Lenne & K. Koch is known as a Carica Dieng. In Banjarnegara and Wonosobo Regencies, Central Java, Indonesia, many Carica processing companies have developed Carica into essential commodities with considerable economic value. The Carica beverage processing business certainly leaves a residue; one of the by-products of Carica fruit processing is the seeds and membranes of Carica seeds. Carica fruit seeds comprise around 22% of the waste from the fruit. These seeds contain 31.84% crude protein, 24.41% crude fiber, and 30.22% carbs per Briones-Labarca *et al.* (2015). These fresh seeds, on the other hand, contain anti-nutritional tannins and saponins. According to preliminary research, fresh Carica seeds contain tannins and saponins (4.27% and 21.23%, respectively). The comparatively high protein content of Carica Dieng seeds is suspected to have potential and can be utilized as a protein source for feed production. This result is consistent with the findings of Yulistiani *et al.* (2017), who claim that using agricultural by-products as feed can reduce methane emissions while increasing feed intake. Brant *et al.* (2021) state that replacing soybean meal with cottonseed meal in sheep feed can be done without affecting performance or meat quality. This substance is easy to obtain, has a reliable sustainability rate, and contains much protein. However, research on the use of Dieng Carica seeds in young sheep feed as a source of protein in a complete feed has yet to be carried out. Therefore, additional research is needed to evaluate the use of Dieng Carica seeds as a source of whole-feed protein for fattening young sheep, especially regarding productivity, growth, carcass, and meat quality. This study aimed to determine the effect of substituting agricultural by-products of *Carica pubescens* seeds meal with some concentrates on productivity, carcass characteristics, and meat quality of local lambs.

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 Sciences, Diponegoro University, Indonesia, with approval number 59-01/A-06/KEP-FPP. The study's duration and setting are at the Research Farm of Meat and Dairy Production Laboratory, Department of Animal Science, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia. The study was conducted between October 2022 and March 2023.

Complete Feed Pellet Preparation

Pakchong grass, concentrate, and refined Carica seeds comprised the complete feed in pellets utilized in the thorough feed research. The companies that manufacture Carica beverages in the Dieng, Banjarnegara, and Wonosobo regions are where Carica seeds were collected. Carica seeds that had already undergone processing were gathered, dried for 3–7 days in the sun until the water content was <20%, and then pulverized. According to a predetermined process, the complete feed was created from grass, concentrate, and Carica seeds. The whole feed was mixed well and then made into pellets for the lambs by the treatment.

In Vivo Study

Eighteen male thin-tailed lambs aged 3-4 months were used in the study; their average body weight was 10.68 ± 1.30 kg, with a 12.17% coefficient of variation. Three treatments and six replications were used in a fully randomized design with the lambs (Steel & Torrie, 1991). The diets included Pakchong Grass (PG) and varying amounts of *C. pubescens* seeds meal in place of concentrate (K) as a source of protein (Table 1). Feed ingredients were prepared into a complete feed with a balance of forage and concentrate 40%:60% with three treatments, namely: T1= 40% PG + 55% K + 5% *C. pubescens*; T2= 40% PG + 47.5% K + 12.5% *C. pubescens*; T3= 40% RG + 40% K + 20% *C. pubescens*. The diet was designed according to standards recommended by (Kearl, 1982) to include 12.02%-14.18% crude protein and 58.96%-60.93% total digestible nutrients (Table 2). The use of *C. pubecens* seed meal levels in complete feed at levels of 5%, 12.5% , and 20% is based on the results of preliminary studies that feed without Carica seeds (0% of *C. pubescens*) produces <12% crude protein. Crude protein below 12% is unsuitable for sheep fattening; it is thought to result in slower growth. This statement is based on the results of research by Purbowati *et al*. (2021), which used fibrous agricultural wastes for fattening young sheep with a crude protein content of 10.36%-11.65%, resulting in an average daily body weight gain of 72.79 g/day.

Table 1. Nutrient content of pakchong grass, concentrate, and *Carica pubescens* seed

Feed ingredients	Nutrient content (% DM)					
	DM	Ash	CP	CF	EE	TDN
Pakchong grass	92.65	4.27	7.89	43.39	1.60	51.91
Concentrate	90.23	17.22	13.58	17.79	1.51	65.55
Carica pubescens seed	87.25	6.57	27.98	29.89	14.85	83.62

Note: DM= dry matter; CP= crude protein; CF= crude fiber; EE= ether extract; TDN= total digestible nutrient.

Table 2. Feed composition and nutritional content of lamb diets containing pakchong grass, concentrate, and *Carica pubescens* seed

Feed composition/ nutritional content	Treatment		
	T1	T2	T3
Feed composition			
Pakchong grass (%)	40	40.0	40
Concentrate (%)	55	47.5	40
Carica pubescens seed (%)	5	12.5	20
Nutritional content			
Dry matter (DM)	91.05	90.82	90.60
Ash (%DM)	11.51	10.71	9.91
Crude protein (CP %DM)	12.02	13.10	14.18
Crude fiber (CF, %DM)	28.63	29.54	30.45
Ether extract (EE, %DM)	2.21	3.21	4.21
Nitrogen-free extract (NFE, %DM)	45.62	43.45	41.24
Total digestible nutrients (TDN)	58.96	58.95	60.23

Note: TDN was calculated from the formula TDN= digested CP + (2.25 × digested EE) + digested CF + digested NFE.
T1= 40% Pakchong Grass + 55% Concentrate + 5% *C. pubescens*; T2= 40% Pakchong Grass + 47.5% Concentrate + 12.5% *C. pubescens*; T3= 40% Pakchong Grass + 40% Concentrate + 20% *C. pubescens*.

Sample Collection and Analysis

The lambs were raised in separate pens. Ad libitum feed and drink were provided. Every morning at 7:00 a.m., the animals were given their diets. Before new feed was given, the leftovers were collected and weighed in the morning. Before feeding, the lambs were weighed to assess growth performance every week. A 7-day digestion study was carried out employing total collection methods. Every day, the amount of feed supplied, the remaining feed, feces, and urine from each animal were weighed and recorded. Individual lambs were sampled for 100 g of each feed supplied, and feed refused during total collection. On every day of the total collection, feces, and urine were sampled and stored at 18 °C. The ultimate pH of the urine was kept under 3. For each animal, 10% of the daily feces and urine were collected and stored in a deep freezer (-20 °C) for chemical analysis. Feed digestibility was assessed from feces (Farenzena *et al.*, 2017).

Productivity Performance

The variables of the carcass and lamb productivity were assessed by body weight gain (BWG), crude protein intake (CPI), dry matter intake (DMI), organic matter intake (OMI), feed conversion ratio (FCR), feed cost/gain (FC/G), carcass characteristics, carcass composition (bones, meat, and fat), and the meat-to-bone ratio are all factors that affect body weight gain and meat quality (physical and chemical profiles). The study period was divided into five stages: preparation (4 weeks), adaptation (2 weeks), preliminary (2 weeks), treatment (10 weeks), and data collection (2 weeks). The data collection stage was done by halal slaughtering 3 lambs in one day. The slaughtering was performed every two days. Each lamb was taken randomly, so there were six days of slaughtering. Lambs that were going to be slaughtered were subjected to 12 hours of fasting while drinking water was still provided *ad libitum*.

The lambs were slaughtered after ten weeks of feeding trials. Lambs were skinned, the visceral organs were separated for the obtained carcass, and each part was weighed. The carcass (kidneys and internal fat included) was chilled in a cold room at 18 °C for 8 hours and then weighed. Each carcass was split along the vertebrae into two halves. The carcass was separated into meat, fat, and bone, weighed, and reported as a percentage of the cold carcass weight (CCW).

Physical and Chemical Quality of Lamb Meat

Meat samples were obtained from the carcass on the right for physical and chemical composition testing. The Longissimus Dorsi (LD) muscle was extracted from the waist, whereas the Biceps femoris (BF) muscle was extracted from the thigh.

Water holding capacity (WHC) was measured using the method of Choi *et al*. (2018). One gram of thawed meat sample was wrapped in absorbent cotton and placed in a 1.5 mL Eppendorf tube. A centrifuge at a speed of 10,000 rpm was performed at a temperature of 4 °C. The tube containing the meat sample was centrifuged for 10 minutes. The sample was then weighed to determine the WHC%, using the following formula: the change in the sample's water content after centrifugation (W2) divided by the sample's original water content before centrifugation (W1) x 100.

pH was measured using a pH meter by weighing 10 grams of LD and BF muscle samples each and adding 5 mL distilled water, ground until smooth and homogenized, then a calibrated pH meter was inserted into the sample solution.

Cooking loss was measured using the method by Santos *et al*. (2022). Measuring meat cooking loss by weighing 30 g of LD and BF samples and placing them in a plastic zip lock bag. The sample was immersed in a water bath for 35 minutes at 70 °C. Cooked samples were then rinsed with cold water until they were cool. The samples were chilled for 40 minutes at 20-23 °C to remove exudates and physically wiped with a tissue (Rant *et al.*, 2019). According to Santos *et al*. (2022), the calculation was performed by subtracting the weight of the sample before and after cooking and then dividing the weight of the sample before cooking.

Meat tenderness was measured using the Texture Analyzer-700 tool. Tenderness measurements can be done by boiling the meat for 35 minutes in a 70 °C water bath until the internal temperature reaches 68 °C. The meat samples were removed and cooled for one hour until constant weight was achieved. The samples were weighed using a digital scale and then taken and cut using a crankcase tool. The samples were formed into a cube with a length, height, and side width of 1 cm, each following the direction of the meat fibers/parallel. The pieces of meat were then measured using a Texture Analyzer-700 to determine the breaking strength value in kg/cm^2.

Water, lipid, ash, and protein contents were among the variables examined (AOAC, 2005). The cholesterol levels were measured based on the method by Aksoy & Ulutas (2016). A lipid sample of approximately 0.3-0.5 g was collected from the cold extracted LD and BF muscles and placed in a closed container glass tube. Then, 0.3 mL KOH 33% and 3 mL 95% ethyl alcohol solution were added and thoroughly combined in a water bath at 60 °C for 15 minutes. The tube was cooled, 10 mL hexane and 3 mL distilled water were added, and the sample was roughly mixed before being maintained for 10 minutes to allow for phase separation. As much as 1 mL of the hexane fraction was extracted and placed in a test tube to evaluate the cholesterol content. Nitrogen gas was used to eliminate hexane. To generate FeCl3 working solutions, 840 mg FeCl3 and 10 mL of concentrated glacial acetic acid were combined to make a stock solution, and the stock solution (1 mL) was raised to 100 mL with concentrated glacial acetic acid. Later, 1.5 mL of FeCl3 solution was added to the test tube, and the solution was roughly stirred. After 15 minutes, 1 mL of concentrated sulfuric acid was added to the sample and mixed for 1 minute in a mixer tube. For 45 minutes, the tube was placed in a dark spot. The resulting purple color absorption value was read at a wavelength of 560 nm on a spectrophotometer. A cholesterol standard curve was established, and the samples' cholesterol content was quantified as mg cholesterol/100 g sample.

Statistical Analysis

The data were examined using analysis of variance, except for the Feed Cost/Gain, which was evaluated descriptively. When there were differences between the treatments, Duncan's multiple range test was applied (Steel & Torrie, 1991). Based on p<0.05, the degree of significance was determined.

RESULTS

Productivity of Lambs

Table 3 displays the impact of *C. pubescens* seed level on sheep productivity. There was no discernible difference in DMI, OMI, or TDN intake between treatment rations. The change in treatment significantly impacted the amount of crude protein consumed (p<0.05); the use of 20% *C. pubescens* treatment had the highest intake, which was not substantially different from the use of 12.5% *C. pubescens* but was considerably different from the use of 5% *C. pubescens*. In all treatments, there was no discernible difference in the DMD, OMD, or CPD. Compared to sheep fed using a 5% *C. pubescens* in ration, the BWG of sheep fed *C. pubescens* level 20% in the feed ration revealed a significant change (p<0.05), but not significantly different from the use of 12.5% *C. pubescens*. Treatment of 20% *C. pubescens* had the lowest FCR, which was substantially different from treatment of 5% *C. pubescens* (p<0.05) and was followed by treatment of 12.5% *C. pubescens*. The BWG of sheep fed 20% *C. pubescens* in the feed ration showed a significant change (p<0.05) but was not significantly different from the treatment use of 12.5% *C. pubescens*. FC/G treatment of 20% *C. pubescens* showed the lowest value compared to other treatments.

Carcass Characteristics

Table 4 shows the impact of *C. pubescens* levels on lamb carcass parameters in the feed. The results for the slaughter weight parameter were statistically different (p<0.05), with the highest slaughter weight results coming from the use of 20% *C. pubescens* treatment, followed by the use of 12.5% *C. pubescens* and the use of 5% *C. pubescens*. The weights of the meat, fat, and cold carcasses were noticeably different from those of the heated carcasses. Following treatments of 12.5% *C. pubescens* and 5% *C. pubescens*, the treatment of 20% addition of Carica level demonstrated the maximum weight of carcass, meat, and fat. Feed treatment containing 12.5% *C. pubescens* had a significantly different intermuscular fat weight from treatment use of 5% *C. pubescens* but not different from the treatment use of 20% *C. pubescens*. The weight of the bones, connective tissue, subcutaneous fat, percentage of (hot carcass, cold carcass, meat, intermuscular fat), meat-to-bone ratio, and lean-bone ratio did not differ significantly.

Physical and Chemical Quality of Lamb Meat

Table 5 presents the physical characteristics and chemical composition of local lambs fed varying amounts of *C. pubescens* seeds. This table demonstrates that adding *C. pubescens* seeds at various levels caused non-significant variation in the moisture, ash, protein, fat, and total cholesterol parameters in LD and BF muscles. The study of the physical quality of lamb meat showed that pH, water-holding capacity, and cooking losses were not significantly different in LD and BF lamb meat. Tenderness of the meat showed quite different results (p<0.05), whereas, in LD muscle, the meat treated with 12.5% was more tender than the use of 5% *C. pubescens* and 20% *C. pubescens*. For BF muscles, 12.5% *C. pubescens* was not different from using 5% *C. pubescens*, but significantly different from using 20% *C. pubescens*.

DISCUSSION

DM, OM, and TDN Intakes were not significantly different, indicating that feed with *C. pubescens* seed level had the same palatability, encouraging livestock to continue consuming feed following their energy needs and rumen capacity. Giving Carica seed levels

Table 3. Productivity of lambs fed diets with different levels of *Carica pubescens* seeds

Variables	Treatments			SEM	p-value
	T1	T2	T3		
DMI (g/days)	702.41	705.97	740.17	18.433	0.680
OMI (g/days)	617.72	620.05	655.88	16.377	0.595
CPI (g/days)	84.43^{b}	92.48^{a}	104.96^{a}	3.083	0.013
TDNI (g/days)	414.14	416.17	445.81	11.206	0,461
DMD (%)	56.68	59.95	64.40	1.697	0.180
OMD (%)	67.19	67.82	69.90	0.944	0.254
CPD (%)	71.70	68.46	66.29	1.377	0.287
BWG (g/days)	83.76^{b}	106.43^{a}	115.60^{a}	4.509	0.004
FCR	8.50^{b}	6.76^{a}	6.40^{a}	0.305	0.004
FC/G (IDR/kg)	27,592	22,156	21,344		

Note: T1= 40% Pakchong Grass + 55% Concentrate + 5% *C. pubescens*; T2= 40% Pakchong Grass + 47.5% Concentrate + 12.5% *C. pubescens*; T3= 40% Pakchong Grass + 40% Concentrate + 20% *C. pubescens*. DMI= dry matter intake; OMI= Organic matter intake; CPI= crude protein intake; TDNI= total digestible nutrient intake; DMD= dry matter digestibility; OMD= Organic matter digestibility; CPD= crude protein digestibility; BWG= body weight gain; FCR= feed cost ratio; FC/G= feed cost per gain.

Table 4. Carcass characteristics of lambs fed diets with different levels of *Carica pubescens* seeds

Variables	Treatments			SEM	p-value
	T1	T2	T3		
Initial weight (kg)	10.51	10.45	11.06	0.198	0.690
Final weight (kg)	16.37[a]	17.90[ab]	19.15[b]	0.198	0.012
Slaughter weight (kg)	16.90[a]	18.63[ab]	19.62[b]	0.454	0.036
Hot carcass (g)	6575[a]	7441[b]	7833[b]	196.497	0.017
Hot carcass percentage (%)	39.07	40.00	40.00	0.655	0.842
Cold carcass (g)	6345[a]	7241[b]	7566[b]	193.323	0.017
Cold carcass percentage (%)	37.73	38.93	38.61	0.681	0.780
Carcass component					
Meat weight (g)	3807[a]	4129[ab]	4490[b]	120.360	0.058
Meat percentage (%)	57.91	55.47	57.25	0.603	0.242
Fat weight (g)	1233[a]	1605[b]	1656[b]	69.809	0.015
Fat percentage (%)	18.65	21.71	21.12	0.696	0.164
Bone weight (g)	1407	1625	1608	51.727	0.163
Bone percentage (%)	21.44	21.70	20.56	0.397	0.498
Connective tissue weight (g)	376	334	355	17.147	0.634
Connective tissue percentage (%)	5.78	4.57	4.63	0.323	0.237
Distribution of carcass fat					
Subcutan fat weight (g)	858	958	1060	59.348	0.403
Subcutan fat percentage (%)	68.33	59.44	63.08	1.996	0.193
Intermuscular fat weight (g)	376[a]	647[b]	596[b]	34.181	0.000
Intermuscular fat percentage (%)	31.67	40.56	36.92		0.193
Meat bone ratio					
Meat bone ratio	3.69	3.64	3.89	0.090	0.516
Lean bone ratio	2.82	2.62	2.65	0.064	0.310

Note: T1= 40% Pakchong Grass + 55% Concentrate + 5% *C. pubescens*; T2= 40% Pakchong Grass + 47.5% Concentrate + 12.5% *C. pubescens*; T3= 40% Pakchong Grass + 40% Concentrate + 20% *C. pubescens*. Means in the same row with different superscripts differ significantly (p<0.05).

Table 5. Physical and chemical quality of lamb meat on the *Longissimus dorsi* and *Biceps femoris* muscle fed diets with different levels of *Carica pubescens* seeds

Variables	Treatments			SEM	p-value
	T1	T2	T3		
Physical quality					
Longissimus dorsi					
pH	6.09	6.13	6.01	0.086	0.874
Water holding capacity (%)	28.42	28.90	27.78	0.570	0.599
Cooking Loss	19.68	18.46	17.22	0.781	0.462
Warner–Bratzler shear force (WBS) (kgf/cm^2)	3.46[b]	2.79[a]	3.69[b]	0.130	0.005
Biceps femoris					
pH	6.06	6.03	5.98	0.359	0.711
Water holding capacity	27.08	26.25	25.68	0.857	0.818
Cooking Loss	16.67	17.64	19.79	0.815	0.294
Warner–Bratzler shear force (WBS) (kgf/cm^2)	3.58[a]	3.36[a]	4.10[b]	0.105	0.050
Chemical quality					
Longissimus dorsi					
Moisture (%)	75.97	75.43	74.50	0.275	0.079
Ash (%)	1.14	1.07	1.19	0.374	0.420
Protein (%)	19.29	19.35	19.51	0.187	0.901
Lipid (%)	3.16	3.27	3.67	0.228	0.653
Total cholesterol	72.42	67.44	70.13	1.638	0.489
Biceps femoris					
Moisture (%)	76.37	75.93	75.09	0.226	0.052
Ash (%)	1.14	1.12	1.14	0.268	0.976
Protein (%)	18.85	19.48	19.36	0.171	0.292
Lipid (%)	2.84	2.93	3.10	0.217	0.887
Total cholesterol	73.23	65.72	73.03	1.889	0.186

Note: T1= 40% Pakchong Grass + 55% Concentrate + 5% *C. pubescens*; T2= 40% Pakchong Grass + 47.5% Concentrate + 12.5% *C. pubescens*; T3= 40% Pakchong Grass + 40% Concentrate + 20% *C. pubescens*. Means in the same row with different superscripts differ significantly (p<0.05).

is considered to provide an excellent aroma to the feed, so it is preferred by the livestock. Urbano *et al*. (2017) state that feed palatability is one factor that affects the amount of feed consumption, affecting differences in the consumption of dry matter, organic matter, and crude protein. Increasing the level of Carica seeds gave different protein levels from the treatment; these results were in line with the research by Prima *et al*. (2019) that sheep-fed feed with varying protein levels resulted in consumption of DM that was not significantly different. The consumption of organic matter in feed is affected by the total consumption of dry matter because the nutrients in organic matter are also contained in the dry matter. Feeding in this study was in the form of pellets. According to Shrinivasa & Mathur (2020) and Li *et al*. (2021), the advantages of pelleted feed are increased feed consumption and efficiency. The use of 20% *C. pubescens* was assumed to have ingested more crude protein than the other treatments because of its greater dry matter intake. The quantity and quality of feed taken affect the amount of nutrients consumed. The higher the quantity and quality of feed, the better the feed's nutrient content. Increasing the amount of CP seeds in the diet will also increase its protein content, which may impact how much CP is consumed. This statement is consistent with the findings of Prima *et al*. (2019), who suggest that increasing the amount of feed protein may increase the consumption of crude protein.

Nutrient digestibility is shown in Table 3, where *C. pubescens* feeding level had no appreciable impact on the digestion of DM, OM, and CP. This result is because the increase in *C. pubescens* in this study was not followed by an increase in energy (iso energy), which is speculated to cause identical microbial formation. Digestibility was identical across all treatments, resulting in the same feed flow rate and feed intake. Feed digestibility and feed intake levels are closely correlated. Abid *et al*. (2020) assert that the amount of feed consumed impacts both dry and organic matter digestibility's. The digestibility values are relatively the same for a given feed consumption. The physical shape of feed materials, ratio composition, temperature, rate of passage through the digestive tract, and the impact on the ratio of the other nutritional compositions are among the variables that affect dry matter digestibility, according to Mertens & Grant (2020). According to Yanti *et al.* (2021), digestibility decreases with increasing crude fiber concentration in the feed ingredients. The study found that each treatment's crude fiber level ranged between 28.63% and 30.45%. Therefore, the dry matter's digestibility value likewise produced results that were not statistically different from each other. According to Avilés-Nieto *et al*. (2013), DMD was not significantly different in sheep-fed levels of *Gliricidia sepium* hay. Malekkhahi *et al*. (2015) produced DMD, and OMD was not considerably different in Baluchi sheep fed a high-concentrate diet.

The BWG of lambs fed ration with *C. pubescens* level of 20% is higher than the result reported by Purbowati *et al*. (2021) that a maximum BWG of 92.5 g/day in local sheep-fed fibrous agricultural waste to replace grass. On the other hand, this result is lower than that of Prima *et al.* (2019), who presented a BWG of 151 g/day in thin-tail sheep. Differences in the nutritional content of the feed given to sheep resulted in variations in BWG. About 24% of *C. pubescens* seeds consist of protein. This high protein content is considered to contribute to the higher BWG of lambs. Protein is a food substance that makes muscles grow, and energy can be used more effectively. NRC (2007) states that several variables affect body weight gain, including the total amount of protein consumed each day, type of livestock, age, genetic condition, environment, individual conditions, and rearing management.

The findings demonstrated that the feed conversion ratio decreased with increasing the level of Carica seeds fed. Sheep fed *C. pubescens* 5% had the highest FCR, whereas sheep fed *C. pubescens* 20% had the lowest FCR, followed by treatment that used *C. pubescens* 12.5%. Nutrient intake and production can be considerably increased by raising the amount of Carica seeds in the feed. The rapid growth rate will be accelerated by the high value of nutrients that can be absorbed, but the conversion value may be decreased. According to Oksbjerg & Therkildsen (2017), the feed conversion ratio will decrease when the rate of muscle growth, the average increase in body weight, and the amount of meat in the carcass increase quickly. When a sheep's muscle grows more quickly, its average body weight rises, and the meat in the carcass increases quickly, the feed conversion ratio may fall (Oksbjerg & Therkildsen, 2017). This study's FCR is superior to that of Purbowati *et al*. (2021), who generated FCR in the range of 9.1-13.5, and Luthfi *et al*. (2021), who caused FCR in sheep in the range of 6.8-10.7. BWG and FCR results affect FC/G. 20% *C. pubescens*-treated lamb had the lowest FC/G, followed by 12.5% *C. pubescens* and 5% *C. pubescens*. The decreased feed cost per kg increase in meat in lambs fed with 20% *C. pubescens* feed may be due to the replacement of the concentrate mixture with *C. pubescens* seeds, which had significantly higher CP digestibility (Devendar *et al.*, 2020). This occurrence follows the findings of Dhawale *et al*. (2018), who report that the replacement of concentrate mixtures at 25% and 50% levels with hydroponic corn feed results in lower production costs per kg for goats.

Adding seed *C. pubescens* levels to complete feed resulted in relatively significant differences in slaughter weight, carcass productivity, meat weight, and fat weight in grams. The optimal sheep ration quality is 12.5% *C. pubescens* and 20% *C. pubescens* treatments, which produce the highest carcass yields. According to Li *et al*. (2014), carcass characteristics have a significant effect because they are influenced by the energy and protein content of the feed provided. However, this study found that the percentage of carcass characteristic units was not significantly different, where sheep that received treatment using 5%, 12.5%, and 20% *C. pubescens* feeds produced the same production or carcass performance. It means that sheep fattened by increasing the seed *C. pubescens* concentration to 20% are ineffective in increasing carcass production significantly. It is estimated that the carcass percentage characteristics are not different because the carcass proportions are not much different, resulting in relatively the same percentage in each treatment. The research results indicated that the shrinkage value of hot and cold carcasses is still within the normal limits, namely no more than 2%. According to Grochowska (2017) and Mamani-Linares *et al*. (2013), the normal range of losses due to the withering or cooling of carcasses is around 1%-2%. This percentage difference can occur due to genetic factors, proportional development that may not yet appear, cutting weight, and handling before cutting. Prado *et al*. (2014) found no differences in carcass characteristics between male Frisian cattle fed low and high-protein rations.

However, in sheep, there were no statistically significant differences in bone weight, connective tissue weight, subcutaneous and intermuscular fat thickness, meat-to-bone ratio, or lean meat-to-bone ratio. Increasing seed *C. pubescens* levels to replace concentrate did not harm carcass production. According to Howes *et al*. (2015), legumes fed to sheep or feedstuffs containing protein sources use the protein more efficiently and grow faster than grass fed to sheep alone because the digestion speed is faster. Feeds containing *C. pubescens* seeds increased slaughter weight, carcass weight, and meat weight, according to the conclusions of Valizadeh *et al.* (2021), which state that carcass weight increases with increasing slaughter weight in livestock. The average slaughter weight and carcass weight in this study were lower than those reported by Purbowati *et al.* (2021) that young sheep had an average slaughter weight of 20.03 kg and carcass weight of 8.02 kg, but similar to the result reported by Setyaningrum *et al*. (2015) that young sheep had an average slaughter weight of 17.5-18.8 kg and a carcass weight of 7.67-8.50 kg.

The hot carcass percentage in this study was similar to the result reported by Somasiri *et al.* (2015) that carcass percentage of 37.5%-40.3% was found in Romney cryptorchid cross rams. According to Sabbioni *et al.* (2016) and Schreurs & Kenyon (2017), carcass production ranges from 40% to 52%. Meat weight is almost the same as the research results of Purbowati *et al.* (2021), which produced an average of 4,500 g of lamb, but lower than Prima *et al.* (2019), which produced an average of 6,700 g of meat, and Luthfi *et al.* (2022) which produced an average of 6,931 g of meat. Variations in feed consumption and slaughter weight can cause different meat yields.

Table 4 shows significantly different fat weights. Sheep fed 20% of *C. pubescens* had the most increased carcass fat, followed by sheep fed 12.5% and 5% *C. pubescens*. In this study, lambs treated with 20% of *C. pubescens* were thought to utilize nutrients to meet the nutritional requirements for maintaining, producing, and enhancing adipose tissue. This opinion aligns with Prache *et al.* (2022), who report that excess energy intake will be used to promote fatty tissue growth. Ponnampalam *et al.* (2008) confirm that livestock in a genotype at a certain age have fat and muscle deposition variations, and the cut weight affects the distribution of subcutaneous and intermuscular fat weight.

This study's bone weight was not different, likely because the research animals comprised young sheep of the same age group. The consumption of feed containing *C. pubescens* seed levels did not stimulate bone formation, and the bones formed in this trial were relatively small. Bone growth in cattle is consistent with prior studies, which found that bone growth occurs with age (Ríos-Rincón *et al.,* 2014; Luthfi *et al.,* 2022). This bone growth will continue until the sheep mature (Moloney & McGee, 2017).

Regarding the edible portion of the carcass, the meat-bone ratio is not a significant parameter. The meat-bone ratio in this study was greater than that of do Prado Paim *et al*. (2013), which reported a Santa Inês ram lamb muscle: bone ratio of 2.07-3.09; Gadekar *et al*. (2014) reported a Malpura lamb meat-bone ratio of 2.40±14; Obeidat *et al*. (2019) reported an Awassi lamb bone meat ratio of 2.95-3.10; Cornigliese sheep has the ratio of 2.22-3.09 as was reported by Sabbioni *et al*. (2016), but nearly similar to Purbowati *et al*. (2021) reported a bone-meat ratio of 3.67.

Table 5 displays the chemical composition of the meat. The results showed that the *C. pubescens* level did not affect lamb meat's water, protein, ash, fat content, and total cholesterol. It is suspected that the *C. pubescens* level does not affect the nutritional content of the meat. This finding is consistent with the results of Luthfi *et al.* (2022), who claim that the feeding level does not affect meat nutrition. These similar results are related to age and body weight because lambs were slaughtered at the same weight and age. Gebrehiwot *et al.* (2018) and Tahuk *et al.* (2018) state that typical meat has a water content value of 75% and 68%-80%, respectively, and the appropriate fat level of 2.5% and 1.5%-13%, respectively. This study's fat content was slightly lower than that of Tiven *et al.* (2015) (3.12%-4.39%), Luthfi *et al*. (2022) (5.06%-5.75%), and Setyaningrum *et al.* (2015), who reported research findings on water content (69.70%-73.97%), ash (0.87%-1.44%), fat (5.21%-9.14%), and protein (14.92%-15.01%). According to De Brito *et al*. (2016) and Ripoll & Panea (2019), consumer or public tastes currently favor meat with a low-fat content (lean meat). Fat also influences the gastro-hormonal circuits that control taste perception (Khan *et al.,* 2015). Although lipids are not considered health-promoting elements in and of themselves, low-fat meat is crucial in the meat industry (Torrico *et al.,* 2018).

Cholesterol is a natural sterol found in animal body tissues' cell membranes and is conveyed in blood plasma. Cholesterol is abundant in animal products. Only a minor fraction of the cholesterol in the body is derived from food; the body generates the majority of cholesterol. This study's total cholesterol level in LD and BF muscles was lower than reported by Aksoy *et al.* (2019), who identified that total cholesterol contents of longissimus dorsi (LD) and semitendinosus (ST) muscle lambs of all breeds were in the range of 99.4-223.28 mg/100g, and 68.7-166.2 mg/100g, respectively. Gonzales-Barron *et al.* (2021) determine a cholesterol content in *Longissimus thoracis et lumborum* in lambs from Biellese (51.73 mg/100g), Sambucana (28.53 mg/100g), and Texel-Merino-Blackhead-Charollais (TMBC) breeds (53.38 mg/100g). The low cholesterol level in lamb meat due to the feeding therapy is partly attributable to the slaughter age of the sheep employed in this study, which is still very young. Because the quantity of *C. pubescens* seed used contains tannins and has a mechanism for lowering cholesterol content, it can be inferred that meat cholesterol is fairly low due to tannins and saponins in the *C. pubescens* seed feed. Saponins reduce cholesterol absorption and enhance excretion (Hou *et al.,* 2023). Saponins can bind to cholesterol in the intestinal lumen, preventing reabsorption. Tannins can promote bile acid excretion, hence lowering cholesterol levels. Tannins have an antihyperlipidemic effect because they limit cholesterol production, decrease dietary cholesterol absorption, lower serum cholesterol levels, and increase bile acid excretion (Choudhary, 2013).

The results of research on pH in LD and BF muscles are higher than the ultimate pH of meat, which is 5.8 (Zhao *et al*., 2022). The higher pH is caused by low muscle glycogen reserves when slaughtered, which causes the lactic acid accumulation to stop since muscle glycogen reserves are depleted before the meat's pH is attained. Weighing cattle can cause stress before slaughter, reducing glycogen levels in the muscle mass. Several previous studies, however, have discovered significant changes in final meat pH amongst sheep breeds (Peña *et al.,* 2014; Ponnampalam *et al.,* 2017). The glycolytic, oxidative, and oxide-glycolytic activities of muscle fibers in skeletal muscle mass are frequently responsible for variance in final meat pH across breeds (Sen *et al.,* 2015; Şirin *et al.,* 2017). Şirin *et al*. (2017) found no significant relationship between pH and muscle fiber characteristics. The water-holding capacity and cooking shrinkage value are related to postmortem biochemical facts such as proteolysis, muscle protein shrinkage (actin and myosin), and cell wall breakdown. Water loss in meat harms meat quality attributes, including tenderness and juiciness.

Tenderness is another crucial factor to consider when buying meat. Tenderness is a quality component that determines the sensory features of meat and is defined as the ease with which flesh is eaten, penetration and cutting sensation, tensile strength, and residual presence. This research showed that tenderness of LD and BF meat was associated with an increased ability to hold water in treatment using 12.5% *C. pubescens* compared to the other two groups. Meat from lambs fed a forage-based diet was generally observed to be less tender than meat from lambs fed concentrates (De Brito *et al*., 2016). The results of this study were softer than those of Tiven *et al.* (2015), which signifies a value of tenderness in the range of 3.85-7.78 kg/cm^2. Dentinho *et al.* (2023) suggest that the consumers' acceptable shear force of sheep is below < 49 N. In this study, cooking loss values of LD and BF were measured as much as 17.22%-19.68% and 16.67%-19.79%. The cooking loss found in the present study was lower than 34.78% reported by Uğurlu *et al.* (2017) and 27.73%-30.54% reported by Aksoy *et al*. (2019).

CONCLUSION

The addition of *C. pubescens* seed to the complete feed of a young sheep fattening program up to 20% has no adverse effect on productivity, carcass, or meat quality. The inclusion level of *C. pubescens* seeds up to 20% increase in body weight gain (115.60 g/day), crude protein intake (104.96 g/day), feed cost ratio (6.40), carcass weight (19.6 kg), meat weight (4.21 kg), fat weight (1.65 kg), and FC/G IDR 21,344. Using *C. pubescens* seed debris as a feed source can be employed and studied at a higher level and with other experimental animals in future studies.

CONFLICT OF INTEREST

The authors state that they do not have any competing interests.

ACKNOWLEDGEMENT

This work was partially supported by BPPT Kemdikbud (Center for Education Financial Services, Ministry of Education, Cultural Research and Technology, LPDP (Indonesian Education Endowment Fund) to fund this research through the Indonesian Education Scholarship (BPI) or the Indonesian Education Scholarship Program Number: 0846/J5.2.3./BPI.06/10/2021, the Faculty of Animal Husbandry and Agriculture at Diponegoro University, and the Faculty of Agriculture at Tidar University. Thank you to the Carica processing companies in the Dieng area, Banjarnegara and Wonosobo Regencies, the Domba Berkah team (Adhi, Utha, Tegar, Rio, Dzakwan, Aan, Riki, Fadli, Alfina, Citra, Aufa, Uji, Dinda, Tina, Laurent, Alsa, Fia, Isti, Helen, Wanda, Dzakiyya, Toti, and Grace), for being a family and assisting in data collection during the project.

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