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Carcass production and physical meat characteristics of local rams fed with noni (*Morinda citrifolia*) seed flour on different levels

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ABSTRACT

This study evaluated effect of noni seed flour (NSF) on the physical characteristics of local ram meat. Twenty thin-tailed rams (aged 3-4 months) with an initial body weight (BW) of 12.43 ± 1.36 kg (CV = 10.95%) were designed in a completely randomized design (CRD) with four treatments and five replicates: T0 (control feed), T1 (90% control feed + 10% NSF), T2 (80% control feed + 20% NSF), and T3 (70% control feed + 30% NSF). Physical meat characteristics analyzed of the Longissimus dorsi (LD) and Biceps femoris (BF). ANOVA was used to analyze data at the 5% significance level, followed by Duncan's multiple range test (DMRT) when significant differences were found. The results showed that the diet did not significantly affect pH, water-holding capacity (WHC), or cooking loss (CL) of LD and BF. However, meat tenderness was significantly affected. LD muscle in T3 (2.56 kg/cm^2) was significantly higher ($P < 0.05$) than in T1 (2.63 kg/cm^2) and T0 (2.65 kg/cm^2) but not significantly different from T2 (2.58 kg/cm^2). Similarly, BF muscle in T3 (2.58 kg/cm^2) and T2 (2.59 kg/cm^2) was significantly higher ($P < 0.05$) than in T1 (2.64 kg/cm^2) and T0 (2.65 kg/cm^2). Average pH, WHC, and CL of LD were 5.43, 30.52%, and 27.57%, respectively, for BF were 5.44, 30.56%, and 27.88%. In conclusion, incorporating up to 30% NSF in the diet does not affect carcass quality and can serve as a carbohydrate source. Additionally, increasing NSF level in the diet tends to enhance meat tenderness.

Introduction

World population growth is steadily increasing. The population of the world has grown 8 billion and is still increasing annually (United Nations, 2025). As a result, the demand for meat is expected to rise. The nutritional content of lamb meat meets the modern consumer's preference for healthy meat. Over the past two decades, lamb has gained popularity worldwide (Li *et al*., 2022). According to the Food and Agriculture Organization of the United Nations, lamb accounts for about 5% of the world's meat consumption. It is especially prominent in Mediterranean countries such as Turkey, Greece, and Croatia. Similarly, in the Middle East, countries like Jordan, Iran, and Afghanistan consume lamb as a staple food. In 2023, global demand for lamb meat reached 16,954 tons (FAO, 2024). The top lamb-consuming countries per capita, according to the OECD Annual Sheep Meat Consumption List, include Australia (6.3 kg), Kazakhstan (5.9 kg), Türkiye (4.6 kg), Saudi Arabia (3.5 kg), and Norway (3.1 kg) (OECD, 2024).

Rams are generally reared using conventional methods, particularly in tropical countries. However, the conventional raising system often fails to achieve the ideal slaughter weight (SW). To address this issue, it is necessary to implement a feedlot system that provides nutrition meeting the rams' dietary needs which ensure high and efficient body weight (BW) gain. Prima *et al*. (2019) reported that rams raised in feedlots from 3-4 months of age for 84 days on a complete feed containing 13.3-17.6% crude protein (CP) and 60.3-61.5% total digestible nutrients (TDN) can reach an SW of 24.8-26.5 kg. Furthermore, feed is a critical factor in supporting livestock productivity and enhancing meat quality. However, high-quality feed is often expensive, making it difficult for farmers to afford, as many lack sufficient capital to purchase costly feed. As one of the solutions to this challenge, agricultural and industrial waste can be used as alternative feed ingredients to reduce high feed costs. Agricultural waste is abundant and underutilized, making it a relatively low-cost feed option. One such agricultural by-product is Noni (*Morinda citrifolia*) seeds, which are consistently available in Indonesia and have the potential to be a source of energy for livestock feed. One hundred grams of noni seeds (NS) contain 55.45 g of carbohydrates, 28.70 g of crude fiber (CF), and 7.47-9.20 g of protein (Jahurul *et al*., 2021).

Feed supplemented with NS is expected to increase rams' BW gain due to its high energy content, which may also improve meat quality. Physical characteristics such as pH, water-holding capacity (WHC), cooking loss (CL), and tenderness are used to evaluate the meat quality. Retrieved from Purbowati *et al*. (2009), age, sex, food, muscle function, and animal species all affect these characteristics. This study aimed to assess the physical characteristics of local lambs fed varying levels of noni seed flour (NSF). This research's outcomes are expected to benefit animal husbandry by demonstrating the viability of NS, an industrial by-product, as a novel energy source for animal feed.

Materials and methods

Animal, diets, and experimental design

For this experiment, a total of twenty thin-tailed rams, aged between 3 and 4 months, were selected, each having an average initial body weight (BW) of 12.00±1.36 kg (with a coefficient of variation, CV, of 10.95%). These animals were then assigned to a completely randomized design (CRD), involving four distinct dietary treatments, each with five replicates. The treatments consisted of varying levels of NSF: T0 received a control feed, T1's diet was 90% control feed plus 10% NSF, T2 was given 80% control feed with 20% NSF, and T3's feed comprised 70% control feed and 30% NSF. Details regarding the composition and nutritional value of these experimental diets can be found in Table 1.

Feeding, slaughtering, and carcass preparation

This experiment involved four key phases: preparation, adaptation,

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Table 1. Dietary ingredients and nutrient content of experimental diets.

Treatment	Experimental Feeds	DM	Nutrient content (%) in 100% DM					TDN[2]
			Ash	CP	EE	CF	NFE[1]	
T0	Control feed	91.25	7.98	14.21	4.19	19	54.62	58.93
T1	Control feed 90% + NSF 10%	93.45	7.52	13.07	4.48	23.24	51.69	57.09
T2	Control feed 80% + NSF 20%	93.4	7.33	12.54	4.38	24.88	50.87	58.1
T3	Control feed 70% + NSF 30%	93.6	7.68	11.63	4.28	27.26	49.15	60.23

[1]NFE was calculated based on Hartadi *et al*. (1986); [2]TDN was calculated based on the digestibility coefficient formula of Tillman *et al*. (1984).
DM= Dry matter, CP= Crude protein, CF= Crude fibre, EE= ether extract, NFE=Nitrogen free extract TDN= Total digestible nutrients

introduction, and treatment. The diet consisted of complete pellets, with feed and water available freely. Rams underwent weekly weigh-ins to track body weight gain and to inform subsequent dietary adjustments.

Rams were slaughtered at a weight of approximately 20-25 kg using the halal method. They were fasted for 12 hours, but water remained available. Slaughtering involved cutting the jugular vein, esophagus, and trachea to ensure complete blood drainage. Thereafter, the carcass was processed by removing the head, front legs, back legs, tail, skin, and all internal organs. The carcass was then weighed to determine the hot carcass weight and stored in a cooler at 18°C for 8 hours. After chilling, the cold carcass was divided symmetrically to obtain right and left halves. Samples of meat were taken from the thigh muscle (Biceps femoris, BF) and loin muscle (Longissimus dorsi, LD) for physical quality testing.

Physical meat characteristics analysis

The parameters used to evaluate meat's physical quality included cooking loss (CL), tenderness, pH value, and water-holding capacity (WHC). The pH value of LD and BF meat was measured using a pH meter after 8 hours of aging. CL was determined by measuring the weight difference between the initial sample (20 rams) and the cooked, which was heated in a water bath for 35 minutes at 71°C(Huang *et al*., 2023). Tenderness was assessed using a TX-7000 device. WHC was determined based on the weight difference between the initial dry filter paper and the wet filter paper after placing a 0.3 g meat sample between two glass plates, which were loaded with 1 kg for 10 minutes (Cohen-Zinder *et al*., 2017).

Statistical Analysis

This experiment was performed using a completely randomized design (CRD). Analysis of variance (ANOVA) with a 5% significance level was used to analyze the collected data. If a significant effect was found ($P < 0.05$), further analysis was performed using Duncan's Multiple Range Test (DMRT) (Astuti, 2007). Statistical analysis was conducted using SPSS version 27.

Results

Feed consumption and ADG

The data in Table 2 summarizes the rams' average daily gain (ADG) and feed consumption. Assessments of dry matter (DM) intake, crude protein (CP), total digestible nutrient (TDN) levels, and ADG revealed no statistically significant differences ($P > 0.05$) among treatments T0, T1, T2, and T3.

Carcass production

Table 3 details the average carcass production. Dietary variations did not significantly impact carcass production, specifically in terms of slaughter weight (SW), hot carcass weight (HCW), or cold carcass weight (CCW) ($P>0.05$).

Tabel 2. Feed consumption and ADG of lambs fed with different levels of NS.

Variable	Treatment			
	T0	T1	T2	T3
DM intake (g/day)	690.13±120.05	797.59±111.18	835.55±186.78	841.61±225.35
(% BW)	3.40±0.36	3.70±0.40	3.70±0.73	3.90±0.68
DM digestible (g/day)	345.2±86.90	404.00±69.80	433.3±126.78	482.7±139.42
DM digestibility (%)	50.02±11.94	50.65±6.26	51.86±3.52	56.07±4.61
CP intake (g/day)	97.4±17.06	108.2±14.53	100.0±23.42	86.7±22.70
CP digestible (g/day)	70.8±19.26	81.1±4.34	72.6±11.74	63.3±8.32
CP digestibility (%)	72.69±6.19	74.95±1.97	72.6±5.32	73.01±4.67
TDN (g/day)	406.68±79.48	455.29±70.22	485.43±116.50	518.46±118.39
ADG (g)	53.36±16.19	60.12±24.34	69.07±36.88	58.59±32.47

DM= Dry matter, CP= Crude protein, TDN= Total digestible nutrient, ADG= Average daily gain, BW= Body weight.

Tabel 3. Carcass Production of lambs fed NS at different levels.

Parameter		Treatment			
		T0	T1	T2	T3
Slaughter weight (Kg)		22.04±0.41	22.28±0.94	23.01±0.85	22.64±0.54
HCW	(Kg)	10.56±0.46	11.50±1.15	11.17±1.49	10.64±0.97
	(%)	47.91±1.75	51.61±3.67	48.54±5.37	46.99±4.19
CCW	(Kg)	9.53±0.48	10.52±1.10	10.19±1.38	9.67±0.92
	(%)	43.24±1.61	47.22±3.52	44.29±4.85	42.71±4.01

HCW= Hot carcass weight, CCW= Cold carcass weight.

Table 4. Physical meat characteristics of lambs fed NS at different levels.

Parameter	Muscle type	Treatments			
		T0	T1	T2	T3
pH	LD	5.43±0.06	5.45±0.02	5.43±0.03	5.42±0.04
	BF	5.44±0.02	5.44±0.01	5.44±0.02	5.42±0.01
WHC, %	LD	30.69±0.49	30.82±0.58	30.39±0.75	30.16±1.41
	BF	31.19±0.30	31.02±1.37	30.15±1.79	30.02±0.92
CL, %	LD	27.61±2.19	28.15±1.41	27.39±2.64	27.13±1.58
	BF	28.41±1.13	28.51±2.08	27.94±1.13	26.65±2.48
Tenderness, kg/cm^2	LD	2.65±0.05^{c}	2.63±0.01^{bc}	2.58±0.02^{ab}	2.56±0.05^{a}
	BF	2.65±0.02^{b}	2.64±0.02^{b}	2.59±0.03^{a}	2.58±0.01^{a}

^{a,b,c} Mean values with different superscripts within the same rows are significantly different at P<0.05.
WHC= Water holding capacity, CL= Cooking loss, LD: Longissimus Dorsi; BF: Biceps Femoris.

Physical meat characteristics

The physical characteristics of the meat are presented in Table 4. The results indicate that pH, WHC, and CL did not differ significantly (P > 0.05). The results of ANOVA on the observation of meat tenderness were significantly different (P<0.05).

Discussion

The absence of variation in DM intake suggests that incorporating NS into the complete feed does not affect palatability, thereby maintaining DM intake at a consistent level. This is supported by the fact that the percentage of consumption relative to body weight (BW) remains within normal limits. Nobre *et al*. (2020) and Purbowati *et al*. (2008) reported that DM intake as a percentage of BW typically ranges from 3.6% to 5.31%. A lower feed intake rate prolongs the residence time of feed in the digestive tract, consequently slowing down the rate of feed consumption. The uniformity in feed particle size may explain the similar DM intake values across treatments, as the rate of passage through the digestive tract remains relatively consistent. Nugroho *et al*. (2013) stated that the physical form and particle size of feed can influence DM intake.

The similarity in CP intake among treatments was likely due to the relatively consistent dry matter (DM) intake. NS contains only 4% protein, so higher inclusion levels reduce the overall CP content of the diet. However, this reduction does not affect average daily gain (ADG). The NS-based diets in this study yielded CP levels ranging from 11.63% to 14.21%, with CP intake recorded at 86.7–108.2 g/day. The CP intake observed in this study closely aligns with the findings of Muktiani *et al*. (2013), who examined local lambs (1 year old, 13.27 kg BW) fed vegetable waste supplemented with minerals and alginate. Their study reported a CP intake range of 87.46–129.10 g/day.

The inclusion of noni seed flour in the diet did not affect dry matter (DM) intake which resulted in similar TDN values. In this study, TDN levels remained relatively consistent (Table 1). Purbowati *et al*. (2009) suggested that when TDN values are similar and DM intake does not differ significantly, TDN is unlikely to show statistical variation. The average TDN observed in this study was 466.46 g/day, which closely aligns with the findings of Purbowati *et al*. (2009), who reported 469.37 g/day. However, the TDN values in this study were lower compared to those reported by Brant *et al*. (2022), who examined Dorper and Santa Inês crossbred lambs and found TDN ranging from 944.59 to 1,022.08 g/day. Brant *et al*. (2022) recorded a DM intake of 1,313–1,420 g/day, whereas DM intake in this study was lower, ranging from 690.1 to 860.8 g/day.

The results of average daily gain (ADG) observations across dietary treatments showed no significant differences due to the similar dry matter (DM) intake, which resulted in relatively consistent crude protein (CP) intake and total digestible nutrients (TDN). The inclusion of noni seed (NS) in the diet did not affect feed consumption which led to an ADG that was not significantly different among treatments. ADG of livestock is influenced by the nutrients consumed. The consumption of DM, CP, and TDN in this study was relatively the same, so the resulting ADG was not significantly different. Purbowati *et al*. (2009) stated that the main nutrient in fattening is energy so TDN between treatments that are not significantly different will be directly proportional to ADG.

The addition of NS to the ration does not impact feed consumption; thus, the lambs exhibit a relatively consistent growth rate and carcass weight, with no significant differences observed. In this study, the lambs were slaughtered at a slaughter weight (SW) ranging from 22.04 to 23.01 kg, with a cold carcass weight (CCW) of 9.53 to 10.52 kg and cold carcass percentages between 42.71% and 47.22%. The same results were also seen in the research of Prima *et al*. (2019) which reported that sheep slaughtered at SW of 24.8-26.5 kg produced a cold carcass percentage of 44.35-46.15%. Jatnika *et al*. (2019) stated that carcass weight will increase at SW between 15-24.5 kg.

In this experiment, the pH values ranged from 5.42 to 5.44, which falls within the normal range. The typical pH value of meat was between 5.4 and 5.8 (Rahayu *et al*., 2015). The supplementation of NSF in the ration produces a similar pH, this is due to the relatively same feed consumption thus the glycolysis activity produced is relatively the same. Falahudin and Imanudin (2018) stated that similar pH of meat may have relatively the same glycogen content in the muscle between dietaries so that the availability of lactic acid in postmortem conditions has a relatively similar amount.

The observation of WHC in this study was not significantly different, which ranged from 30.02-31.19%. The WHC in this study was classified as normal. This is supported by the results of research by Nobre *et al*. (2020) who reported the results of WHC of 31.15-34.29%. The results of this study are lower than the research of Cohen-Zinder *et al*. (2017) who reported the results of WHC of 44.14-45.01%. This is thought to be due to the higher pH difference in meat. The research of Cohen-Zinder *et al*. (2017) reported a pH ranging from 5.68-7.02 while this study had a lower pH value of 5.42-5.45. Harsita and Najah (2024) argued that the higher the pH value will increase the WHC. The supplementation of NSF in the ration does not affect WHC, because the amount of WHC is correlated with the pH of the meat. During rigor mortis, glycolysis affects muscle proteins, causing water to leave the muscle fibers (Rahayu *et al*., 2015). High levels of muscle protein will increase the ability to hold water to reduce the free water content, when the higher the amount of free water, it can reduce its WHC (Komariah and Sarjito, 2009).

The observed CL values in this study did not differ significantly, ranging from 26.65% to 28.51%. These values fall within the normal range, as supported by Silva *et al*. (2024), who reported meat CL values between 22.7% and 32.3%. Relatively similar research results were also reported by Falahudin *et al*. (2018) who got CL of 28.57-30.45%. The supplementation of NSF in the ration did not affect the CL of meat. CL can be influenced by the pH value, the amount of water that comes out of the meat, the age of the meat, the ability of the meat to hold water, and protein degradation (Falahudin and Imanudin, 2018). The pH and WHC of the meat from this study were relatively the same, so CL was also relatively the same. The high value of CL indicates the amount of cell membrane destruction and protein degradation which is quite a lot so the ability of meat to hold water decreases (Rahayu *et al*., 2015).

The results of statistical analysis showed that the tenderness of LD at T3 was significantly lower than T0 and T1 but not significantly different from T2. LD in T2 was more tender ($P<0.05$) than T0, but relatively the same with T1. On the other hand, LD meat in T1 and T2 was relatively similar. In BF, the tenderness value in T3 was not significantly different from T2, but significantly different ($P<0.05$) from T0 and T1, and the tenderness of T0 and T1 meat was relatively similar. The supplementation of NSF in the ration affected meat tenderness because it had a higher TDN content than the control feed. A higher level of NSF supplementation increases the TDN content in feed, which tends to enhance its energy value. When excess energy remains after meeting basic living needs, it is utilized for growth and body fat formation, potentially improving meat tenderness. This aligns with the findings of Darmayanti *et al*. (2013), who stated that a high feed energy content, increased feed consumption, and limited movement activity contribute to more tender meat.

Conclusion

This study concludes that the physical characteristics of ram meat from rams fed NSF at levels up to 30% indicate that it can be used as a carbohydrate source in feed without negatively affecting carcass quality. Moreover, increasing the NSF level in the diet tends to enhance meat tenderness.

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Conflict of interest

The authors have no conflict of interest to declare.

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