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Research article

Lamb meat quality and fatty acid composition from diets supplemented with water spinach waste

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Abstract

The research investigated the effect of feed-containing water spinach on meat quality in male and female sheep post-weaning. A total of 16 thin-tailed sheep aged five months old were distributed into two treatments. Feed treatment was control (T1) and pelleted feed with 20% water spinach (T2). Data physical properties and chemical composition of meat were analyzed variance using a 2 × 2 factorial completely randomized design. The result shows that feeding lambs with water spinach pellets did not significantly alter the physical properties, such as cooking loss, moisture content, tenderness, and pH, of either LD or BF muscles. However, male lambs showed increased tenderness in LD and a higher redness level (a*) in BF compared to females. Regarding chemical composition, feeding with water spinach pellets had no significant impact ($P>0.05$) on the moisture, protein, fat, and ash content of lamb meat, although sex differences were observed. Male lambs showed higher cholesterol levels and larger percentage of saturated fatty acids (SFA) in the LD, while female lambs had higher protein content in the BF ($P<0.05$). Fatty acid analysis found that the addition of water spinach on feed enhanced linolelaidic acid (C18:2n6t) in the LD muscle ($P<0.05$). This increase in polyunsaturated fatty acids (PUFA), particularly linolelaidic acid and linolenic acid, that is the nutritional potential of water spinach as a feed ingredient. Overall, the application of pelleting technology in this study has no negative impact on meat quality, and it will be a feasible technique for feeding animals efficiently.

Keywords: Feed, Lamb, Pellet, Sheep, Water spinach.

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INTRODUCTION

Forage is the primary source of feed for ruminants; therefore, its quality will affect livestock productivity. Most of the forage that breeders widely use comes from agricultural waste. The weakness of this forage quality is the high fiber and low content of other nutrients, which causes inefficient nutrient utilization (Yanti and Yayota, 2017; Georganas et al., 2020).

One technology that can be applied to break down cell walls and increase the efficiency of nutrient utilization in the rumen is pellet technology. Pellet feed can reduce fiber content (Neutral detergent fiber (NDF), Acid detergent fiber (ADF), Acid detergent lignin (ADL), cellulose), and anti-nutritional content and does not affect reducing the protein content of the feed (Oyaniran et al., 2018) when compared to unprocessed pelleting feed. In addition, pelleted feed facilitates non-palatable feed ingredients and can increase the productivity of sheep (Eldin et al., 2011; Zhong et al., 2018).

Water spinach is a forage source of fiber and protein that is widely produced in Indonesia. The land area planted with water spinach reaches 47,805 ha, with production reaching 276,976 tonnes or 5.79 tonnes/ha (Statistic Indonesia, 2017). Water spinach contains crude protein reaching 5.18-24.60%, fiber 13.00-17.67%, dry matter 10.30%, and organic matter 87.60% (Umar et al., 2007). In addition, water spinach also contains high minerals, amino acids (Ndamitso et al., 2015), and fatty acids such as linoleic, linolenic, and nervonic acid (Mukherjee et al., 2010).

The nutrient content of the feed affects the meat quality specially on fatty acids that is also criticized because of its composition (Ramírez-Retamal and Morales, 2014; Assan, 2020). Fatty acid composition has a significant impact on the nutritive value and the organoleptic characteristics of meat that is influenced by changes in both the total amount and relative proportions of certain fatty acids (Díaz et al., 2002; Fisher et al., 2000). Lamb meat typically exhibits a low ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA), which may elevate the risk of cardiovascular issues and other health concerns. The P/S ratio in a standard diet is 1.0 (WHO, 2008), whereas in lamb meat, it is 0.16-0.23 (Miltko et al., 2019). Numerous research have established that the composition of fatty acids in meat can be affected by production procedure, animal breed and sex, slaughter age and live weight, and level of fatness (Ekiz et al., 2013; Boughalmi and Araba, 2016; Domínguez et al., 2018). However, research on the supplementation of feed with pelleted water spinach to enhance lamb meat quality remains limited. This technology would be a promising concept to investigate a novel feeding strategy in sheeps. Therefore, the study aimed to evaluate the potential of water spinach pellets as animal feed to improve the meat quality of lamb.

MATERIALS AND METHODS

Ethical approval

This experimental study was approved by the Research Ethics Committee of the Faculty of Veterinary Medicine, Universitas Gadjah Mada, Yogyakarta, Indonesia with the ethical clearance No: 00025/EC-FKH/Eks./2021.

Study period and location

The study was conducted from June 2019 to April 2021 at the Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Experimental design, animals, and diet

This study's experimental design was a completely randomized design 2 × 2 factorial. Sixteen 5-month-old thin-tailed sheep with an average weight of 10.81 ± 0.78 kg for males and 11.76 ± 1.07 kg for females were studied. The sheep were divided into two dietary treatments: *Pennisetum purpureum cv. Mott* fed pelleted as control (T1) and pellet feed contain 20% water spinach (T2). The number of sheep for each treatment was four males and females, respectively. Sheep was placed in an individual cage and equipped with a place for eating and drinking for three months of the experiment period. The adaption period was carried out for 14 days and then followed by a preliminary period for seven days to determine animal feed requirement. Feed and water were provided *ad libitum* with the feed formulation based on National Research Council (NRC, 2007). The nutrient composition of the ingredients and pelleted feed, as presented in Table 1 and Table 2, was determined through proximate analysis. All feed ingredients were analyzed for dry matter (DM; method 930.15; AOAC, 2005), crude protein (CP; method 990.03; AOAC, 2005), extract ether (method 954.02; AOAC, 2005), and crude fiber (CF; method 973.18; AOAC, 2005). The pelleting process commenced with the reduction of feed material particle size utilizing a 3 mm hammer mill. The feed ingredients were subsequently combined with molasses, which served as a binder, and heated to a temperature of 75-80°C for 15 minutes. The moisture content of the mixture was then adjusted to 16-18% by maintaining a temperature of 60-65°C. Finally, the mixture was subjected to milling and pelletizing using a 6 mm screen. Feeding pellets were started in the second week in stage, namely 20, 40, 60, 80, and 100% for four days per additional pellet feed. Feeding 3% of the sheep's body weight and given twice a day in the morning at 07.00 and afternoon at 15.00.

Table 1 Nutrient content of feed ingredients

Parameters (%)	*Pennisetum purpureum cv. Mott*	Concentrate	Water spinach	Soybean meal
Dry matter	92.93	88.87	89.42	89.15
Organic matter	83.43	89.77	84.60	92.40
Crude fiber	31.49	17.59	21.62	5.10
Crude protein	6.70	12.60	10.65	48.54
Extract ether	1.35	2.66	1.86	1.30
Ash	16.57	10.23	15.40	7.60
Nitrogen-free extract	43.89	56.92	50.47	37.46
Total digestible nutrient	47.16	61.85	54.28	93.71
Hemicellulose	21.18	28.48	27.24	-
Cellulose	30.70	25.35	26.88	-
Lignin	12.67	11.47	12.22	-

Slaughter and lamb quality

At the end of the experiment period (3 months), four sheep from each feed treatment and sex were slaughtered to determine lamb quality. After slaughter, the carcasses were cooled to 4°C for 24 h. The *Longissimus dorsi* (LD) and *Bicep femoris* (BF) of lamb were collected (500g each) for physical properties and chemical composition test. Analysis of the physical properties of lamb consisted of cooking loss, moisture content, tenderness, pH, and meat color. The lamb chemical composition tested includes dry matter (DM), organic matter (OM), crude protein (CP), extract ether (EE), and cholesterol.

Determination of lamb physical properties

First, the prevalence of FPL was calculated for all cats examined in the accepted studies. The Chi-square test was used to assess significant variation among countries (GraphPad Prism for Windows version 9, USA). Commercial Meta-Analysis software was used (Comprehensive Meta-Analysis software version 2, Biostat, Englewood, NJ, USA). In both random- and fixed effects models, effect size, 95% confidence intervals, variance, heterogeneity, relative weight, and publication bias were the main tests. The effect size was expressed by both *P* and standardized Z-statistics. Cochran's Q test was conducted to assess heterogeneity, and the I^2 statistic was used to determine the proportion of heterogeneity (Duffield et al., 2008). A funnel plot was generated to assess the degree of publication bias (Higgins et al., 2011). Egger's linear regression intercept (Egger et al., 1997) and the Begg–Mazumdar rank correlation tests were also applied (Begg and Mazumdar, 1994).

Table 2 Formulation and nutrient content of the pelleted feed

Feed	T1	T2
Formulation (%)		
Pennisetum purpureum cv. Mott	60	40
Water spinach	0	20
concentrate	25	28
Soybean meal	15	12
Total	100	100
Nutrient composition (%)*		
Dry matter	90.74	90.39
Organic matter	86.27	87.91
Crude protein	13.72	14.36
Extract ether	2.14	2.02
Crude fiber	21.43	22.03
Ash	13.73	12.09
Nitrogen-free extract	48.97	49.51
Total digestible nutrient	57.27	58.15
Hemicellulose	19.77	22.86
Cellulose	18.60	23.83
Lignin	12.48	10.55

T1: control; T2: Pelleted feed with 20% of water spinach (T2); *: Proximate analysis

Determination of lamb chemical composition

The chemical quality of the meat tested include dry matter (DM), organic matter (OM), crude protein (CP), extract ether (EE), was determined by the method of (AOAC, 2005). The cholesterol level was measured using the spectrophotometric method (Dinh et al., 2008). One gram of meat sample was added 10 mL of acetone:alcohol (1:1) in a test tube and then heated in a water bath until boiled. The solution was cooled at room temperature and centrifuged for 15 minutes at 3000 rpm. The supernatant was evaporated using a water bath until the residue remains and was added with 2 mL of chloroform and 2 mL of concentrated sulfuric acid:acetic anhydrite (1:30), then vortexed until homogeneous. The solution was read using a spectrophotometer at 680 nm. Fatty acids were analyzed using carcass meat on the right side of the loins, thighs, and shoulders. The preparation of meat fatty acid methylation was carried out by in situ transesterification method, and the levels of fatty acids were read using gas chromatography (Shantha and Napolitano, 1992).

Statistical Analysis

The data of lamb quality were statistically measured using a completely randomized design 2 × 2 factorial. Data analysis was conducted using IBM SPSS Statistics 26 statistical program and Duncan's Multiple Range Test (DMRT) was used to compare means between the treatments. The statistical significance of all analyses was set at $P < 0.05$ for probability values.

RESULTS

Physical properties

The physical properties of *Longissimus dorsi* (LD) and *Bicep femoris* (BF) lamb fed with pellets containing water spinach shown in Table 3 and Table 4. Sheep feed with water spinach pellets did not affect the physical properties of LD and BF lamb. Male LD lamb had higher (P<0.05) tenderness than female, while male BF lamb had higher (P<0.05) redness level than female. There was no interaction between pellet feed and sex on the physical properties of LD and BF lamb.

Table 3 Physical properties of *Longissimus dorsi* (LD) and *Bicep femoris* (BF) lamb fed water spinach pellets

Parameters	Treatment				p-value		
	T1		T2		Feed	Sex	Feed*sex
	Male	Female	Male	Female			
Longissimus dorsi							
Cooking Loss (%)	26.68	27.47	27.86	25.79	0.949	0.869	0.713
Moisture content (%)	59.71	56.24	58.80	53.83	0.558	0.163	0.789
Tenderness (kg/cm³)	3.70	3.18	4.42	2.50	0.954	0.017	0.118
pH	5.54	5.28	5.77	5.61	0.126	0.241	0.766
Bicep femoris							
Cooking Loss (%)	35.36	32.41	39.17	33.59	0.351	0.130	0.615
Moisture content (%)	54.61	52.15	58.01	53.45	0.369	0.195	0.682
Tenderness (kg/cm3)	3.52	3.11	3.19	3.38	0.949	0.829	0.542
pH	5.68	5.39	5.67	5.82	0.127	0.558	0.106

T1: control; T2: Pelleted feed with 20% of water spinach (T2)

Table 4 Color of *Longissimus dorsi* (LD) and *Bicep femoris* (BF) lamb fed water spinach pellets

Parameters	Treatment				p-value		
	T1		T2		Feed	Sex	Feed*sex
	Male	Female	Male	Female			
Longissimus dorsi							
Lightness	46.36	42.44	40.14	40.80	0.194	0.571	0.431
Redness	16.49	19.94	15.92	16.27	0.133	0.171	0.254
Yellowness	5.33	7.40	4.11	5.14	0.151	0.195	0.645
Bicep femoris							
Lightness	44.32	47.51	44.68	40.59	0.208	0.856	0.167
Redness	20.29	14.89	21.35	19.19	0.105	0.034	0.296
Yellowness	5.79	4.20	7.45	6.78	0.117	0.374	0.712

T1: control; T2: Pelleted feed with 20% of water spinach (T2)

Chemical composition

The chemical composition of lamb on LD and BF by feeding pellets containing water spinach was shown in Table 5. The addition of water spinach to sheep feed pellets did not affect the chemical composition of LD and BF lamb. Female BF lamb had higher protein than the male. Male LD lamb cholesterol was higher than the female (P<0.05), although CP of BF was lower (P<0.05) than female. In addition, other meat chemical compositions were not affected by sex. There was an interaction between pellet feed and sex on the protein content of the BF lamb.

Table 6 shows the research results for the sex variable. It shows that male sheep in the LD section produced more SFA (C14:0; C15:0; C17:0; C17:1) and PUFA in the form of linolenic acid (C18:3n6) than female sheep. On the other hand, the feed treatment (T2) significantly increased the amount of PUFA in LD, particularly linolelaidic acid (C18:2n6t). Furthermore, the influence of feed and sex shows a significant effect on the stearic (C18:0) and linolelaidic acid (C18:2n6t) content in the LD section. The BF section of the lamb (Table 7) displays a different result, indicating that the feed treatment has no effect on the lamb's fatty acid content. However, the difference in sex shows significant results consistent with the fatty acid content in the LD section, where male lambs produce higher SFA

(C17:0; C18:0) compared to females. Meanwhile, the influence of feed and sex differences shows significant results on linolenic acid. (C18:3n3).

Table 5 Chemical composition of *Longissimus dorsi* (LD) and *Bicep femoris* (BF) lamb fed water spinach pellets

Parameters	Treatment				p-value		
	T1		T2		Feed	Sex	Feed*sex
	Male	Female	Male	Female			
Longissimus dorsi							
Dry Matter (%)	64.74	67.28	66.27	67.55	0.463	0.143	0.604
Organic Matter (%)	69.14	65.97	63.25	67.77	0.739	0.912	0.535
Extract ether (%)	5.87	6.03	5.67	5.88	0.363	0.338	0.867
Crude protein (%)	23.24	21.52	21.88	22.60	0.363	0.530	0.152
Cholesterol (mg/100g)	66.54	36.91	55.23	37.77	0.446	0.008	0.379
Bicep femoris							
Dry Matter (%)	67.62	66.90	68.66	69.66	0.433	0.955	0.717
Organic Matter (%)	68.23	72.84	68.42	60.21	0.406	0.805	0.392
Extract ether (%)	5.81	5.77	5.38	5.52	0.179	0.810	0.705
Crude protein (%)	21.40	20.93	19.94	23.76	0.258	0.019	0.006
Cholesterol (mg/100g)	73.08	39.10	47.59	53.24	0.686	0.327	0.184

T1: control; T2: Pelleted feed with 20% of water spinach (T2)

Table 6 The fatty acid of *Longissimus dorsi* (LD) lamb fed water spinach pellets

Parameters	Treatment				p-value		
	T1		T2		Feed	Sex	Feed*sex
	Male	Female	Male	Female			
Myristoleic (C14:0)	6.71	4.71	7.56	4.98	0.568	0.040	0.764
Pentadecanoic (C15:0)	0.68	0.49	0.76	0.49	0.037	0.027	0.335
Palmitoleic (C16:1)	24.86	26.52	24.51	26.16	0.382	0.070	0.982
Heptadecanoic (C17:0)	0.69	0.52	0.77	0.49	0.548	0.001	0.189
Cis-10 Heptadecenoic Acid (C17:1)	1.32	1.11	1.28	1.02	0.386	0.012	0.756
Stearic (C18:0)	0.36	0.21	0.18	0.38	0.943	0.688	0.033
Linoleic Acid (C18:2n6c)	22.92	16.88	19.48	18.47	0.637	0.099	0.219
Linolelaidic Acid (C18:2n6t)	38.87	46.61	49.35	45.17	0.028	0.322	0.008
Linolenic Acid (C18:3n6)	2.00	1.66	2.82	1.83	0.103	0.037	0.257
Linolenic Acid (C18:3n3)	0.24	0.23	0.42	0.24	0.132	0.145	0.158
Arachidic Acid (C20:0)	0.43	0.45	0.64	0.38	0.504	0.216	0.146
Cis-8-11-14 Eicosatrienoic Acid (C20:3n6)	0.13	0.11	0.12	0.133	0.545	0.760	0.153
Arachidonic Acid (C20-4n6)	0.24	0.20	0.30	0.22	0.236	0.087	0.557
Heneicosanoic Acid (C21:0)	0.50	0.36	0.54	0.49	0.423	0.806	0.653
Eruchic Acid (C22:1n9)	0.12	0.15	0.13	0.133	0.862	0.395	0.493

T1: control; T2: Pelleted feed with 20% of water spinach (T2)

DISCUSSION

Physical properties

There was no significant difference in cooking loss, moisture content, tenderness, and pH of LD and BF lamb among the dietary treatment groups. Similarly, Du et al. (2019) of alfalfa did not affect cooking losses, tenderness, and pH. Sex has a significant effect on the tenderness value of LD lamb. According to the result, male sheep had higher meat tenderness than females. These results contradict various other studies that indicate male lamb produce leaner carcasses than ewes. Leaner carcasses are associated with less juicy and less tender meat (Gkarane et al., 2017; Hoffman et al., 2020). Tenderness related to proteolysis that is enzymatic system of calpains in skeletal muscle which activated by free calcium and inhibited by protein called calpastatin (Koohmaraie, 1994; Boleman et al., 1997). Meat from males is less tender compared to females due to higher calpastatin and μ-calpain activity at 24 hours post mortem in meat (Morgan et al., 1993). In addition, calpain and μ-calpain activities are also related to various factors such as temperature, pH, and oxidation (Baht et al., 2018). High temperatures cause an earlier loss of μ-calpain activity and lower calpain stability. Moreover, high temperatures (above 25°C) during the rigor process also decrease calpain activity (Geesink et al., 2000; Li et al., 2004). Sheep-fed pellets with water spinach addition have no different meat color. Research by Du et al. (2019) showed that sheep fed with pellets and grass had no difference in the L*, a*, and b* value of meat. The use of grass in feed does not affect the color of lamb (Díaz et al., 2002). Hwang et al. (2018) reported that alfalfa use in goat feed did not affect the L*, a*, and b* color of goat meat than commercial pellet feed.

Table 7 The fatty acid of *Bicep Femoris* (BF) lamb fed water spinach pellets

Parameters	Treatment				p-value		
	T1		T2		Feed	Sex	Feed*sex
	Male	Female	Male	Female			
Myristoleic (C14)	3.89	4.25	4.23	4.09	0.915	0.892	0.755
Pentadecanoic (C15:0)	0.37	0.44	0.39	0.38	0.741	0.537	0.370
Palmitoleic (C16:1)	22.45	24.21	25.26	24.21	0.256	0.752	0.274
Heptadecanoic (C17:0)	0.81	0.63	0.69	0.50	0.121	0.036	0.946
Cis-10 Heptadecenoic Acid (C17:1)	1.36	1.19	1.30	0.99	0.622	0.357	0.786
Stearic (C18:0)	1.23	0.41	0.86	0.43	0.461	0.027	0.422
Linoleic Acid (C18:2n6c)	43.38	44.05	35.44	45.11	0.493	0.312	0.375
Linolelaidic Acid (C18:2n6t)	0.50	0.37	0.52	0.69	0.343	0.355	0.363
Linolenic Acid (C18:3n6)	4.25	4.43	3.50	4.18	0.233	0.296	0.522
Linolenic Acid (C18:3n3)	0.59	0.29	0.22	0.60	0.737	0.688	0.007
Arachidic Acid (C20:0)	0.31	0.34	0.32	0.33	0.960	0.727	0.920
Cis-8-11-14 Eicosatrienoic Acid (C20:3n6)	0.29	0.27	0.26	0.24	0.857	0.826	0.833
Arachidonic Acid (C20-4n6)	0.76	0.72	0.75	0.74	0.961	0.808	0.884
Heneicosanoic Acid (C21:0)	2.53	1.90	2.09	2.37	0.976	0.757	0.419
Eruchic Acid (C22:1n9)	0.65	0.55	0.37	0.56	0.145	0.571	0.129

T1: control; T2: Pelleted feed with 20% of water spinach (T2)

Male BF lamb had a higher a* value than female, but LD lamb color was no different. A higher a* value indicates that meat has more red. Due to a higher myoglobin concentration, the redness meat color results in more red color (Kim et al., 2010; Suman and Joseph, 2013). Male livestock has a higher myoglobin content and heme iron (Seideman et al., 1984; Florek et al., 2016), the highest iron levels have led to more redness of meat (Suman and Joseph, 2013). In addition, female lamb contains more intramuscular fat than male, which causes a lower a* value (Okeudo and Moss, 2007; Holman et al., 2014). In the present study, we have found that color was affected by sex, but the results show more inconsistency. Marenčić et al. (2018) showed that male beef has lower redness than females. Santos et al. (2015) found significantly lower redness values in male lamb, but Rodrigues et al. (2011), de Araújo et al. (2017), and Mazon et al. (2017) did not find color differences between sex. Okeudo and Moss (2008) study indicates that sex affects a* value of lamb but not L* and b*.

Chemical composition

Sheep fed with pellets containing water spinach has a no different chemical composition of meat. The result was in line with research by (Paula et al., 2013; Islam et al., 2017; Du et al., 2019; Li et al., 2021), who reported that sheep fed with pellets and grass had the same meat chemical composition. The addition of alfalfa in goat feed did not affect the moisture content, protein, fat, and ash of meat (Hwang et al., 2018). Pelleting technology could be attributed to the higher feed intake, which likely contributed to improved growth performance (Li et al., 2021).

Female BF lamb had higher protein content than males, while the DM, OM, and EE were not different. Feed protein is used by livestock for muscle and bone development, body maintenance, and reproductive processes. Presumably, the lower protein content in males' lamb is due to feed protein in weaning male sheep was used for reproduction preparation, leading to lower deposition in meat. The study of Vnučec et al. (2016) showed that the chemical composition of both male and female lamb was no different. de Araújo et al. (2017) reported that the meat of male and female sheep had no different moisture, protein, fat, and ash content. The moisture content, protein, and ash of meat were not different among both sexes (Rodrigues et al., 2011).

The better ability of male sheep to synthesize fat causes the cholesterol of male sheep were higher than female (Chen, 1962; Moon et al., 2016; Palmisano et al., 2018). In addition, female lamb has progesterone hormone, which has a negative effect on cholesterol synthesis. The hormone progesterone inhibits sterol movement for cholesterol biosynthesis from the lysosome to the plasma membrane and from the membrane to the endoplasmic reticulum. It inhibits the production of acetyl CoA (Amir and Fessler, 2013). Because of this process, the cholesterol synthesis in female livestock was lower than in males.

The results (Table 6 and 7) contradict the observation of Nürnberg et al. (1998), Lisitsyn et al. (2013) who showed that male livestock has a higher *polyunsaturated fatty acid* (PUFA), but female livestock have a higher *saturated fatty acid* (SFA) content. According to Ye et al. (2020a) female lambs tended to deposit more fat and provide more SFA profile than male lambs. Female sheep produce lower levels of PUFA (Hopkins and Mortimer, 2014) but better in *eicosapentaenoic acid* (EPA) and docosahexaenoic acid (DHA) (Ponnampalam et al., 2014). However, other researches showed that sex affects PUFA content, but SFA and MUFA were no different (de Araújo et al., 2017). There was no difference in fatty acid content between male and females lamb except at C18:0 and C18:2 (Arsenos et al., 2006) and C16:0 (Mazon et al., 2017). This findings are not in agreement with Villalobos-Villalobos et al. (2014); Vnučec et al. (2016) who presented that sex does not affect the fatty acid content of LD lamb.

This study indicates that the feed treatment with water spinach (T2) resulted in an increase in linolelaidic acid (C18:2n6t) in the LD. According to Wood et al. (2007) and Wood et al. (2008), several factors such as diet, fat level, age, body weight, sex, and breed influenced the variation of the fatty acid composition of meat (Meale et al., 2015; Nguyen et al., 2017). Mukherjee et al. (2010) showed that water spinach has a high unsaturated fatty acid content compared to other plants, especially at C18:2, C18:3, and nervonic acid (C24:1). Therefore, an increase in several fatty acids in lamb is due to the high fatty acid content of water spinach. Wood et al. (2004) reported that healthy meat possesses a higher rasio of polyunsaturated (PUFA) to saturated fatty acids and a more optimum balance between n-6 and n-3 PUFA. The foods with a lower n-6/n-3 ratio are better for lowering the risk of coronary artery disease, hypertension, diabetes, arthritis, osteoporosis, autoimmune disorders, cancer, and mental health, as well as the underlying mechanisms (Simopoulos, 2002; Dal Bosco et al., 2022). Linoleic acid (18:2n-6, LA) and α-linolenic acid (18:3n-3, ALA) constitute n-6 and n-3 fatty acids, respectively. Linoleic acid is transformed into arachidonic acid and α-linolenic acid in EPA and DHA, and there is rivalry between n-6 and n-3 fatty acids for enzyme desaturation—n-3 to n-6 for Δ-4 and Δ-6 desaturation is preferred (Crupi and Cuzzocrea, 2022).

The fatty acid composition not only affects the nutritional value, but also organoleptic properties, and the consumer preferences for meat (Turner et al., 2014). Francisco et al. (2015) and Holman et al. (2023) elaborated a positive correlation between PUFA concentration in meat and sensory parameters. The flavor of meat is modified by increased levels of linoleic and linolenic fatty acids, with their ratios influencing the physicochemical characteristics of lipids and the progression of lipid oxidation during storage and cooking process, resulting in the formation of primary and secondary oxidative compounds.

The application of pelleting technology in feed provision in this study aims to improve livestock palatability without affecting meat quality. This is congruent with the findings of Wondra et al. (1995) and Behnke and Beyer (2004), who observed that pellets had a stronger influence on intake due to their increased density, shorter length, and hardness. The particle structure and density increased passage rate. Fiber particle size affects rumen function and digestion kinetics, larger particles resulting in longer rumen retention time and improved fiber digestion. Smaller particles in the pellet diet could increase surface area for microbial attachment, enhancing rumen degradation (Bonfante et al., 2016). However, feed pelleting had no effect on meat quality characteristics such as marbling, meat color, or large eye muscle area (Font-i-Furnols and Guerrero, 2014; Ye et al., 2020b; Li et al., 2021). Pellet applications have been developed through the study of their nutritive value, productivity, and adaptability to various conditions (Abdollahi et al.,2013; O'Doherty et al., 2000). Many cattle and sheep owners have found that pelleting is an easier method of feeding animals because feed pellets are easy to handle, dispense, and store (O'Doherty et al., 2000).

CONCLUSION

The application of pellet feed containing 20% water spinach improves meat quality both of male and female lamb. This treatment showed improvement of fatty acids composition such as linolelaidic and linolenic acids (PUFA) especially on LD part. Overall, the application of pelleting technology in this study has no negative impact on meat quality, and it will be a feasible technique for feeding animals efficiently.

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CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

AUTHOR CONTRIBUTIONS

Himmatul Hasanah: Collected, analyzed the data and drafted the manuscript. Joelal Achmadi: Supervised the experiment and modified the manuscript. Eko Pangestu: Supervised the experiment and modified the manuscript. Muhsin Al Anas: Collected, analyzed the data, and drafted the manuscript. Ali Agus: Designed study concepts, supervised the experiment, and modified the manuscript.

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