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Research Article

Effects of Dried White Mulberry Pomace on Fattening Performance and Metabolic Profile Parameters in Lambs

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Abstract

The purpose of this study was to examine the impacts of dried white mulberry pomace on yield performance in lambs. study used 42 weaned Merino lambs, both male and female, at 3 months of age. The experiment was conducted in 3 groups: control, MP150 (150 grams of mulberry pomace), and MP300 (300 grams of mulberry pomace), each containing 7 male and 7 female lambs. The lambs were subjected to a 14-day phase of adaption and 90-day fattening period feeding, and performance parameters were examined in 15-day intervals. Blood samples were collected from the lambs during the experiment's beginning, middle, and end of analyze metabolic profile parameters. The average increase in live weight in the study was determined as 60,9% in the MP150 group, 58,7% in the MP300 group, and 46.7% in the control group. The daily average live weight gains were found to be 0,20 kg/day in the MP150 group, 0,18 kg/day in the MP300 group, and 0,16 kg/day in the control group, although there was no statistically significant difference between the groups (p>0,05). There was no noticeable difference detected between groups in dry matter consumption (p>0,05). Changes were observed in metabolic profile parameters, but there were no discernible variations in terms of group and group × time interactions (p>0,05). Consequently, it may be claimed that mulberry pomace has positive effects on daily and average live weight gains, feed consumption, and feed efficiency ratios of lambs. In line with the effects of mulberry pomace, it shows that it has alternative feed source potential. This study, in which mulberry pomace is examined in many aspects, is thought to guide future research.

Keywords: Fattening performance, lamb fattening, metabolic profile, mulberry pomace

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Introduction

The growing global population and declining per capita arable land have led to a shortage of forage crops which can be used to produce high-quality animal products and are thus unable to meet increasing demand (Du et al 2023). The world market of animal products is projected to grow by 70% by 2050 (Acosta 2018). This percentage of increment has necessitated the need to study more cost effective alternative feed resources for the sustainability of the animal production system (Rauw et al 2020, Ponnampalam and Holman 2023).

Mulberry (*Morus alba* L.), a woody plant source characterized by excellent yield and ease of cultivation and broad versatility, is used as an alternative to address feed shortages (Inanc et al 2022). The leaves of the mulberry plant (*Morus alba*) are primarily used as feed for silkworms. Mulberry is common in polysaccharides, alkaloids, flavonoids, and other bioactive elements beneficial for animal health (He et al 2020). With its high protein content and essential amino acid profile, mulberry is a highly palatable source. The protein content of mulberry by-products is higher than that of conventional forage crops, making them a potential high-quality protein source for livestock. Mulberry may, therefore, prove to be the ideal fruit biological resource to help alleviate the feed supply crisis.

Türkiye considering its geographical conditions, is a suitable country for sheep farming. While sheep breeding in Türkiye is mostly conducted extensively, the number of enterprises engaged in intensive production has increased in recent years. The use of alternative feed sources in small ruminant nutrition is important for improving animal performance, enhancing product quality, and supporting agricultural sustainability. In this context, research has focused on the use of valuable wild plant genetic resources and agricultural industrial by-products as feed.

Studies have shown that mulberry and its by-products improve the standard of animal products (meat, eggs and milk) (Nkosi et al 2016, Arun et al 2020). The inclusion rate of mulberry and its by-products in rations varies according to the animal species, physiological status, age, and the purpose of supplementation. Mulberry pomace, which is mostly utilized as a soil improver or sent directly to waste sites causing environmental issues, has the potential to be a highly suitable feed source for ruminants (Zhou et al 2012). Although there is considerable research on the nutritional value and antioxidant properties of mulberry pomace, current knowledge about its effects on ruminants is limited.

The present study aims to contribute to the determination of the use of mulberry pomace in ruminant animals.

Material and Methods

The Selcuk University Faculty of Veterinary Medicine's Animal Care and Ethics Committee approved this study (approval number 03.06.2021, 2021/067). The animals involved in the experiments were housed and cared for at the Selcuk University Faculty of Veterinary Medicine Proff. Dr. Humeyra Ozgen Research and Application Farm.

Animal Material and Experimental Groups

In this study, 42 weaned 3-month-old Merino breed male and female lambs, obtained from the Selcuk University Faculty of Veterinary Medicine Proff. Dr. Humeyra Ozgen Research and Application Farm, were used as the animal material. Lambs were selected to ensure similar live weights, body condition scores, and health status. The trial was conducted in three groups: CONRTOL (The group without added mulberry pomace), MP150 (Group given 150 g mulberry pomace) and MP300 (Group given 300 g mulberry pomace), with each group consisting of 7 males and 7 females, totaling 14 lambs per group. After determining the live weights of the lambs, group distributions were made to ensure similar average live weights across groups.

Experimental Pens

A total of 42 separate pens were constructed in the sheep unit, which is an open area with a covered top. Each pen, measuring 150x150x100 cm, housed one lamb. Each pen was equipped with a feed bucket (approx. 50 L) for both concentrate and roughage, and a 50 L plastic water bucket. The pens were cleaned at regular intervals.

Feed Material

The mulberry pomace required for the lamb rations during the trial was obtained from a company in Malatya producing mulberry molasses. The pomace was sun-dried on a flat and clean surface until a constant weight was reached (3-4 days). The composition of the rations utilized in the research is presented in Table 1 and Table 2.

Animal Feeding

The experiment included a 90-day term and a 14-day adaption phase fattening period. All animals were maintained and fed under the same conditions throughout the study. At the beginning of the adaptation period, all lambs were treated for internal parasites (Rabenzole). Mixed vaccines (Tetrandoll – Coglovax) were administered twice, before the trial and 15 days later. Rations were weighed and provided once daily. Leftover feed was weighed daily to calculate feed intake. Clean water was always available.

Calculation of Live Weight Gain

To calculate live weight gains, the first weighing was conducted after the adaptation period, at the start of the fattening period. Subsequent weighings were conducted on days 15, 30, 45, 60, 75, and 90 before morning feeding. Average daily live weight gain was calculated as follows:

$$\text{ADG, g} = \frac{\text{Ultimate Live Weight (kg) - Starting Live Weight (kg)}}{\text{Number of Days}} \text{x 1000}$$

Determination of Feed Intake

Throughout the study, leftover feed in the feeders was weighed before morning feeding, and daily feed intake was calculated (Polat et al 2006).

Determination of Feed Conversion Ratio(FCR)

FCR was calculated by considering live weight gains and feed intake over the 90-day fattening period:

$$\text{FCR (g)} = \frac{\text{Daily Feed Intake (g)}}{\text{Daily Live Weight Gain (g)} \times} \text{x 1000}$$

Metabolic Profile Parameters

At the beginning, middle, and end of the trial, samples of blood are taken from the jugular vein of all lambs before feeding. After being separated, the serum was kept at -18°C until analysis. The following parameters were measured: Blood urea nitrogen, Calcium, Magnesium, Phosphorus, Aspartate aminotransferase, Gamma-glutamyl transferase, Glucose, Cholesterol, Total Protein, Albumin, Ketone, Non-esterified fatty acids, Triglyceride, and Creatinine.

Chemical Analyses

The Dry matter, crude protein, crude fiber, crude fat and crude ash analyses of all samples to be used in the research

Table 1. Feed ingredient compositions of lamb diets			
Feeds (g)	Groups		
	CONTROL	MP150	MP300
Straw	100	70	90
Alfalfa	185	80	50
Barley	1370	1356	1200
Limestone	16	19	17
Salt	5	5	5
Premix	5	5	5
Mulberry Pomace	0	150	300

CONTROL: The group without added mulberry pomace, MP150: Group given 150 g mulberry pomace, MP300: Group given 300 g mulberry pomace.

were determined according to the analysis methods specified in AOAC (1990). NDF, ADF, and ADL levels of the samples were recognized using "The Ankom 200 Fiber Analyzer" determined on the method reported by Goering and Van Soest (1970). For mineral content determination of mulberry pomace, mineral contents were analyzed using a Bruker 820-MS ICP-MS device. Ionization of atoms is achieved by sending samples with high-purity argon carrier gas into argon plasma at high temperature (approximately 1000°C). The ions were detected in the mass spectrometer under vacuum after passing through the sampling and skimmer cone interface, and quantities were calculated using calibration equations obtained with standard calibration solutions in the software system (Tokalıoğlu 2012).

Statistical Analysis

SPSS (ver. 25.0) package program was utilized in the statistical evaluation of the study. A repeated general linear model (GLM) was created to determine the effect of mulberry pomace addition to lamb ration on performance parameters. In the created model, experimental groups, time, and group×time were included as fixed factors, and initial trial weights were included as covariates. One-Way ANOVA was performed to ascertain the distinctions between experimental groups in terms of total feed utilization rates. For the metabolic profile, a repeated general linear model (GLM) was created for blood samples taken periodically from lambs. In the created model, experimental groups, time, and group × time were determined as fixed factors. In case of significant interactions between fixed factors for each variable, independent samples t-test was employed to ascertain the significance of difference between means obtained from 2 independent samples, dependent samples t-test was used when 2 samples were time-dependent, and One-way Analysis of Variance was used when there were more than two factors. The significance of differences in multiple comparisons was determined by Bonferroni multiple comparison test. The statistical significance level for all analyses conducted in the study was approved as p<0,05.

Results

At the conclusion of the trial, the mean live weights of MP150 and MP300 groups appear higher compared to the control group. Throughout the time from the beginning to the end of the trial, live weight increases of approximately %46,7 in the control group, %60,9 in the MP150 group, and %58,7 in the MP300 group were achieved (Table 3). The presence of significant interaction between test groups and time in terms of daily live weight gain (p<0,05) and its high levels in the MP150 group during most weeks shows significance. Live weight and live weight gains of lambs fed with mulberry pomace according to measurement intervals are shown in Table 3 and Table 4. The adding 150 g and 300 g of mulberry pomace into rations negatively affect the live weight gain of lambs. The average daily live weight gains were determined as 0,20 kg/day in the MP150 group, 0,18 kg/day in the MP300 group, and 0,16 kg/day in the control group. Although daily live weight gain was numerically higher in groups given mulberry

Table 2. Nutrient composition of study diets (% DM basis)				
	MP	CONTROL	MP150	MP300
DM (%)	100	100	100	100
DM, as fed (%)	37,13	-	-	-
CP (%)	13,7	12,15	11,83	12,02
EE (%)	14,9	1,70	2,66	2,91
NDF (%)	35,8	49,70	43,31	49,09
ADF (%)	35,9	10,51	12,74	15,96
NFC (%)	13,9	31,15	33,15	27,79
ADL (%)	18,3	2,36	5,49	5,98
Ash (%)	21,7	5,31	9,05	8,19

DM: Dry Matter, CP: Crude Protein, EE: Ether Extract (Crude Fat), NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, NFC: Non-Fiber Carbohydrates, ADL: Acid Detergent Lignin, CONTROL: The group without added mulberry pomace, MP150: Group given 150 g mulberry pomace, MP300: Group given 300 g mulberry pomace.

Table 3. Study groups periodic live weights during fattening period			
Day	CONTROL	MP150	MP300
0	28,7±4,31	28,9±4,25	28,8±4,81
15	30,0±4,82	30,6±4,47	30,4±4,74
30	31,7±5,34	32,9±3,99	32,5±4,70
45	33,2±5,36	35,3±4,16	34,4±4,62
60	37,0±4,96	38,8±4,86	37,7±4,38
75	39,3±4,37	41,4±5,15	40,6±4,56
90	42,1±5,73	46,5±5,36	45,7±5,08

CONTROL: The group without added mulberry pomace , MP150: Group given 150 g mulberry pomace, MP300: Group given 300 g mulberry pomace, ± : standard error means

pomace, these group distinctions were not found to be statistically significant. A significant interaction was determined between the experimental groups depending on the measurement time (p<0,05).

As no statistically significant difference was observed between the groups in terms of feed consumption (p>0,05), group and time interaction was statistically significant (p<0,01) (Table 5). A general increase in daily feed consumption is observed over time in all groups. The effect of mulberry pomace added into lamb rations on FCR was not found to be significant. However, it can be said that the addition of mulberry pomace had a mathematically positive effect on FCR.

As with dry matter consumption, no statistically significant difference was found between the groups in terms of group × time interaction (p>0,05) (Table 6). A general increase in dry matter consumption is observed over time in all groups. After the 60th day of the study, dry matter consumption increased significantly.

The results of the metabolic profile tests examined from blood samples taken at the beginning (weaning), middle, and end of the 3-month study period are given in Table 7 Notable fluctuations were observed among the parameters. No significant differences were detected in terms of both group and group x time interaction for all metabolic parameters examined.

Discussion

Mulberry belongs to the legume family, which generally has higher HP and lower fiber content than grasses. The chemical composition of mulberry pomace can vary depending on the species and the climate of the region where it is grown (Yang et al 2010, Liang et al 2020, Paunović et al 2020). The nutritional composition of mulberry pomace used in the study is similar to the results in other studies (Deshmukh et al 1993, Shayo 1997, Phiny et al 2003, Bamikole et al 2005, Kabi and Bareeba 2008).

The mineral content of mulberry pomace is given in Table 8. The macromineral content of mulberry leaves in this study is similar to the results in other studies (Rauw et al 2020, Simbaya et al 2020). When examining the mineral content of mulberry pomace, it appears to be in good condition in terms of Mg, P, and Fe. These contents in

Table 4. Daily live weight gains of lambs by periods (kg)							
Groups	Day						
	0-15	15-30	30-45	45-60	60-75	75-90	p
CONTROL	0,11^{b}	0,13^{ab}	0,11^{b}	0,30^{a}	0,18^{ab}	0,12^{b}	**
MP150	0,14	0,18	0,19	0,27	0,20	0,21	-
MP300	0,14	0,16	0,16	0,26	0,22	0,18	-
Average	0,13^{b}	0,16^{b}	0,15^{b}	0,27^{a}	0,20^{ab}	0,17^{b}	***
Group		Average		SEM			
CONTROL		0,16		0,013		-	
MP150		0,20					
MP300		0,18					
Group × Time						*	

p>0,05; *:p<0,05; **:p<0,01; ***:p<0,001; ab; Differences between values with different letters in the same row are significant, CONTROL: The group without added mulberry pomace, MP150: Group given 150 g mulberry pomace, MP300: Group given 300 g mulberry pomace.

Table 5. Daily feed intake(kg) and feed conversion ratio of lambs during periods

Groups	Day							FCR
	0-15	15-30	30-45	45-60	60-75	75-90	p	0-90
CONTROL	0,968[c]	1,194[b]	1,334[ab]	1,428[a]	1,435[a]	1,366[ab]	**	8,20
MP150	1,035[d]	1,127[cd]	1,248[c]	1,255[c]	1,349[b]	1,554[a]	*	6,24
MP300	1,015[b]	1,142[b]	1,216[ab]	1,238[a]	1,227[a]	1,289[a]	**	6,01
Average	1,006[c]	1,155[c]	1,266[b]	1,307[b]	1,354[ab]	1,400[a]	***	6,81
Group		Average		SEM				SEM
CONTROL		1,29		0,02		-		0,21
MP150		1,26						
MP300		1,20						
Group × Time						**		

p>0,05; *:p<0,05; **:p<0,01; ***:p<0,001; abcd; Differences between values with different letters in the same row are significant, CONTROL: The group without added mulberry pomace, MP150: Group given 150 g mulberry pomace, MP300: Group given 300 g mulberry pomace, SEM: Standard Error, FCR: Feed Conversion Ratio.

mulberry pomace show similarity with the values reported by Liu et al (2019).

At the end of the 90-day in vivo experiment in the study, the mean live weights were found to be 42,1±5,73 kg in the control group, 46,5±5,36 kg in the MP150 group, and 45,7±5,08 kg in the MP300 group. At the end of the experiment, the mean live weights of the MP150 and MP300 groups were higher compared to the control group. The mean live weight of the MP150 group at the end of the experiment was approximately 4,4 kg higher than the control group. Similarly, the mean live weight of the MP300 group was 3,6 kg higher than the control group.

In the study groups, the highest daily live weight gain occurred during the 45-60 day interval (average 0,27 kg/day). During this period, the control group exhibited a daily live weight gain of 0,30 kg/day, the MP150 group 0,27 kg/day, and the MP300 group 0,26 kg/day. However, the differences among the groups during this period were not statistically significant. In the control group, the daily live weight gain was the lowest (0,11 kg/day) in the intervals of 0-15 and 30-45 days, while it was the highest (0,30 kg/day) in the interval of 45-60 days. These differences are statistically significant (p<0,01). It is observed that the highest growth rate in all groups occurred during the 45-60 day interval.

When examining the average daily live weight gains throughout the experimental period, it was found to be 0,20 kg/day in the MP150 group, 0,18 kg/day in the MP300 group, and 0,16 kg/day in the control group. Although the daily live weight gain was numerically higher in the groups receiving mulberry pomace, these differences between groups were not statistically significant. However, the data suggests that mulberry pomace supplementation has a potential positive effect on lamb live weight gain and indicates that mulberry pomace could be considered as an alternative feed additive in lamb feeding.

Table 6. Dry Matter intake of Lambs During the Fattening Period (kg)

Groups	Day						
	0-15	15-30	30-45	45-60	60-75	75-90	p
CONTROL	11,14[c]	14,86[b]	16,61[ab]	17,77[a]	17,86[a]	17,00[a]	***
MP150	11,94[d]	14,10[c]	15,61[bc]	15,70[bc]	16,87[b]	19,32[a]	
MP300	11,68[b]	14,24[a]	15,16[a]	15,44[a]	15,92[a]	16,07[a]	
Average	11,59[c]	14,40[c]	15,79[b]	16,30[b]	16,88[b]	17,46[a]	
Group			Average		SEM		
CONTROL			15,88		0,27		-
MP150			15,60				
MP300			14,76				
Group × Time							**

p>0,05; *:p<0,05; **:p<0,01; ***:p<0,001; abc; Different letters in the same row indicate significant differences (p<0,001), CONTROL: The group without added mulberry pomace, MP150: Group given 150 g mulberry pomace; MP300: Group given 300 g mulberry pomace, SEM; Standard Error

Table 7. Effect of Dried White Mulberry Pomace on Serum Biochemical and Metabolic Parameters in Lambs at 0th, 45th and 90th				
CONTROL				
Parameters	0	45	90	SEM
BUN (mg/dl)	13,84± 2,77	13,17± 1,94	13,44± 3,11	0,87
Ca (mg/dl)	9,74± 0,89	9,82± 1,18	9,72± 0,96	0,06
Mg (mg/dl)	1,99± 0,21	1,93± 0,21	1,99± 0,19	0,05
Phosphorus (mg/dl)	6,58± 1,71	6,62± 1,33	6,76± 1,44	0,23
AST/SGOT(Ul/l)	121,21± 50,09	111,36± 21,26	105,21± 13,64	7,85
Gamma Gt (Ul/l)	55,07± 11,6	57,93± 10,95	56,48± 11,8	1,86
Glucose (mg/dl)	62,79± 6,90	65,36± 11,08	67,21± 14,88	1,07
Cholesterol (mg/dl)	68,07± 17,7	76,86± 31,32	71,07± 14,07	3,20
Total Protein (g/dl)	6,54± 0,75	6,52± 0,76	6,56± 0,59	0,09
Albumin (g/dl)	3,4± 0,38	3,38± 0,44	3,3± 0,35	0,03
Ketone(mmol/l)	0,42± 0,14	0,41± 0,07	0,38± 0,14	0,34
NEFA (mmol/l)	0,66± 0,298	0,75± 0,195	0,83± 0,307	0,04
Triglyceride (mg/dl)	19,44± 1,18	20,79± 1,63	37,50± 5,58	1,16
Creatinine (mg/dl)	1,02± 0,12	1,03± 0,17	1,09± 0,15	0,05
MP150				
BUN (mg/dl)	19,73± 4,43	19,67± 5,63	24,14± 6,7	0,87
Ca (mg/dl)	10,3± 0,35	10,35± 0,71	10,39± 0,61	0,06
Mg (mg/dl)	2,06± 0,19	2,2± 0,34	2,24± 0,3	0,05
Phosphorus (mg/dl)	6,41± 1,28	6,96± 1,04	6,91± 0,64	0,16
AST/SGOT(Ul/l)	173,93± 86,99	122,36± 76,01	114,79± 32,16	7,85
Gamma Gt (Ul/l)	73,21± 18,18	81,71± 20,58	77,19± 19,65	1,86
Glucose (mg/dl)	87,07± 15,52	90,64± 13,12	91,14± 8,55	1,07
Cholesterol (mg/dl)	45,36± 11,42	50,36± 14,24	47,21± 10,31	3,20
Total Protein (g/dl)	6,43± 0,59	6,42± 0,38	6,54± 0,28	0,09
Albumin (g/dl)	3,18± 0,31	3,19± 0,31	3,25± 0,39	0,03
Ketone(mmol/l)	0,18± 0,07	0,19± 0,13	1,96± 6,63	0,34
NEFA (mmol/l)	0,28± 0,259	0,18± 0,183	0,25± 0,266	0,04
Triglyceride (mg/dl)	19,57± 2,03	22,50± 1,84	30,64± 2,07	1,16
Creatinine (mg/dl)	0,8± 0,1	0,76± 0,06	0,85± 0,13	0,05
MP300				
BUN (mg/dl)	19,87± 5,39	20,13± 5,52	19,37± 4,7	0,87
Ca (mg/dl)	9,73± 0,52	9,47± 0,72	9,51± 0,83	0,06
Mg (mg/dl)	1,77± 0,16	1,76± 0,26	1,81± 0,22	0,05
Phosphorus (mg/dl)	6,40± 0,6	6,11± 0,94	6,13± 0,84	0,13
AST/SGOT(Ul/l)	82,57± 20,67	82,71± 17,35	97,93± 25,96	7,85
Gamma Gt (Ul/l)	80,5± 35,03	67,21± 15,05	79,5± 30,43	1,86
Glucose (mg/dl)	76,5± 8,06	74,71± 11,88	73,64± 10,43	1,07
Cholesterol (mg/dl)	54,5± 8,11	55,29± 11,81	58,29± 17,84	3,20
Total Protein (g/dl)	6,21± 0,39	5,94± 0,4	6,06± 0,59	0,09
Albumin (g/dl)	2,58± 0,17	2,56± 0,15	2,57± 0,14	0,03
Ketone(mmol/l)	0,23± 0,06	0,26± 0,1	0,18± 0,06	0,34
NEFA (mmol/l)	0,74± 0,418	0,78± 0,474	0,66± 0,325	0,04
Triglyceride (mg/dl)	20,64± 1,09	23,50± 1,96	30,29± 3,68	1,16
Creatinine (mg/dl)	1,05± 0,45	1,11± 0,49	1,17± 0,42	0,05

CONTROL: The group without added mulberry pomace, MP150: Group given 150 g mulberry pomace, MP300: Group given 300 g mulberry pomace, BUN: Blood urea nitrogen, Ca: Calcium, Mg: Magnesium, AST/SGOT: Aspartate aminotransferase, Gamma GT: Gamma-glutamyl transferase, NEFA: Non-esterified fatty acids, SEM: Standard error of the mean

Table 8. Mineral contents of mulberry pomace	
Mineral	MP
Ca, (%)	1,13
K, (%)	0,60
Mg, (%)	0,48
P, (%)	0,19
S, (%)	0,10
B, (ppm)	13,06
Cu, (ppm)	14,63
Fe, (ppm)	6151,01
Mn, (ppm)	67,24
Na, (ppm)	183,12
Zn, (ppm)	21,82

MP: Mulberry pomace, Calcium (Ca), Potassium (K), Magnesium (Mg), Phosphorus (P), Sulfur (S), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Sodium (Na), Zinc (Zn)

Gonzalez Garcia and Milena (2002) reported that mulberry increased feed consumption and growth performance in goats, with the highest weight gain being 86,2 g/day with 2,5% mulberry supplementation. In a study conducted on quail, adding mulberry pomace to rations up to 8% did not create a negative effect on feed consumption of experimental groups, while higher rates (12%) resulted in significant decreases in feed consumption (Sengul et al 2021). In another study, it was reported that the addition of mulberry leaves to the ration increased daily live weight gain in lambs and goats (Valdes et al 2017). Shayo (1997) suggested that mulberry leaf is a good source of energy and protein for ruminant animals. These studies support the findings obtained in our research.

Niu et al (2016) suggested that rumen bacteria, especially fiber-degrading bacteria, proliferated more in cattle fed with mulberry pomace silage. This situation might be a reason for the higher DM consumption in groups containing mulberry pomace.

The increase in daily feed consumption observed as the fattening period progressed indicates that the feed consumption capacity of lambs also increased with their growth. Looking at the average values, the lowest feed consumption (1,01 kg/day) was observed in the 0-15 day interval, while the highest feed consumption (1,40 kg/day) was found in the 75-90 day interval ($p<0,001$). While the highest daily feed consumption in the control group occurred in the 60-75 day interval (1,44 kg/day) ($p<0,01$), it was reached in the MP150 (1,55 kg/day) ($p<0,05$) and MP300 group (1,29 kg/day) ($p<0,01$) in the 75-90 day interval. Daily feed consumption in the control and MP300 groups did not show a significant increase after the 30-45 day interval. In a study conducted on sheep by Sun et al (2020), it was reported that groups with mulberry leaves in their rations had higher dry matter consumption. Feed consumption can be affected by physiological factors and chemical composition of the ration, environmental conditions, and other external factors. As the NDF concentration of the ration increases, dry matter consumption generally decreases, and as ADF concentration increases, digestibility generally decreases (Arelovich et al 2008). Although there was no significant difference in the mulberry pomace ration group used in the experiment, lower dry matter consumption may be due to higher NDF and ADF contents.

In a study conducted on mulberry leaves converted into silage, it was reported that mulberry leaf silage used instead of corn and cottonseed meal had the same effect on animal growth performance (Zhou et al 2014). In the same study, it was reported that adding mulberry leaves up to 5% to cereals did not affect the dry matter consumption of ruminants, and silage mulberry leaves and sun-dried mulberry pomace could be used without causing any adverse effects in ruminants. These results support the findings in this study.

Studies have reported that mulberry pomace has positive effects on animal health and growth performance. Bioactive compounds found in mulberry leaves such as 1-deoxynojirimycin, gamma-aminobutyric acid, and phenolic compounds have strong antioxidant properties (Cheong et al 2012). This indicates that mulberry pomace can be used as a functional feed to improve growth performance and health parameters of ruminants.

Plasma glucose, albumin, cholesterol, triglyceride values were not affected by mulberry pomace. Additionally, glutamyl transferase and aspartate aminotransferase concentrations were not affected by the rations. This indicates that there was no liver disorder in the animals (France and Dijkstra 2005, Walsh et al 2009).

The addition of mulberry pomace to the ration did not affect serum cholesterol concentrations, indicating that heart and liver health was not harmed in lambs (Hocquette and Bauchart 1999). The similarity of serum albumin and total protein concentrations between groups can probably be explained by the similar transport of microbial protein to the intestines and the same amount of amino acids available for absorption.

Amino acid metabolism depends on crude protein level. Blood urea nitrogen (BUN) has a negative relationship with nitrogen accumulation and protein utilization rate in the organism (Lopez-Campos et al 2011, Bailey et al 2012). Ammonia formed by the breakdown of crude protein in the rumen is used for microbial protein synthesis, and the remaining ammonia is absorbed from the rumen wall into the blood and enters the liver where it is converted to urea (Szkudelska et al 2016). In this study, lower plasma urea concentration was observed in the control group compared to other groups; this may be due to the control group having lower microbial protein concentration. The absence of difference in BUN concentrations between groups indicates that there is no amino acid deficiency or imbalance.

The inclusion of agricultural by-products, particularly those rich in bioactive compounds, in cattle diets can influence their metabolic activity. For instance, grape pomace has been shown to regulate metabolic syndrome, and wine by-products have been reported to decrease plasma triglyceride and phospholipid levels (Hogan et al 2010, Sagdic et al 2011). However, the current findings indicated that such effects were not observed in this study.

Conclusion

Although mulberry trees grow well in many regions of Turkey, information about the use of mulberry pomace as a feed source for ruminants remains insufficient. The chemical composition of mulberry pomace can vary depending on the species, climate of the growing region, and harvest time of the leaves. When evaluating the chemical composition of the mulberry pomace used in the research, it can be said that it has the potential to meet the protein needs of ruminant animals during critical periods when quality feed shortages are exposed. The numerically higher daily weight gain in groups given mulberry pomace suggests that it has a potential positive effect on weight gain and that mulberry pomace can be considered as an alternative feed additive in lamb feeding. As a result, it has been concluded that mulberry pomace, which has alternative feed source potential, can increase the productivity of ruminants. It is thought that this study will also shed light on future studies with mulberry by-products.

Declarations

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Competing Interests

Authors declare that there are no conflicts of interest related to the publication of this article.

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Availability of Data and Materials

The data that support the findings of this study are available on request from the corresponding author.

Ethical Statement

The Selcuk University Faculty of Veterinary Medicine's Animal Care and Ethics Committee approved this study (approval number 03.06.2021, 2021/067). The animals involved in the experiments were housed and cared for at theSelcuk University Faculty of Veterinary Medicine Proff. Dr. Humeyra Ozgen Research and Application Farm.

Author Contributions

Motivation / Concept: ZSI, HDA; Design: ZSI; Control/Supervision: ZSI, HDA; Data Collection and Processing: ZSI; Analysis and Interpretation: ZSI, HDA; Literature Review: ZSI, Writing the Article: ZSI, HDA; Critical Review: ZSI, HDA

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