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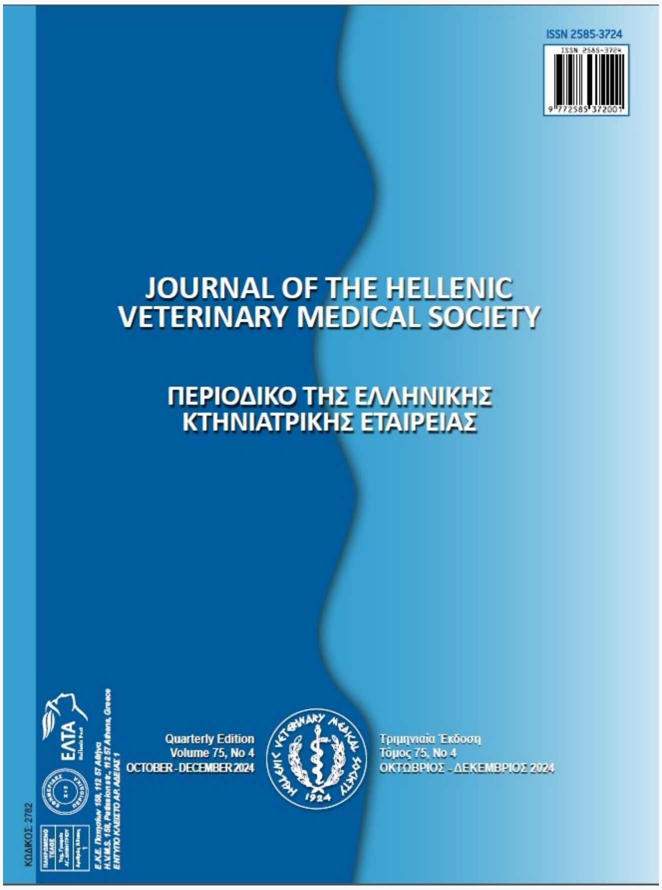

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Research article
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A prospective evaluation of growth performance, health and welfare status in feedlot fattened dairy lambs under different feeding regimes

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ABSTRACT: The objective of this study was to prospectively assess the growth performance, health and welfare status in feedlot dairy breed lambs fattened under different feeding regimes. A total of 193, 3-month-old weaned lambs of two indigenous Greek breeds were enrolled in two longitudinal cohort studies. The first study (S1) included 75 Chios lambs and the second one (S2) 118 Serres lambs, which were randomly allocated into two groups. Each group was fed a diet containing either soybean meal (groups AC and AS, for Chios and Serres lambs, respectively) or canola meal (groups BC and BS, for Chios and Serres lambs, respectively) as its main protein source. Lambs were fattened for 13 weeks in S1 and 15 weeks in S2 to reach an average of ca. 35 to 40 kg pre-slaughter live body weight. Growth performance, and health and welfare indicators were recorded weekly during the fattening period. The most prevalent health and welfare problems in fattening lambs were nasal and ocular discharges. In group BC, body condition score and average daily gain were significantly increased [by 6.7% ($P \leq 0.001$) and 12.9% ($P < 0.05$), respectively] compared to group AC. Moreover, group AC had significantly increased odds for nasal discharge compared to group BC [odds ratio (OR) = 1.59, $P < 0.05$], and group AS for ocular discharge (OR = 1.72, $P < 0.05$), and body abscesses (OR = 5.00, $P \leq 0.001$) compared to group BS. Dairy lambs of Chios and Serres breeds demonstrated a satisfying fattening performance under different feeding regimes, despite the observed health and welfare challenges. The demand for further studies and interventions to improve feed efficiency and appropriately address health and welfare issues in feedlot fattening dairy lambs is evidenced.

Keywords: dairy breed lambs; fattening; health and welfare traits; longitudinal study

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INTRODUCTION

Fattening is the major activity in meat sheep farming systems worldwide, where lambs are mainly grass-fed and fattened to be slaughtered at 30 to 40 kg of live body weight (LBW) (at ca. 4 to 5 months of age) to produce carcasses of 16 to 23 kg (Sañudo et al., 1998, Beriain et al., 2000). In dairy sheep farming systems, lamb fattening is considered a secondary activity of questionable profitability and is currently practised by the farmers until weaning; in these farms, early weaning (25 to 60 days and 13 to 20 kg LBW) and slaughtering of lambs for the production of light carcasses (7 to 12 kg) are the norm (Sañudo et al., 1998, Bello et al., 2016). Nevertheless, fattening of dairy breed lambs and slaughtering beyond 30 kg LBW can be considered an added-value activity for sheep farmers and lamb-fattening operations, as it may disengage the local meat industry from the seasonal lamb-meat availability.

In feedlot lambs, apart from the demand for the achievement of sufficient average daily gain (ADG) and pre-slaughter LBW at a reasonable production cost, health and welfare challenges are also emerging as production methods become more intensive. Consequently, both farmers and the public are increasingly concerned about the well-being of the intensively fattened animals (Coleman et al., 2016). That is also the case in lambs, where feedlot systems are likely to be associated with poor health and welfare due to inappropriate flock health management, housing conditions (increased stocking density, adverse microclimate conditions, and inadequate infrastructure and equipment), and hygiene status (Berg et al., 2014). For this reason, on-farm health and welfare recording and assessment in fattening lamb operations is crucial to determine the main health and welfare issues and propose evidence-based preventive measures, as well as to improve the productive capacity of animals and the intrinsic and extrinsic quality of the products thereof. Hence, the objectives of this study were: i) to prospectively study growth performance and health and welfare status and ii) to assess the effects of different feeding regimes on the growth performance and health and welfare status, in dairy lambs of two indigenous Greek sheep breeds (i.e., Chios and Serres) across the fattening period.

MATERIALS AND METHODS

Animals and diets

Two longitudinal cohort studies were carried out in a commercial lamb fattening operation located at Argolida in Southern Greece (altitude: 200 m above sea level, latitude: 37˚71’00’’, longitude: 22˚57’05’’). A total of 193 ca. 3-month-old weaned lambs of two indigenous Greek breeds were enrolled in these studies; namely, 75 Chios and 118 Serres lambs in the first (S1) and the second (replication) study (S2), respectively. Lambs originated from two farms in northern Greece rearing purebred Chios and Serres dairy ewes; the first (Chios farm) was located in the region of Drama, and the second one in the region of Serres (Serres farm), ca. 760 and 710 km away from the feedlot site, respectively. In both farms, natural suckling for 50 to 60 days was practiced, and the same creep-feeding scheme was followed from the 4th week until weaning; namely, lambs were separated from their dams for 4 to 8 hours per day, and *ad libitum* concentrates and barley straw were provided. In both studies, transferring of lambs in the feedlot was performed in winter, while the transferring duration was similar. At arrival, the lambs involved in each study were allocated in a separate pen, where they remained for two weeks to adapt. After the adaptation period, lambs were randomly allocated in two equal groups (groups A and B), based on their LBW and sex, and were fed with two different rations, resulting in groups A and B Chios lambs (groups AC and BC, respectively) for S1, and groups A and B Serres lambs (groups AS and BS, respectively) for S2 (Table 1). The ration fed in group A included soybean meal (SBM) as the main protein source, while in the ration fed in group B SBM was replaced by canola meal (CM). The two rations were appropriately formulated to be isocaloric and isonitrogenous. The chemical composition of the two rations used in S1 and S2 is presented in Table 2. Diets were formulated using these rations, as well as alfalfa hay and barley straw. The quantities fed twice per day were equal in the two groups and modified based on the nutritional demands and according to the fattening stage (0.6 to 0.9 kg for concentrates, 0.3 to 0.4 kg for alfalfa hay, and barley straw ad libitum). Following a period of one-week adaptation on the rations, lambs were fattened for 13 weeks in S1 and 15 weeks in S2 to reach 35 to 40 kg pre-slaughter LBW.

During each study, group A and B lambs were fattened in two different but neighbouring pens. They were permanently housed, with a floor area of 0.7 m^2/lamb and a volume of about 3.2 m^3/lamb inside the barn. The ventilation was natural and moderate, the floor was concrete, and wheat straw was added as bedding material every 3 to 5 days, depending on

Table 1. Descriptives of live body weight in males and females, Chios and Serres lambs in the two groups at the beginning of fattening.

	Group A†		**Group B**††		Group A		Group B	
	n*	Mean±SD (kg)	n	Mean±SD (kg)	n	Mean±SD (kg)	n	Mean±SD (kg)
Males	24	22.1±3.98	16	22.3±2.96	33	19.9±2.52	34	18.9±2.96
Females	15	21.3±3.84	20	21.6±4.22	25	18.0±2.72	26	19.5±2.52
Overall	39	21.8±3.89	36	21.9±3.68	58	19.1±2.76	60	19.1±2.72

†: Group A = lambs fed with ration containing soybean meal
††: Group B = lambs fed with ration containing canola meal
*: n = number of lambs

Table 2. Chemical composition of the rations fed in groups A (ration with soybean meal) and B (ration with canola meal) in the two studies.

	Ration A	**Ration B**
Study 1 (Chios lambs)		
Dry matter (%)	91.9	90.6
Ash (%DM)	5.7	5.4
Crude protein (%DM)	14.2	13.7
Fat (%DM)	3.1	4.2
Crude fibre (%DM)	3.3	4.7
Study 2 (Serres lambs)		
Dry matter (%)	91.7	91.1
Ash (%DM)	5.6	8.2
Crude protein (%DM)	13.2	13.3
Fat (%DM)	3.3	4.7
Crude fibre (%DM)	3.5	6.1

the bedding condition. Premises were disinfected twice a year using commercial disinfectants and lime. Feeding troughs and waterers were sufficient to avoid lambs queuing during eating and drinking. Lambs were treated against parasites with netobimin (10 mg/kg b.w., orally, Hapadex®, Schering-Plough Animal Health) three days after their arrival at the operation, and they were twice vaccinated against clostridial diseases and pasteurellosis four and thirty days later (Dialuene-P, MSD® Animal Health, at 3 and 4 months of age).

Animal recording and health and welfare assessment protocol

During the studies, each lamb was weighed, and its health and welfare status was assessed weekly by the same group of one veterinarian and two animal scientists. The assessment protocol was designed based on a modified version of the AWIN (animal welfare indicator) protocol (AWIN Welfare Assessment Protocol for Sheep, 2015) and incorporated the routine physical examination procedures for sheep (Jackson and Cockcroft, 2007). The following health and welfare traits were recorded: i) lameness, arthritis, nasal and ocular discharge, soft-wet faeces, body abscesses, skin lesions in the head, body, limbs, perineum, and tail (0 = absence, 1 = presence), ii) fleece cleanliness (0 = clean, 1 = dirty) and quality (0 = good quality, 1 = poor quality), and iii) submandibular, parotid, and prescapular lymph nodes size (0 = normal size, 1 = swollen). The locomotion score was evaluated using a five-degree scale (1 = normal gait, 5 = unwilling to bear weight on one foot when standing or walking) as described by Ley et al. (1994). The body condition score (BCS) of each lamb was assessed by palpating the lumbar vertebrae and using a five-point scale with 0.25 increments (1 = emaciated, 5 = obese) as proposed by Russel et al. (1969). The studies were approved by the Ethics Committee on Animal Use of the Agricultural University of Athens (protocol no 104).

Statistical analyses

Morbidity frequency measures were estimated using the records from the two longitudinal studies. In particular, point and period prevalence were calculated as the proportion of lambs with health and welfare issues at the beginning (i.e., after the two adaptation periods) and during the fattening period, respectively.

The incidence rate was defined as the number of new cases of the studied trait per 1,000 lamb-weeks at risk, while cumulative incidence represented the number of new cases of the studied health and welfare traits divided by the total number of animals enrolled. As a new case was defined the lamb identified to have the health and welfare issue under investigation for the first time during the fattening period. Lamb-weeks at risk were defined as the actual time at risk (expressed in weeks) that all lambs of the studied cohort contributed to the study while remaining free from the health and welfare issue under investigation. Data were analysed for each one of the studies separately using SPSS v26 software (IBM Corp., Armonk, NY, USA), with the statistical significance being set at the 0.05 level. In particular, descriptives (mean±standard deviation) were calculated for LBW, BCS, and ADG. Mixed linear and binary models were used to estimate the effects of ration, week of fattening, and sex on growth performance variables [LBW, BCS, and mean value of ADG (model 1)] as well as on health and welfare traits (model 2), as described below:

$$Y_{ijkl} = \mu + R_i + S_j + W_k + R_i \times W_k + S_j \times W_k + R_i \times S_j \times W_k + E_l + e_{ijkl} \quad (1)$$

$$Q_{ijkl} = \mu + R_i + S_j + W_k + E_l + e_{ijkl} \quad (2)$$

where, Y_{ijkl} = dependent continuous variables (growth performance variables; LBW, BCS, and ADG), Q_{ijkl} = dependent binary variables (health and welfare traits), μ = intercept, R_i = fixed effect of the ration group (l = 2 levels; 0 = group B, 1 = group A), S_j = fixed effect of the sex (j = 2 levels; 0 = male, 1 = female), W_k = fixed effect of the week of fattening (k = 13 levels for S1 and 15 levels for S2), $R_i \times W_k$ = the interaction term effect between ration group and week of fattening, $S_j \times W_k$ = the interaction term effect between sex and week of fattening, $R_i \times S_j \times W_k$ = the interaction term effect of ration group, sex, and week of fattening, E_l = random effect of the lth lamb, and e_{ijkl} = random residual.

The identity and probit link functions were fitted in the model for the analyses of normally (LBW, BCS, and ADG) and binomially distributed variables (health and welfare traits), respectively. Among first-order autoregressive (ARH1) and compound symmetry, the covariance structure with the lowest Akaike's information criterion (AIC) was selected to improve the model's prediction capacity. The models met the assumptions of normal distribution, homoscedasticity, and linearity, which were checked using quantile-quantile and probability-probability plots of standardized residuals, as well as the scatterplot of standardized predicted values against standardized residuals. Based on the model, the estimated marginal means of LBW, BCS, and ADG were estimated in S1 and S2 for the studied groups and sexes. The odds ratios (OR) for health and welfare issues were computed as the exponent of the relevant regression coefficients derived by the model (2).

RESULTS

Growth performance traits

Mean values of LBW and BCS pre-slaughter and ADG were 39.2 kg, 3.4, and 190.0 g/day and 34.8 kg, 3.1, and 149.7 g/day for Chios and Serres lambs, respectively; the respective values according to the ration group and sex are presented in Table 3.

Table 3. Mean±SD of live body weight (LBW) and BCS pre-slaughter, and ADG of Chios (S1) and Serres lambs (S2) according to the ration group and sex.

Study 1 (Chios lambs)	Group A† (n*= 39 lambs)	Group B†† (n = 36 lambs)	Males (n = 40 lambs)	Females (n = 35 lambs)	Overall (n = 75 lambs)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
LBW (kg)	38.8±6.69	39.7±5.96	42.1±5.68	35.9±5.40	39.2±6.32
BCS (1-5)	3.2±0.45	3.6±0.32	3.5±0.40	3.3±0.47	3.4±0.44
ADG (g/day)	184.5±164.18	196.0±147.29	218.5±160.90	157.5±144.37	190.0±156.33
Study 2 (Serres lambs)	**Group A (n = 58 lambs)**	**Group B (n = 60 lambs)**	**Males (n = 67 lambs)**	**Females (n = 51 lambs)**	**Overall (n = 118 lambs)**
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
LBW (kg)	35.1±6.90	34.5±6.88	36.9±7.11	32.2±5.56	34.8±6.86
BCS (1-5)	3.0±0.40	3.1±0.51	3.1±0.46	3.1±0.47	3.1±0.46
ADG (g/day)	152.2±155.40	147.2±142.27	167.0±157.71	126.9±133.05	149.7±148.85

†: Group A = lambs fed with ration containing soybean meal
††: Group B = lambs fed with ration containing canola meal
*: n = number of lambs

Morbidity frequency measures of the studied health and welfare traits

Point and period prevalence values of the studied health and welfare traits in Chios and Serres lambs during fattening are summarized in Table 4. During S1, the most prevalent health- and welfare-related issues in Chios lambs were nasal discharge (94.9% and 94.4% in groups AC and BC, respectively), ocular discharge (79.5% in group AC), dirty fleece (82.1% and 72.2% in groups AC and BC, respectively), and soft-wet faeces (74.4% and 63.9% in groups AC and BC, respectively). During S2, the highest period prevalence in Serres lambs was found in group AS for nasal discharge (67.2%), dirty fleece (63.8%), and

Table 4. Point and period prevalence (%) and new cases (in parentheses) of the recorded health and welfare traits in Chios (S1) and Serres (S2) lambs during fattening.

Study 1 (Chios lambs)		Group A† (n* = 39 lambs)		Group B†† (n = 36 lambs)	
Health and welfare traits		Point prevalence** (n)	Period prevalence§ (n)	Point prevalence (n)	Period prevalence (n)
	Lameness	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
	Arthritis	2.6 (1)	20.5 (8)	0.0 (0)	22.2 (8)
	Ocular discharge	17.9 (7)	79.5 (31)	11.1 (4)	55.6 (20)
	Nasal discharge	17.9 (7)	94.9 (37)	22.2 (8)	94.4 (34)
	Soft-wet faeces	5.1 (2)	74.4 (29)	0.0 (0)	63.9 (23)
	Dirty fleece	41.0 (16)	82.1 (32)	38.9 (14)	72.2 (26)
	Poor fleece quality	0.0 (0)	2.6 (1)	0.0 (0)	0.0 (0)
Swollen lymph nodes	Submandibular	0.0 (0)	0.0 (0)	0.0 (0)	2.8 (1)
	Parotid	0.0 (0)	2.6 (1)	0.0 (0)	0.0 (0)
	Prescapular	2.6 (1)	15.4 (6)	0.0 (0)	19.4 (7)
	Body abscesses	0.0 (0)	23.1 (9)	0.0 (0)	0.0 (0)
Skin lesions	Head	5.1 (2)	38.5 (15)	2.8 (1)	38.9 (14)
	Ears	0.0 (0)	2.6 (1)	0.0 (0)	2.8 (1)
	Body	0.0 (0)	2.6 (1)	0.0 (0)	0.0 (0)
	Limbs	0.0 (0)	12.8 (5)	0.0 (0)	27.8 (10)
	Perineum	0.0 (0)	12.8 (5)	0.0 (0)	13.9 (5)
	Tail	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Study 2 (Serres lambs)		**Group A (n = 58 lambs)**		**Group B (n = 60 lambs)**	
	Lameness	0.0 (0)	5.2 (3)	0.0 (0)	1.7 (1)
	Arthritis	0.0 (0)	12.1 (7)	0.0 (0)	10.0 (6)
	Ocular discharge	29.3 (17)	43.1 (25)	16.7 (10)	25.0 (15)
	Nasal discharge	34.5 (20)	67.2 (39)	16.7 (10)	48.3 (29)
	Soft-wet faeces	10.3 (6)	55.2 (32)	5.0 (3)	46.7 (28)
	Dirty fleece	37.9 (22)	63.8 (37)	35.0 (21)	51.7 (31)
	Poor fleece quality	1.7 (1)	3.4 (2)	0.0 (0)	0.0 (0)
Swollen lymph nodes	Submandibular	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
	Parotid	0.0 (0)	10.3 (6)	0.0 (0)	0.0 (0)
	Prescapular	0.0 (0)	20.7 (12)	0.0 (0)	5.0 (3)
	Body abscesses	0.0 (0)	62.1 (36)	0.0 (0)	6.7 (4)
Skin lesions	Head	6.9 (4)	37.9 (22)	6.7 (4)	53.3 (32)
	Ears	0.0 (0)	1.7 (1)	0.0 (0)	5.0 (3)
	Body	0.0 (0)	1.7 (1)	0.0 (0)	0.0 (0)
	Limbs	0.0 (0)	10.3 (6)	1.7 (1)	31.7 (19)
	Perineum	0.0 (0)	0.0 (0)	0.0 (0)	10.0 (6)
	Tail	3.4 (2)	13.8 (8)	0.0 (0)	21.7 (13)

†: Group A = lambs fed with ration containing soybean meal
††: Group B = lambs fed with ration containing canola meal
*: n = number of lambs
**: Point prevalence = the proportion of lambs with health and welfare issues at the beginning of the studies and after the two adaption periods.
§: Period prevalence = the proportion of lambs with health and welfare issues during the fattening period.

body abscesses (62.1%) (Table 4). Lameness was not a common issue and was observed only in four Serres lambs and mainly in the group AS (3 out of 4 lame animals).

Table 5 summarizes the number of new cases, incidence rate, and cumulative incidence of the recorded health and welfare traits during the Chios and Serres lambs fattening. During S1, group AC had a higher incidence rate and cumulative incidence for nasal and

Table 5. Number of new cases, lamb-weeks at risk, incidence rate (new cases/1,000 lamb-weeks), and cumulative incidence of the recorded health and welfare traits in Chios (S1) and Serres (S2) lambs.

Study 1 (Chios lambs)		**Group A† (n* = 39 lambs)**				**Group B†† (n = 36 lambs)**			
Health and welfare traits		**New cases****	**Lamb-weeks at risk§**	**Incidence rateΠ**	**Cumulative incidence (%)£**	**New cases**	**Lamb-weeks at risk**	**Incidence rate**	**Cumulative incidence (%)**
	Lameness	0	546	0.0	0.0	0	504	0.0	0.0
	Arthritis	7	496.5	14.1	17.9	8	452	17.7	22.2
	Ocular discharge	24	288	83.3	61.5	16	330	48.5	44.4
	Nasal discharge	30	206	145.6	76.9	26	256	101.6	72.2
	Soft-wet faeces	27	265	101.9	69.2	23	302	76.2	63.9
	Dirty fleece	16	380	42.1	41.0	12	372	32.3	33.3
	Poor fleece quality	1	536.5	1.9	2.6	0	504	0.0	0.0
Swollen lymph nodes	Submandibular	0	546	0.0	0.0	1	502	2.0	2.8
	Parotid	1	543	1.8	2.6	0	504	0.0	0.0
	Prescapular	5	506	9.9	12.8	7	434	16.1	19.4
	Body abscesses	9	501.5	17.9	23.1	0	504	0.0	0.0
Skin lesions	Head	13	437	29.7	33.3	13	387	33.6	36.1
	Ears	1	532.5	1.9	2.6	1	499.5	2.0	2.8
	Body	1	536.5	1.9	2.6	0	504	0.0	0.0
	Limbs	5	517.5	9.7	12.8	10	429	23.3	27.8
	Perineum	5	517.5	9.7	12.8	5	475.5	10.5	13.9
	Tail	0	546	0.0	0.0	0	504	0.0	0.0
Study 2 (Serres lambs)		**Group A (n = 58 lambs)**				**Group B (n = 60 lambs)**			
	Lameness	3	907.5	3.3	5.2	1	955.5	1.0	1.7
	Arthritis	7	851.5	8.2	12.1	6	882	6.8	10.0
	Ocular discharge	8	817	9.8	13.8	5	895	5.6	8.3
	Nasal discharge	19	695	27.3	32.8	19	693	27.4	31.7
	Soft-wet faeces	26	678	38.3	44.8	25	688	36.3	41.7
	Dirty fleece	15	745	20.1	25.9	10	841	11.9	16.7
	Poor fleece quality	1	915.5	1.1	1.7	0	960	0.0	0.0
Swollen lymph nodes	Submandibular	0	928	0.0	0.0	0	960	0.0	0.0
	Parotid	6	898	6.7	10.3	0	960	0.0	0.0
	Prescapular	12	865	13.9	20.7	3	941	3.2	5.0
	Body abscesses	36	612.5	58.8	62.1	4	941	4.3	6.7
Skin lesions	Head	18	727	24.8	31.0	28	704	39.8	46.7
	Ears	1	918.5	1.1	1.7	3	924.5	3.2	5.0
	Body	1	920.5	1.1	1.7	0	960	0.0	0.0
	Limbs	6	869	6.9	10.3	18	789	22.8	30.0
	Perineum	0	928	0.0	0.0	6	894	6.7	10.0
	Tail	6	847	7.1	10.3	13	805.5	16.1	21.7

†: Group A = lambs fed with ration containing soybean meal
††: Group B = lambs fed ration containing canola meal
*: n = number of lambs
**: New case = a lamb identified to have the respective health and welfare issue for the first time during the fattening period.
§: Lamb-weeks at risk = the actual time at risk (expressed in weeks) that all lambs of the studied contributed to the study while remaining free from the studied health and welfare issue.
Π: Incidence rate = the number of new cases of the studied trait per 1,000-lamb weeks at risk.
£: Cumulative incidence = the number of new cases of the studied health and welfare issues divided by the total number of lambs.

ocular discharge and for soft-wet faeces (146, 83, and 102 new cases per 1,000 lamb-weeks and 76.9%, 61.5%, and 69.2%, respectively) compared to group BC, whereas in group BC the respective indices were higher for nasal discharge and soft-wet faeces (102 and 76 new cases per 1,000 lamb-weeks and 72.2% and 63.9%, respectively). During S2, group AS had a higher incidence rate and cumulative incidence for body abscesses (59 new cases per 1,000 lamb-weeks and 62.1%, respectively) compared to group BS.

The effects of diet and sex on fattening performance and health and welfare status

Estimated marginal means of LBW in groups A and B during the fattening of Chios and Serres lambs are presented in Figures 1 and 2. The live body weight of lambs in group BC tended to increase after the 4th week of fattening compared to group AC (Figure 1). On the contrary, LBW of lambs in groups AS and BS demonstrated a similar tendency across the fattening period (Figure 2).

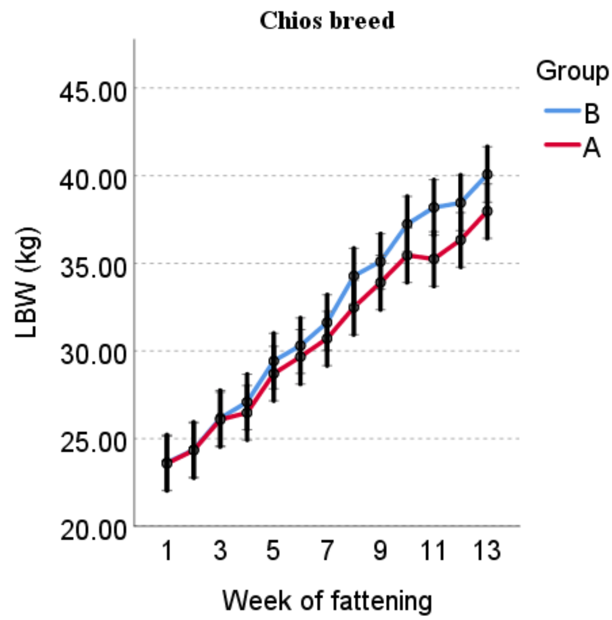

Figure 1. Estimated marginal means of live body weight (LBW) in groups A and B of Chios lambs

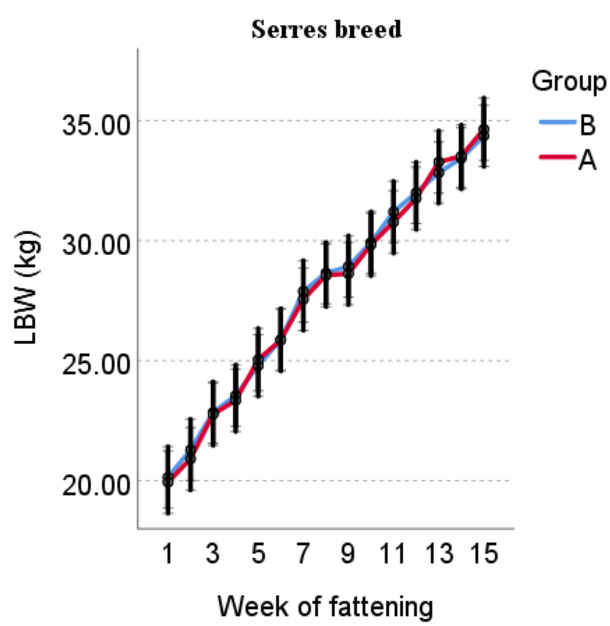

Figure 2. Estimated marginal means of live body weight (LBW) in groups A and B of Serres lambs.

Effects of diet and sex on the lambs' LBW, BCS, and ADG are presented in Table 6. In Chios lambs, the replacement of SBM by CM had a significant effect on BCS and ADG (F = 13.64, P ≤ 0.001, and F = 4.91, P = 0.027, respectively) (Table 6). Specifically, lambs in group BC had higher BCS and ADG (increased by 6.7% and 12.9%, respectively) compared to group AC.

Sex significantly affected LBW and ADG in Chios (F = 11.78, P ≤ 0.001 and F = 39.36, P ≤ 0.001, respectively) and Serres lambs (F = 10.45, P = 0.001 and F = 22.62, P ≤ 0.001, respectively). Live body weight and ADG were increased by 12.5% and 41.7% in male Chios lambs compared to female lambs, respectively. Similarly, Serres male lambs had higher LBW and ADG (increased by 10.9% and 31.7%, respectively) compared to female lambs.

In Chios lambs, week of fattening (WF) and the interactions between Group×WF and Sex×WF had statistically significant effects on LBW (F = 178.76, P ≤ 0.001, F = 6.54, P ≤ 0.001, and F = 5.00, P ≤ 0.001, respectively), BCS (F = 47.37, P ≤ 0.001, F = 10.03, P ≤ 0.001, and F = 2.77, P ≤ 0.001, respectively), and ADG (F = 37.48, P ≤ 0.001, F = 6.74, P ≤ 0.001, and F = 1.77, P = 0.049, respectively). Additionally, in Serres lambs, WF and Group×WF had a statistically significant overall effect on LBW (F = 179.27, P ≤ 0.001 and F = 3.20, P ≤ 0.001, respectively), ADG (F = 26.27, P ≤ 0.001 and F = 3.18, P ≤ 0.001, respectively), and BCS (F = 39.43, P ≤ 0.001 and F = 2.92, P ≤ 0.001). Moreover, Sex×WF had a statistically significant effect on LBW (F = 4.24, P ≤ 0.001).

Table 7 summarizes the effects of diet and sex on the occurrence of the studied health and welfare traits. The likelihood of nasal discharge was 1.59 times in-

Table 6. Estimated marginal means and comparisons between the studied groups and sexes on live body weight (LBW), BCS, and ADG in Chios (S1) and Serres (S2) lambs.

	Group†			Sex†		
	A††	B*		Male	Female	
	EMM** (±SE)	EMM (±SE)	P-value	EMM (±SE)	EMM (±SE)	P-value
Study 1 (n§ = 75 Chios lambs)						
LBW (kg)	30.8 (±0.76)	32.0 (±0.77)	0.289	33.3 (±0.74)	29.6 (±0.79)	0.001
BCS (1-5)	3.0 (±0.04)	3.2 (±0.04)	0.000	3.2 (±0.04)	3.1 (±0.04)	0.189
ADG (g/day)	176.4 (±7.23)	199.2 (±7.37)	0.027	220.2 (±7.09)	155.4 (±7.50)	0.000
Study 2 (n = 118 Serres lambs)						
LBW (kg)	27.8 (±0.64)	27.9 (±0.62)	0.925	29.3 (±0.59)	26.4 (±0.67)	0.001
BCS (1-5)	2.8 (±0.05)	2.9 (±0.04)	0.233	2.9 (±0.04)	2.9 (±0.05)	0.848
ADG (g/day)	149.0 (±6.02)	144.9 (±5.91)	0.625	167.1 (±5.55)	126.9 (±6.36)	0.000

†: Reference categories for the variables group and sex are Group A and female, respectively.
††: A = group of lambs fed with ration containing soybean meal
*: B = group of lambs fed ration containing canola meal
**: EMM = marginal means as estimated by the regression models
§: n = number of lambs

Table 7. Effects of ration group and sex on the main health and welfare issues observed in the two studies.

	Group†			Sex†		
	B†† (±SE)	OR* (95% CI)	P-value	B (±SE)	OR (95% CI)	P-value
Study 1 (n= 75 Chios lambs)**						
Ocular discharge	-0.31 (±0.23)	0.73 (0.46-1.17)	0.180	-0.05 (±0.23)	0.95 (0.60-1.51)	0.841
Nasal discharge	-0.47 (±0.21)	0.63 (0.42-0.94)	0.024	0.03 (±0.21)	1.03 (0.68-1.54)	0.892
Soft-wet faeces	-0.26 (±0.17)	0.77 (0.55-1.08)	0.136	-0.18 (±0.17)	0.84 (0.60-1.17)	0.298
Dirty fleece	-0.33 (±0.25)	0.72 (0.44-1.16)	0.176	0.16 (±0.25)	1.17 (0.72-1.90)	0.516
Swollen prescapular lymph nodes	-0.07 (±0.38)	0.94 (0.45-1.96)	0.858	-0.30 (±0.38)	0.74 (0.35-1.54)	0.421
Head skin lesions	-0.28 (±0.27)	0.76 (0.45-1.28)	0.295	-0.49 (±0.27)	0.61 (0.36-1.04)	0.068
Limb skin lesions	0.71 (±0.40)	2.03 (0.92-4.45)	0.078	0.29 (±0.40)	1.33 (0.61-2.92)	0.477
Study 2 (n= 118 Serres lambs)						
Ocular discharge	-0.55 (±0.27)	0.58 (0.34-0.98)	0.043	0.36 (±0.28)	1.43 (0.83-2.45)	0.199
Nasal discharge	-0.31 (±0.19)	0.74 (0.51-1.07)	0.108	0.47 (±0.19)	1.60 (1.09-2.34)	0.016
Soft-wet faeces	-0.07 (±0.15)	0.93 (0.70-1.24)	0.616	-0.14 (±0.15)	0.87 (0.65-1.16)	0.346
Dirty fleece	-0.16 (±0.19)	0.85 (0.58-1.25)	0.418	0.03 (±0.20)	1.03 (0.70-1.52)	0.867
Body abscesses	-1.59 (±0.23)	0.20 (0.13-0.32)	0.000	-0.11 (±0.19)	0.90 (0.61-1.31)	0.580
Head skin lesions	0.32 (±0.26)	1.39 (0.84-2.30)	0.204	-0.48 (±0.26)	0.62 (0.37-1.03)	0.065
Limb skin lesions	0.57 (±0.33)	1.76 (0.93-3.33)	0.082	0.05 (±0.32)	1.05 (0.55-1.98)	0.890
Tail lesions	0.32 (±0.22)	1.37 (0.90-2.10)	0.143	-0.89 (±0.22)	0.41 (0.27-0.64)	0.000

†: Reference categories for the variables group and sex are Group A and female, respectively.
††: B = regression coefficient
*: OR = odds ratio
**: n = number of lambs

creased in group AC compared to group BC (95% CI: 1.06 to 2.38, $P \leq 0.05$). Moreover, lambs in group AS were more likely to present ocular discharge (OR = 1.72, 95% CI: 1.02 to 2.94, $P \leq 0.05$), and body abscesses (OR = 5.00, 95% CI: 3.13 to 7.69, $P \leq 0.001$) compared to lambs in group BS. No other significant differences were found concerning the rest of the studied health and welfare traits between groups AC and BC (S1) and groups AS and BS (S2).

DISCUSSION

The production of heavy carcasses from indigenous Greek dairy breeds of lambs is a novelty *per se*, taking into consideration that both management as well as breeding and selection criteria in these breeds are milk-production oriented. There are few studies, dating more than two decades ago, which have demonstrated growth performance of lambs from three Greek breeds (Boutsko, Serres, and Karagouniko) (Arsenos, 1997, Arsenos et al., 2000, 2002) and Boutsko×Karagouniko crossbreds (Zervas et al., 1999), which were fattened to reach either a fixed LBW or specific proportions of mature weight pre-slaughter. Fattening of dairy breed lambs has been attempted in other countries and breeds as well; however, in most of the cases, the targeted slaughter weight was lower than in our study, where the lambs were fattened to reach the age of 6 to 6.5 months and a LBW of ca. 35 to 40 kg. For example, in the study by Joy et al. (2008), Churra Tensina lambs were fattened to reach 20 kg LBW, while Rodriguez et al. (2008), and Haddad and Husein (2004) fattened Assaf breed lambs to reach a slaughter body weight of 22 to 25 kg and 31 kg, respectively.

The use of various alternative protein sources to substitute SBM in fattening lamb rations and the respective effects on growth performance have been extensively assessed and documented in the available literature (Hadjipanayiotou, 2002, Irshaid et al., 2003, Alves et al., 2016, Silva et al., 2016, Pérez-Trejo et al., 2022, Agwa et al., 2023). Nevertheless, there are no previous studies on the effects of replacing SBM with CM, as the main protein source in lamb fattening rations, concerning the growth performance of fattening dairy breed lambs. On the contrary, in meat breed lambs, as well as in beef and monogastric animals, partial or total replacement of SBM by CM has been assessed in terms of growth performance traits and was not found to have any adverse effects on them (Sami et al., 2010, Leeson et al., 2011, Yun et al., 2017, Sekali et al., 2020,Yusuf et al., 2022). This is in accordance with our study, where the total replacement of SBM by CM not only had no unfavourable effect on the LBW, BCS, and ADG in both Chios and Serres lambs, but Chios lambs fed with CM had significantly higher BCS and ADG compared to those fed with SBM; this finding, though, was not observed in Serres lambs. Increased BCS in group BC indicates a favourable muscle development and higher subcutaneous fat deposition compared to group AC lambs.

Breed-related differences in growth performance and carcass quality seem to be possible and have already been reported between fat- and thin-tailed indigenous breeds (Argyriadou et al., 2022). Nevertheless, in our case, the study design does not allow direct comparisons between the two breeds, and despite fattening protocols were the same, the fact that Chios and Serres lambs were fattened during different periods makes it impossible to separate the fattening period effect from the breed effect. A larger-scale study with the inclusion of lambs from both breeds at the same fattening period and operation is needed to reveal differences between the breeds. To sufficiently justify the use of dairy breed lambs for fattening in feedlots, further studies, including more fattening operations, breeds, and animals, are warranted. For these studies, the improvement of feeding and the elimination of significant health and welfare issues are crucial, while cost-benefit analyses in terms of environmental, social, and financial sustainability are also important to justify them.

Furthermore, it is known that sex affects growth performance in lambs irrespective of the breed or the productive orientation; indeed, as expected, male lambs of the two studied breeds had significantly higher LBW and ADG than female ones (Wylie et al., 1997, Rodríguez et al., 2011, Facciolongo et al., 2018), more likely associated with the higher dry matter intake, better feed efficiency, and increased growth rate in male lambs.

Lambs' health and welfare have been comparatively assessed in the past, either under different farming systems (intensive, semi-intensive, extensive) (Bodas et al., 2021) or housing conditions (Teixeira et al., 2012, 2015, Aguayo-Ulloa et al., 2014). However, to our knowledge, this is the first time lambs of Greek dairy breeds are fattened in a feedlot, and prospectively studied concerning their health and welfare status, thus providing evidence for the morbidity frequency measures of relevant health and welfare issues (prevalence, incidence rate, and cumulative incidence). The most prevalent health and welfare issues in our studies were nasal and ocular discharge. Despite the limited scientific data, the European Food Safety Authority (EFSA) has concluded that the most common health issues of fattening lambs in feedlots are primarily attributed to the ovine respiratory complex (ORC), which is considered the major cause of lamb mortality, and secondarily to digestive diseases, with coccidiosis being the most significant one (Berg et al., 2014, González et al., 2016). The ovine respiratory complex refers to a complex disease resulting from the interaction between bacterial agents and compromised host defense mechanisms. Stressor factors predispose to its occurrence, and it is mainly characterized by fever, cough, nasal, and ocular discharge (Bell, 2008, Navarro et al., 2020), whereas it is commonly observed in feedlot lambs exposed to inappropriate environmental, housing, and hygiene conditions. Nasal and ocular discharge can also be caused by non-infectious agents; for example, dusty environment and the increased ammonia concentration irritate the upper and lower respiratory tract, disrupting its integrity and leading to inflammation. As ambient temperature increases and humidity drops, the microenvironment becomes hot and dusty, particularly in fattening operations located in hot and dry regions, as in our study. Also, the dust in the rations further deteriorates these conditions. Other causes of ocular discharge include infectious keratoconjunctivitis, ophthalmitis, and less commonly entropion (Naglić et al., 2000, Bell, 2008), which, though, were not observed in the studied lambs.

The main causative agents of soft-wet faeces in fattening lambs are coccidia, gastrointestinal nematodes, and digestive disorders (e.g., ruminal acidosis) (Mitchell and Linklater, 1983, Sargison, 2004, Bayne and Edmondson, 2021). Despite being likely that many of the lambs were infected by coccidia during fattening, in the studied lambs, fecal samples were not collected regularly to perform parasitological examinations and justify a causative effect of parasitic infections on soft-wet faeces. Therefore, it is not possible to conclude whether soft-wet faeces were due to coccidial infections or other infectious diseases and/or digestive disorders. An additional problem challenging health of Serres lambs and mainly group AS was the occurrence of body abscesses. It is likely that the causative agent of body abscesses was caseous lymphadenitis given that the vast majority of the abscesses were located at lymph nodes and mainly in one group, implying the horizontal transmission of the pathogen within the pen. However, infections by various other pyogenic bacteria cannot be excluded from the differential diagnosis (De La Fuente et al., 1985, Al-Gaabary et al., 2009, Rzewuska et al., 2019).

The forementioned health and welfare issues are known to be associated with improper housing, microenvironment, and hygiene conditions; indeed, in the studied fattening operation, the ventilation was inadequate, disinfection of premises was not sufficiently practiced (e.g., the frequency was low and the disinfectants used were not effective against coccidia), and marginal stocking density was the norm. All these factors are likely to have predisposed to respiratory and gastrointestinal infections, explaining the increased occurrence of signs from the upper respiratory and the digestive system. According to Navarro et al. (2020), the proportion of lambs with clinical signs of conjunctivitis, respiratory diseases, and coccidiosis was higher in feedlots when compared to those fattened in the farms of origin. This is also the case in cattle feedlots, where the main health and welfare challenges are respiratory diseases and secondary digestive disorders (e.g., ruminal acidosis, coccidiosis), leading to reduced growth performance, poor welfare status, and deaths (Smith, 1998, Malafaia et al., 2016). In our study, it was not possible to comparatively assess the occurrence and incidence rate of the observed health and welfare issues between the fattening operation and the farms of origin, hence, it is not possible to conclude where the causative agents of these issues derive from. Further research, under various environmental conditions, is necessary to better understand the main health and welfare challenges during fattening and to identify the most efficient fattening protocols of dairy breed lambs, considering feeding and husbandry practices, housing conditions, and flock health management.

Replacement of SBM by CM, as the main protein source in lamb fattening rations, in terms of the health and welfare status of fattening dairy breed lambs, has not been studied in the past. It was found that this replacement may have beneficial effects on some of the studied health and welfare traits; namely, Chios lambs fed with CM had lower odds of nasal discharge compared to those fed with SBM. Likewise, Serres lambs fed with CM had lower odds of ocular discharge and body abscesses compared to those fed with SBM. Unfortunately, studies about the CM components and their properties associated with the observed beneficial effects on feedlot lambs' health and welfare are scarce, hindering the elucidation of the underlying mechanisms. To this purpose, future research efforts need to focus on the ingredients of CM and demonstrate the above mentioned beneficial effects.

CONCLUSIONS

Lambs of Chios and Serres breeds demonstrated a satisfactory growth performance, which was evidenced when they were fed either with the ration including SBM or CM as main protein sources. However, the observed variation in the LBW increasing rate between breeds and groups implies that growth performance in these lambs could be further improved by more efficiently standardizing management and housing conditions. Based on our findings, it is concluded that some of the most prevalent health and welfare issues observed herein were potentially associated with adverse environmental conditions during fattening. Therefore, in feedlot lambs of dairy breeds, special attention needs to be paid to respiratory and digestive system disorders to conclude their etiology, to treat them, and control their spread by revealing predisposing factors. Although the causative agents of the main health and welfare issues observed in our study were not further investigated, in all cases, relevant risk factors were evident, while some potential protective factors were also found. Among them, the replacement of SBM by CM was found to be associated with beneficial effects on specific health and welfare traits in both breeds; namely, nasal and ocular discharge, and body abscesses.

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CONFLICT OF INTEREST

None declared

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