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Performance and Carcass Characteristics of Australian Prime Lambs Grazing Lucerne and Cocksfoot Pastures Are Enhanced by Supplementation with Plant Oil Infused Pellets

Hung V. Le [1,2], Quang V. Nguyen [1,3], Don V. Nguyen [1,2], Bunmi S. Malau-Aduli [4], Peter D. Nichols [1,5] and Aduli E. O. Malau-Aduli [1,*]

1 Animal Genetics and Nutrition, Veterinary Sciences Discipline, College of Public Health, Medical and Veterinary Sciences, Division of Tropical Health and Medicine, James Cook University, Townsville, QLD 4811, Australia; vanhung.le@my.jcu.edu.au (H.V.L.); quang.nguyen2@my.jcu.edu.au (Q.V.N.); donviet.nguyen@my.jcu.edu.au (D.V.N.); peter.nichols@csiro.au (P.D.N.)
2 National Institute of Animal Science, Thuy Phuong, Bac Tu Liem, Hanoi 129909, Vietnam
3 Faculty of Animal Science and Veterinary Medicine, Thai Nguyen University of Agriculture and Forestry, Thai Nguyen 252166, Vietnam
4 College of Medicine and Dentistry, Division of Tropical Health and Medicine, James Cook University, Townsville, QLD 4811, Australia; bunmi.malauaduli@jcu.edu.au
5 CSIRO Oceans & Atmosphere, P.O. Box 1538, Hobart, TAS 7001, Australia
* Correspondence: aduli.malauaduli@jcu.edu.au; Tel.: +61-7-4781-5339

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Abstract: The aim of this study was to determine the effects of pasture (cocksfoot cv. porto (CFP) and lucerne) and supplementation of grazing lambs with pellets with or without plant oil infusion on performance and carcass characteristics. Forty-eight White Suffolk x Corriedale first-cross weaners were randomly assigned to one of four treatments in a split-plot experimental design: (1) CFP or lucerne pastures only (control); CFP or lucerne pastures supplemented with pellets infused with oil from (2) canola (CO); (3) rice bran (RBO) and (4) no oil pellets (NOP). Lucerne and CFP pastures were considered as the main plot effect, and played the role of basal pastures. Lambs grazing lucerne or CFP pastures with pellet supplementation achieved carcass weights of >22 kg at 9 weeks, which met the specific requirements of Asian and United States of American export markets. Pellet supplementation did not affect final liveweight, average daily gain, body length, withers height and chest girth of grazing lambs. Dressing percentage of lambs grazing CFP pasture with pellet supplementation and lambs grazing lucerne pasture with RBO supplementation increased compared with lambs on pasture grazing only. Although supplementing lambs on CFP pasture with CO had relatively negligible impact on feed conversion efficiency, it significantly increased over the hook trade value compared with lambs grazing CFP pasture only. In conclusion, lucerne or CFP pasture plus pellet supplementation produced lamb carcasses >22 kg suitable for the export market. CO had relatively low feed cost per unit daily gain (0.9 $AU/kg on CFP pasture and 0.6 $AU/kg on lucerne pasture) and could also be used as a tactical supplementation tool for increasing the carcass weight of lambs grazing CFP pasture.

Keywords: carcass; cocksfoot; lucerne; prime lambs; canola oil; rice bran oil

1. Introduction

The lamb industry plays an important role in the Australian economy accounting for 7% ($4.2 billion) of the gross value of agricultural production and 6% ($2.8 billion) of the agricultural export income in 2018–19 [1]. The Australian lamb industry benefits from the large grazing land area of approximately 341 million hectares [2] because animal production based on grazing systems is relatively low cost compared to more intense production systems [3]. Meat from lambs finished on green pastures is generally regarded as a good source of iron, zinc and omega-3 polyunsaturated fatty acids (n-3 PUFA) [4]. However, lamb production based on grazing systems is dependent on pasture quantity and quality, which in turn, is dependent on seasonal patterns and climate variability [5]. In addition, export markets in Asia and the USA which represent more than 50% of the total Australian lamb export volume [6], prefer carcasses of heavier weight specifications (22 kg or more) [7]. Therefore, there is a need to evaluate the effect of legumes, improved pastures and specialized forages in lamb finishing systems on growth rate, carcass characteristics and fatty acid profiles of grazing lambs. The additional use of supplementation with diverse oils of plant origin and subsequent effects on growth rate and carcass traits also needs to be evaluated in order to support lamb producers in the production of high quality and heavier carcasses for meeting the requirements of specific export markets [8].

Cocksfoot cv. porto (*Dactylis glomerata* L. cv. Porto) (CFP) was released in Tasmania in 1972 [9]. This grass has the potential to produce healthy, premium quality meat with high contents of n-3 PUFA and n-3 long-chain ($\geq C_{20}$) PUFA (n-3 LC-PUFA) [10]. However, there is a scarcity of available published information on the effect of CFP on lamb performance and carcass characteristics. Lucerne dominant pastures have been shown to consistently produce premium lamb carcasses for both the Australian local and export markets [7]. Nevertheless, available knowledge on the effect of lucerne pasture on prime lamb production and carcass characteristics in Tasmania characterized by a cool, temperate climate and considered as Australia's coolest state with a 'clean, green image' [11,12], is generally limited.

Canola oil is commercially extracted from canola seeds [13]. Rice bran oil is a by-product of rice processing [14]. Canola and rice bran oils have been studied for their effect on prime lamb performance and carcass characteristics in a confined system. Supplementation of lambs with rice bran oil and canola oil in confined systems had comparatively lower feed costs, without compromising average daily gain (ADG), carcass characteristics and over the hooks (OTH) trade income [15]. It has been demonstrated previously that supplementation of prime lambs with canola oil infused pellets in a confined system did not cause significant differences in daily feed intake, growth performance and carcass characteristics compared with supplementation with a none-oil containing pellet [16]. However, there is no peer-reviewed and published information on the effect of rice bran and canola oil supplementation on the performance and carcass characteristics of prime lambs managed on cocksfoot and lucerne dominated grazing systems. Therefore, the objective of this study was to evaluate the effects of CFP and lucerne pastures and supplementation with pellets with or without plant oil infusion on lamb performance and carcass characteristics.

2. Materials and Methods

2.1. Animal Ethics

The research was carried out at the Tasmanian Institute of Agriculture's Cressy Research and Demonstration Station, Burlington Road, Cressy, Tasmania, Australia, from October to December, 2016. The use of animals and procedures performed in this study were all approved by the University of Tasmania Animal Ethics Committee (Permit No A0015657).

2.2. Animals, Experimental Design, Diets and Feed Sampling Procedures

The animals, experimental design and fatty acid profiles in muscle and edible organs of pasture grazing lambs had previously been described elsewhere [10]. In brief, forty-eight White Suffolk × Corriedale first-cross, weaned prime lambs, with an average liveweight (LWT) of 38.7 ± 0.7 kg and six months of age were used in a split-plot design. The diagrammatic representation of the split-plot experimental design is presented in Figure 1. The main plot comprised cocksfoot cv. porto (CFP) and lucerne pastures, which played the role of basal diets. There was a total of 1.5 ha for each pasture split into 12 equal 0.125 ha sub-plots as the main plot units. These 24 plots of basal pastures were used for rotational grazing. All lambs were randomly assigned to 12 groups of four lambs each, balanced by gender. Lambs in each group were allocated to one of four treatments: (1) CFP or lucerne pastures only as the control treatment; (2) canola oil infused pellets (CO); (3) rice bran oil infused pellets (RBO); and (4) CFP or lucerne pastures supplemented with: no oil pellets (NOP). Thereafter, the 12 groups of lambs were allocated to six CFP and six lucerne pasture subplots. The experimental lambs were grazed daily on pastures from 07:00 to 18:00 h and rotated on fresh pasture subplots every 14 days throughout the trial. Fresh water was provided ad libitum during the grazing trial. Before being transferred to pastures, lambs in the supplemented groups were individually fed pellets at the rate of 1 kg/head/day. The total duration of the grazing trial was nine weeks, including three weeks of adjustment prior to commencement of the study, and six weeks of post-adjustment data collection. The pasture samples were collected weekly from five sites within an area of 50 cm × 50 cm of each subplot. These samples were bulked, thoroughly mixed and sub-samples taken for laboratory analyses. Samples of the pelleted feeds were taken from each bag and stored at −20 °C until the end of the trial before being subjected to laboratory analyses. The composition of experimental pellets is shown in Table 1.

Table 1. Ingredient composition of the experimental pellets *.

Ingredient (g/kg)	NOP	CO	RBO
Wheat	575	465	525
Paddy rice	220	280	220
Lupins	148	148	148
Canola oil, mL/kg	-	50	-
Rice bran oil, mL/kg	-	-	50
Ammonium sulphate	12.6	12.6	12.6
Salt	10	10	10
Limestone	20.9	20.9	20.9
Sheep premix	1	1	1
Acid buff	6.25	6.25	6.25
Sodium bicarbonate	6.25	6.25	6.25

* NOP: wheat-based pellets without infused oil; CO: wheat-based pellets infused with 50 mL/kg DM of canola oil; RBO: wheat-based pellets infused with 50 mL/kg DM of rice bran oil.

2.3. Feed Intake, Body Conformation Measurements and Liveweight

Pellet intake was calculated using the difference between the daily amount of total offered feed and the residual left-over feed. Feed conversion efficiency (FCE) was calculated according to Flakemore et al. [17]: the average daily feed intake (g)/1000 × 42 [days of supplementation]/total weight gain (kg) over the full trial period. Feed cost per kg of live animal weight gain was calculated as follows: FCE × ($/kg) of supplementary pellet.

NOP: wheat-based pellets without infused oil; CO: wheat-based pellets infused with 50 mL/kg DM of canola oil; RBO: wheat-based pellets infused with 50 mL/kg DM of rice bran oil; Control: grazing lambs without pellets supplementation.

Pellet price was based on the market ingredient costs of AU$ 0.147/kg, AU$ 0.160/kg and AU$ 0.194/kg for NOP, RBO and CO diets, respectively. Body conformation parameters including body length (BL), chest girth (CG) and withers height (WH) were measured weekly according to Holman et al. [18]. Body condition scores (BCS) were recorded at the same time by the same researcher on a scale of 1 to 5 using the method described by Kenyon et al. [19]. Body conformation and BCS parameters were measured while lambs were restrained in a relaxed state with heads comfortably erect and standing stably on all four legs on flat ground to minimise stress [20]. LWT was recorded weekly after measuring body condition score using a calibrated Ruddweigh 3000XT Walkover weighing electronic scale (Gallagher Group Limited, Hamilton, New Zealand) with animals standing in a relaxed position.

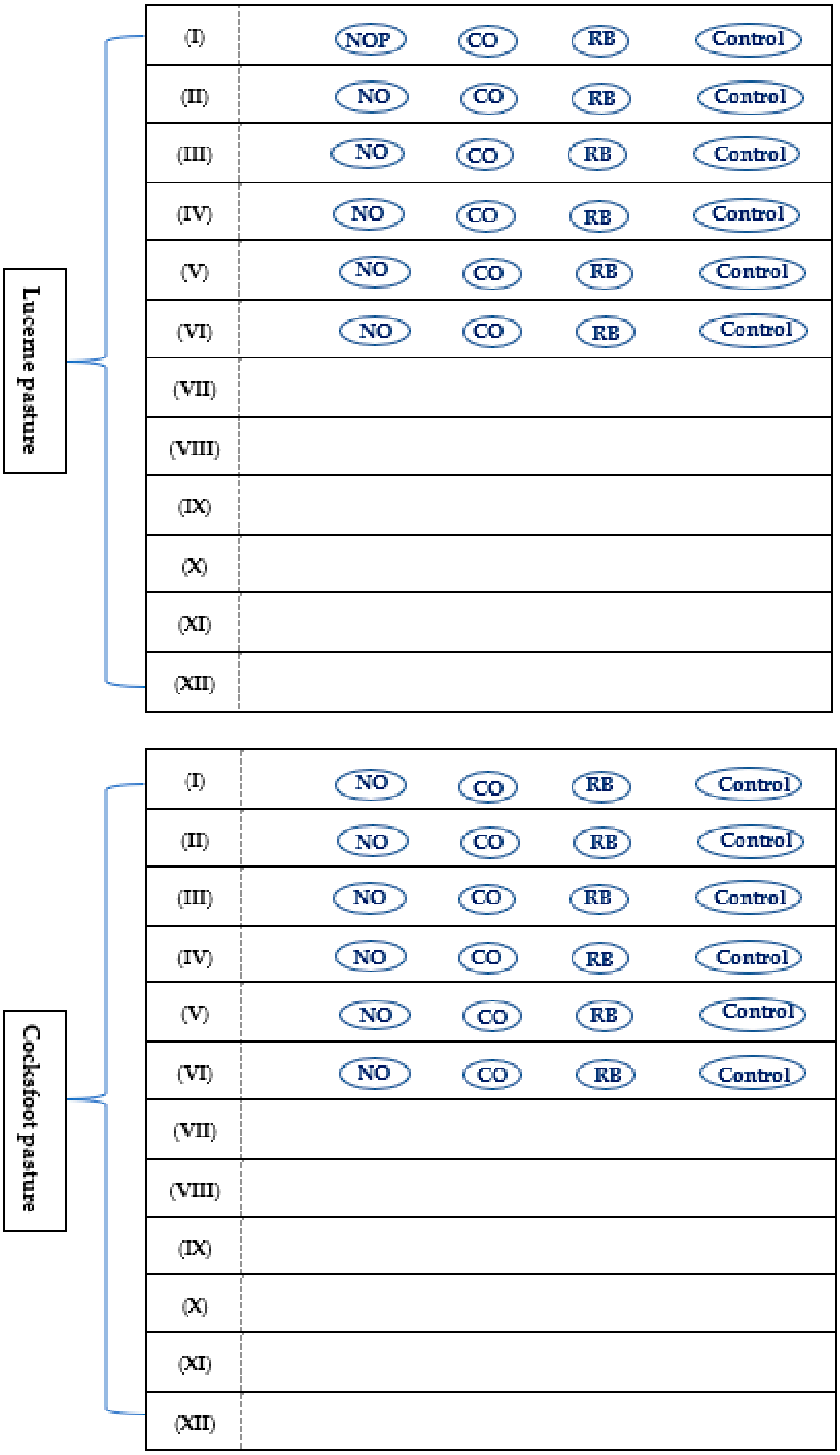

Figure 1. Diagrammatic representation of the split-plot experimental design.

2.4. Analysis of Pellet and Pasture Samples

Representative samples of pellets and pastures were dried at 60 °C for 72 h, ground to pass through a 1 mm sieve using a Laboratory Mill (Thomas Model 4 Wiley® Mill; Thomas Scientific) and analysed using standard methods of AOAC [21] for dry matter (DM) and ash. Neutral detergent (NDF) and acid detergent (ADF) fibre contents were determined using an Ankom Fibre Analyzer (ANKOM2000; ANKOM Technology, Macedon, NY, USA). Nitrogen content was quantified using a Thermo Finnigan EA 1112 Series Flash Elemental Analyzer and the values multiplied by 6.25 to give the crude protein (CP) percentage. Ether extract (EE) was analysed using an ANKOMXT15 fat/oil extractor (ANKOM Technology, Macedon, NY, USA). Total digestible nutrients (%TDN) were calculated as TDN (% of DM) = 82.38 − (0.7515 × ADF [% of DM]) [22]. Metabolisable energy (ME) was calculated by converting %TDN to digestible energy (DE [Mcal/kg] = %TDN × 0.01 × 4.4) which was converted as ME = (DE (Mcal/kg) × 0.82) × 4.185 [23].

2.5. Slaughter Protocol and Carcass Characteristics Measurements

All experimental lambs were fasted for 12 h with free access to water before transportation to a near-by commercial abattoir (Tasmanian Quality Meats, Cressy, Tasmania) adjacent to the experimental site in strict compliance with Meat Standards of Australia guidelines [24]. Pre-slaughter weight of lambs was taken and hot carcass weights (HCW) recorded immediately after slaughter and removal of non-edible carcass components (head, hide, gastrointestinal tract, and internal organs). Dressing percentage (DP) was computed as DP (%) = (HCW/LWT) × 100. The carcasses were chilled for 24 h at 4 °C before conveyance to Robinson Meats, Glenorchy, Hobart, Tasmania, Australia, for commercial boning out into retail cuts and for carcass measurements. Carcass characteristics, including fat thickness, body wall thickness and rib eye area, were determined according to Flakemore et al. [17]. The following equation was used to calculate the percentage boneless, closely trimmed retail cuts (BCTRC):%BCTRC = (49.936 − (0.0848 × 2.205 × HCW) − (4.376 × 0.3937 × FT) − (3.53 × 0.3937 × BWT) + (2.456 × 0.155 × REA), where HCW is hot carcass weight; FT is fat thickness; BWT is body wall thickness and REA is rib eye area [25]. OTH trade value in Australian dollars was calculated as HCW × 500¢/kg divided by 100¢ to make an average total dollar value per carcass for animals from each treatment group. The 500¢/kg used in the present study was the amount received per kg for the sale of the lambs in 2016, and is within the range for OTH prices for 2016 [26].

2.6. Statistical Analysis

All data were analysed using the split-plot model in general linear model procedures (PROC GLM) of the Statistical Analysis System software [27]. The main plot and sub-plot effects were pasture types and supplementation of pellets with or without oil infusion, respectively. Initial descriptive summary statistics were computed with least square means, standard errors, and scrutinized for data entry errors and outliers. Non-significant interactions between fixed effects were dropped from the analytical model and treatment differences were declared significant at $p \leq 0.05$ using Bonferroni probabilities.

3. Results

3.1. Chemical Composition of Pastures and Supplementary Feeds

The proximate analysis of experimental diets is presented in Table 2. Dry matter (DM) of pastures was 20.6%, which was considerably lower than supplemented pellets (~90%). Lucerne pasture had the highest crude protein (CP) of 18.6%, which was higher than that of the supplemented pellets, while CFP had the lowest CP (13.3%). The acid detergent fibre (ADF) and neutral detergent fibre (NDF) of pastures were triple and double those of supplemented pellets, respectively. Canola (CO) and rice bran (RBO) oil infused pellets had higher ether extract (EE) than no oil pellets (NOP) and pastures. The metabolizable energy (ME) of the supplemented pellets was similar and higher than that of the pastures.

Table 2. Proximate analysis of supplementary feeds and pastures *.

Chemical Composition (% DM)	Lucerne	CFP	NOP	CO	RBO
DM	20.7	20.5	89.1	91.1	90.2
CP	18.6	13.3	15.7	15.3	14.7
ADF	25.6	26.7	6.8	7.4	8.0
NDF	35.9	43.8	18.3	19.9	18.7
EE	1.8	3.0	2.1	4.6	3.9
ASH	6.8	6.4	4.0	6.5	5.0
%TDN	63.2	62.3	77.2	76.8	76.4
DE (Mcal/kg)	2.8	2.7	3.4	3.4	3.4
ME (MJ/kg)	9.5	9.4	11.7	11.6	11.5

* CFP: cocksfoot cv. porto pasture; DM: dry matter; NDF: neutral detergent fibre; ADF: acid detergent fibre; EE: ether extract; CP: crude protein; %TDN: total digestible nutrients, calculated as (% of DM) = 82.38 − (0.7515 × ADF [% of DM]). ME: metabolisable energy, calculated by converting %TDN to digestible energy (DE [Mcal/kg] = %TDN × 0.01 × 4.4) which was converted as ME = (DE (Mcal/kg) × 0.82) × 4.185. All other abbreviations as in Table 1.

3.2. Effect of Pellet Supplementation on Liveweight, Concentrate Intake, Body Conformation and Carcass Characteristic of Prime Lambs

3.2.1. Liveweight, Concentrate Intake and Body Conformation

The final LWT and average daily gain (ADG) of grazing lambs were unaffected by pellet supplementation as depicted in Table 3. Lucerne grazing lambs supplemented with RBO had significantly greater concentrate intake than those lambs supplemented with NOP or CO. Lambs grazing CFP with no oil pellet (NOP) supplementation had higher FCE than CFP grazing lambs with CO and RBO supplementation. CFP grazing lambs supplemented with RBO had lower feed cost per unit gain (FCPUG) than those lambs grazing CFP with NOP or CO supplementation. Pellet supplementation did not affect changes in the body length, withers height and chest girth of grazing lambs. Supplementation of RBO to CFP grazing lambs increased change in body condition score (Δ BCS) in comparison to grazing lambs with NOP supplementation or without supplement.

3.2.2. Carcass Characteristics

Carcass characteristics of grazing lambs are shown in Table 4. Pellet supplementation did not affect pre-slaughter weight, fat thickness, body wall thickness and percentage boneless, and closely trimmed retail cuts (BCTRC%) of grazing lambs. Supplementation with NOP and CO significantly increased the HCW of CFP grazing lambs compared with CFP grazing only. Lambs grazing CFP with CO and RBO supplementation had greater GR (girth rib) fat score than CFP only grazing lambs. Pellet supplementation significantly increased the dressing percentage of CFP grazing lambs. Only RBO supplementation increased the dressing percentage of lucerne grazing lambs. The grazing lambs with NOP supplementation had greater rib eye area than lambs grazing only without supplementation. NOP and CO supplementation to CFP grazing lambs significantly increased over the hooks trade (OTH trade) in comparison to the only CFP grazing lambs.

3.3. Effect of Pastures on Liveweight, Concentrate Intake, Body Conformation and Carcass Characteristics of Prime Lambs

Table 5 shows liveweight, concentrate intake and body conformation, while Table 6 depicts carcass characteristics of prime lambs as impacted by different pastures. There was no significant difference in initial and final LWT, change in body length (ΔBL) between lucerne and CFP grazing lambs. The ADG, change in withers height (ΔWH), chest girth (ΔCG) and body condition score (ΔBCS) of lucerne grazing lambs was greater than that of lambs that grazed pastures containing CFP. Concentrate intake, FCE and FCPUG of lucerne grazing lambs was lower than that of CFP grazing lambs. The different pasture types did not affect pre-slaughter weight, dressing percentage, rib eye area, BCTRC% and GR fat score. Lucerne grazing lambs had higher HCW, fat thickness, body wall thickness and OTH trade than CFP grazing lambs.

Table 3. Effect of pellet supplementation on liveweight, concentrate intake and body conformation of prime lambs (LSM ± SE) *.

Items	Control		NOP		CO		RBO	
	CFP (*n* = 6)	Lucerne (*n* = 6)	CFP (*n* = 6)	Lucerne (*n* = 6)	CFP (*n* = 6)	Lucerne (*n* = 6)	CFP (*n* = 6)	Lucerne (*n* = 6)
Initial LWT (kg)	41.9 ± 0.8	41.0 ± 0.8	42.6 ± 0.8	40.9 ± 0.8	41.4 ± 0.8	41.0 ± 0.8	40.9 ± 0.8	41.6 ± 0.8
Final LWT (kg)	49.3 ± 1.2	50.1 ± 1.2	48.1 ± 1.2	50.5 ± 1.2	48.5 ± 1.2	50.8 ± 1.2	49.5 ± 1.2	51.1 ± 1.2
ADG (g)	181.3 ± 21.9 ^{abc}	221.9 ± 21.9 ^{ab}	134.2 ± 21.9 ^{c}	234.1 ± 21.9 ^{ab}	172.4 ± 21.9 ^{bc}	240.7 ± 21.9 ^{a}	209.4 ± 21.9 ^{ab}	231.7 ± 21.9 ^{ab}
Concentrate intake (kg DM/head/day)	-	-	0.9 ± 0.04 ^{a}	0.7 ± 0.04 ^{b}	0.8 ± 0.04 ^{a}	0.6 ± 0.04 ^{b}	0.8 ± 0.04 ^{a}	0.9 ± 0.04 ^{a}
FCE	-	-	6.6 ± 0.4 ^{a}	3.0 ± 0.4 ^{c}	4.9 ± 0.4 ^{b}	2.9 ± 0.4 ^{c}	4.3 ± 0.4 ^{b}	3.9 ± 0.4 ^{bc}
FCPUG ($AU/kg)	-	-	1.0 ± 0.1 ^{a}	0.4 ± 0.1 ^{c}	0.9 ± 0.1 ^{a}	0.6 ± 0.1 ^{bc}	0.7 ± 0.1 ^{b}	0.6 ± 0.1 ^{bc}
Initial BL (cm)	64.8 ± 0.4	64.0 ± 0.4	64.7 ± 0.4	64.8 ± 0.4	64.7 ± 0.4	64.3 ± 0.4	64.3 ± 0.4	64.8 ± 0.4
Δ BL (cm)	3.5 ± 0.5	4.5 ± 0.5	4.2 ± 0.5	4.3 ± 0.5	3.3 ± 0.5	4.3 ± 0.5	3.7 ± 0.5	3.8 ± 0.5
Initial WH (cm)	62.8 ± 0.6	62.2 ± 0.6	62.8 ± 0.6	62.5 ± 0.6	62.5 ± 0.6	62.7 ± 0.6	62.3 ± 0.6	61.8 ± 0.6
Δ WH (cm)	2.8 ± 0.6 ^{bc}	4.7 ± 0.6 ^{a}	2.7 ± 0.6 ^{c}	4.5 ± 0.6 ^{ab}	3.2 ± 0.6 ^{abc}	3.5 ± 0.6 ^{abc}	3.5 ± 0.6 ^{abc}	4.7 ± 0.6 ^{a}
Initial CG (cm)	80.8 ± 0.7	81.2 ± 0.7	81.7 ± 0.7	80.7 ± 0.7	81.0 ± 0.7	80.5 ± 0.7	81.7 ± 0.7	81.2 ± 0.7
Δ CG (cm)	3.3 ± 0.8 ^{c}	6.2 ± 0.8 ^{ab}	3.7 ± 0.8 ^{c}	6.8 ± 0.8 ^{a}	4.5 ± 0.8 ^{bc}	6.3 ± 0.8 ^{ab}	5.3 ± 0.8 ^{abc}	7.0 ± 0.8 ^{a}
Initial BCS	3.0 ± 0.04	3.0 ± 0.04	3.1 ± 0.04	3.0 ± 0.04	3.0 ± 0.04	3.0 ± 0.04	3.1 ± 0.04	3.0 ± 0.04
Δ BCS	0.4 ± 0.1 ^{c}	0.8 ± 0.1 ^{ab}	0.4 ± 0.1 ^{c}	0.9 ± 0.1 ^{a}	0.6 ± 0.1 ^{bc}	0.7 ± 0.1 ^{abc}	0.8 ± 0.1 ^{ab}	0.8 ± 0.1 ^{ab}

* LWT: liveweight; ADG: average daily gain;.FCE: concentrate feed conversion efficiency (kg DM concentrate/kg gain per animal); FCPUG: feed cost per unit gain (concentrate cost/kg LWT gain); Δ: change in; CG: chest girth; WH: withers height; BL: body length; BCS: body condition score; LSM: least square mean; SE: standard error. All other abbreviations as in Tables 1 and 2. Values within the same row bearing different superscripts differ ($p < 0.05$).

Table 4. Effect of pellet supplementation on carcass characteristics of prime lambs (LSM ± SE) *.

Items	Control		NOP		CO		RBO	
	CFP (*n* = 6)	Lucerne (*n* = 6)	CFP (*n* = 6)	Lucerne (*n* = 6)	CFP (*n* = 6)	Lucerne (*n* = 6)	CFP (*n* = 6)	Lucerne (*n* = 6)
Pre-slaughter weight (kg)	45.6 ± 1.1	46.9 ± 1.1	47.9 ± 1.1	47.5 ± 1.1	46.9 ± 1.1	47.9 ± 1.1	46.7 ± 1.1	48.3 ± 1.1
HCW (kg)	22.5 ± 0.7 ^{c}	24.1 ± 0.7 ^{abc}	24.4 ± 0.7 ^{ab}	25.4 ± 0.7 ^{ab}	24.6 ± 0.7 ^{ab}	25.2 ± 0.7 ^{ab}	23.8 ± 0.7 ^{bc}	25.7 ± 0.7 ^{a}
Dressing percentage (%)	45.6 ± 0.8 ^{c}	48.2 ± 0.8 ^{b}	50.8 ± 0.8 ^{a}	50.3 ± 0.8 ^{ab}	50.8 ± 0.8 ^{a}	49.7 ± 0.8 ^{ab}	48.1 ± 0.8 ^{b}	50.4 ± 0.8 ^{a}
Fat thickness (mm)	6.0 ± 1.0 ^{c}	11.0 ± 1.0 ^{a}	8.3 ± 1.0 ^{abc}	8.3 ± 1.0 ^{abc}	8.2 ± 1.0 ^{abc}	8.7 ± 1.0 ^{abc}	7.8 ± 1.0 ^{bc}	9.2 ± 1.0 ^{ab}
Body wall thickness (mm)	16.5 ± 1.5 ^{b}	21.7 ± 1.5 ^{a}	18.3 ± 1.5 ^{ab}	21.2 ± 1.5 ^{a}	20.7 ± 1.5 ^{ab}	20.8 ± 1.5 ^{a}	18.8 ± 1.5 ^{ab}	22.0 ± 1.5 ^{a}
Rib eye area (cm^2)	13.6 ± 0.7 ^{c}	14.7 ± 0.7 ^{bc}	15.8 ± 0.7 ^{ab}	16.8 ± 0.7 ^{a}	15.3 ± 0.7 ^{abc}	16.0 ± 0.7 ^{ab}	15.0 ± 0.7 ^{abc}	15.8 ± 0.7 ^{ab}
BCTRC%	48.0 ± 0.3 ^{a}	46.9 ± 0.3 ^{b}	48.0 ± 0.3 ^{a}	47.8 ± 0.3 ^{ab}	47.4 ± 0.3 ^{ab}	47.5 ± 0.3 ^{ab}	47.8 ± 0.3 ^{ab}	47.1 ± 0.3 ^{ab}
GR fat score (1–5)	2.7 ± 0.2 ^{b}	3.5 ± 0.2 ^{a}	3.2 ± 0.2 ^{ab}	3.3 ± 0.2 ^{a}	3.3 ± 0.2 ^{a}	3.3 ± 0.2 ^{a}	3.3 ± 0.2 ^{a}	3.5 ± 0.2 ^{a}
OTH trade ($AU)	112.3 ± 3.3 ^{c}	120.5 ± 3.3 ^{abc}	122.2 ± 3.3 ^{ab}	127.0 ± 3.3 ^{ab}	123.2 ± 3.3 ^{ab}	126.2 ± 3.3 ^{ab}	119.2 ± 3.3 ^{bc}	128.7 ± 3.3 ^{a}

* Pre-slaughter weight: the weight of animals prior to transport for slaughter; HCW: hot carcass weight; BCTRC%: boneless, closely trimmed retail cuts; OTH: over the hooks trade (this was based on 500AU¢ return per kg of HCW). All other abbreviations as in Tables 1–3. Values within the same row bearing different superscripts differ ($p < 0.05$).

Table 5. Effect of different pasture types on liveweight, concentrate intake and body conformation of prime lambs (LSM ± SE) *.

Items	Pastures		*p* Value
	CFP (n = 24)	Lucerne (n = 24)	
Initial LWT (kg)	41.7 ± 0.37	41.1 ± 0.37	0.057
Final LWT (kg)	48.9 ± 0.62	50.6 ± 0.62	0.247
ADG (g)	174.3 ± 10.93 ^{b}	232.1 ± 10.93 ^{a}	0.001
Concentrate intake (kg DM/head/day)	0.85 ± 0.02 ^{a}	0.72 ± 0.02 ^{b}	0.001
FCE	5.25 ± 0.24 ^{a}	3.26 ± 0.24 ^{b}	<0.0001
FCPUG ($AU/kg)	0.87 ± 0.04 ^{a}	0.54 ± 0.04 ^{b}	<0.0001
Initial BL (cm)	64.6 ± 0.18	64.5 ± 0.18	0.630
Δ BL (cm)	3.7 ± 0.27	4.3 ± 0.27	0.137
Initial WH (cm)	62.6 ± 0.29	62.3 ± 0.29	0.427
Δ WH (cm)	3.0 ± 0.31 ^{b}	4.3 ± 0.31 ^{a}	0.005
Initial CG (cm)	81.3 ± 0.37	80.9 ± 0.37	0.426
Δ CG (cm)	4.2 ± 0.39 ^{b}	6.6 ± 0.39 ^{a}	0.001
Initial BCS	3.0 ± 0.02	3.0 ± 0.02	0.167
Δ BCS	0.5 ± 0.05 ^{b}	0.8 ± 0.05 ^{a}	0.001

* All other abbreviations as in Tables 1–3. Values within the same row bearing different superscripts differ (p < 0.05).

Table 6. Effect of different pasture types on carcass characteristics of prime lambs (LSM ± SE) *.

Items	Pastures		*p* Value
	CFP (n = 24)	Lucerne (n = 24)	
Pre-slaughter weight (kg)	46.8 ± 0.56	47.7 ± 0.56	0.247
HCW (kg)	23.8 ± 0.33 ^{b}	25.1 ± 0.33 ^{a}	0.009
Dressing percentage (%)	48.8 ± 0.39	49.6 ± 0.39	0.143
Fat thickness (mm)	7.6 ± 0.50 ^{b}	9.3 ± 0.50 ^{a}	0.021
Body wall thickness (mm)	18.6 ± 0.74 ^{b}	21.4 ± 0.74 ^{a}	0.011
Rib eye area (cm^2)	14.9 ± 0.35	15.8 ± 0.35	0.080
BCTRC%	47.8 ± 0.16	47.3 ± 0.16	0.051
GR fat score (1–5)	3.1 ± 0.11	3.4 ± 0.11	0.061
OTH trade ($AU)	119.2 ± 1.63 ^{b}	125.6 ± 1.63 ^{a}	0.009

* All abbreviations as in Tables 1, 2 and 4. Values within the same row bearing different superscripts differ (p < 0.05).

4. Discussion

4.1. Chemical Composition of Pastures and Supplementary Feeds

The CP and ME contents of supplemented pellets were over the 10.7% CP and 11.5 MJ/kg requirements for ideal lamb growth [28]. The chemical compositions of CO and RBO pellets were similar to our previous findings in indoor systems [15,20,29,30]. Although the CP content of the pastures in this study was well over the CP requirement for ideal lamb growth, the ME content of the pastures was lower than the ME requirement for ideal lamb growth [28]. The DM and CP contents of lucerne in the present study were similar to the results of Robertson et al. [31].

4.2. Effect of Pellet Supplementation on Liveweight, Concentrate Intake, Body Conformation and Carcass Characteristics of Prime Lambs

4.2.1. Effect of Pellet Supplementation on Liveweight, Concentrate Intake, Body Conformation

There was no significant difference in the final LWT and ADG of grazing lambs with and without pellet supplementation. This result is in contrast to Fajardo et al. [32] who reported that supplementation with concentrates at 2.5% of lamb body weight significantly increased the ADG of grazing lambs. Although the pastures in this study had ME that was lower than the requirement for ideal lamb growth, lambs that ingested only pastures still had similar growth rates to lambs that were supplemented with pellets. This could be due to the grazing behaviour of lambs, which allowed them to selectively graze and obtain enough ME for growth, resulting in no significant differences in final LWT and ADG compared to supplementation. Douglas et al. [33] demonstrated that the diet selected by grazing lambs was mainly leaf, which had lower NDF content and higher organic matter digestibility than pre-grazing herbage samples. The result of our study was in line with the findings of Santos-Silva et al. [34] who found no significant differences in liveweight and ADG when unprotected unsaturated fat was used as a supplement for grass-fed lambs. The FCPUG in our study ranged from 0.4 to 1.0 $AU/kg, which was considerably lower than FCPUG of RBO and CO supplementation in the indoor system of 3 $AU/kg [15]. The higher FCE in CFP grazing lambs supplemented with NOP could be the reason for greater FCPUG of the NOP treatment compared with that of the RBO treatment. The higher price of CO in comparison to RBO (AU$ 0.194/kg vs. AU$ 0.160/kg) resulted in the greater FCPUG of the CO treatment.

The BL, WH and CG of grazing sheep have been shown to be highly correlated with body weight [35]. Our finding of no significant differences in the BL, WH and CG of grazing lambs in this study, could be associated with the similar weight of the experimental lambs irrespective of treatment. This finding was also in agreement with the results of Holman et al. [18] and Malau-Aduli et al. [20,29], who reported that the BL, WH and CG of prime lambs were not affected by dietary protein-rich *Spirulina* supplements. The BCS can be used to assess the subcutaneous fat and muscle reserves of sheep [19]. It is likely that the lambs that grazed CFP pasture with RBO supplementation had better nutrient utilization than the grazing CFP lambs with NOP supplementation as demonstrated by the low FCE and high changes in BCS of RBO supplemented lambs.

4.2.2. Carcass Characteristics

The carcass weight of lucerne grazing lambs with or without pellet supplementation was similar and well over the 22 kg threshold that is required for export [7]. The unchanged carcass weight of lucerne grazing lambs is likely due to the quality of the lucerne pasture available, with its nutritional composition, and in particular, high protein content, being adequate to support the growth of fast growing lambs. Ponnampalam et al. [7] also demonstrated that the carcass weight of lambs grazing lucerne pasture was similar to that of lambs in a feedlot system (>22 kg), and was sufficient to meet carcass requirements for the export market. Supplementation of lambs that grazed CFP pasture with NOP and CO also increased their carcass weight to over 22 kg, which met market requirements for export. The findings of this study are in line with the results of Moron-Fuenmayor et al. [36] who reported that concentrate supplementation significantly increased the hot carcass weight of grazing lambs. Furthermore, De Brito et al. [8] revealed that lambs under extensive systems with supplementation had heavier carcass weights than lambs that were grazing only without supplementation.

Sheep dressing percentage is affected by a range of factors including nutrition, maturity, wool growth, and breed [37]. The observed higher dressing percentage in lambs grazing CFP with pellet supplementation than that of lambs grazing lucerne with RBO supplementation in Table 4, could have been as a result of their increased concentrate intake in comparison to their unsupplemented peers. Supplementation of grazing lambs with concentrates may have reduced grazing time and increased idle time, resulting in the observed higher forage intake in grazing lambs without concentrate supplementation [32]. Sheridan et al. [38] found that lambs on a diet with an increased roughage component had higher associated gut-fill and lower dressing percentages. In addition, Díaz et al. [39] reported that pasture only grazing lambs had lower dressing percentages than concentrate-fed lambs. The higher REA of grazing lambs supplemented with NOP in this study in comparison with pasture only grazing lambs, is in agreement with the findings of Turner et al. [40].

4.3. Effect of Pastures on Liveweight, Concentrate Intake, Body Conformation and Carcass Characteristics of Prime Lambs

Liveweight, Concentrate Intake and Body Conformation

Lambs grazing lucerne pasture had higher ADG than CFP grazing lambs. This could be due to the fact that legume-fed lambs have more efficient dietary protein utilisation and a faster rate of digestion [8]. Higher ADG in legume-fed lambs compared with grass-fed lambs was also observed by Fraser et al. [41]. The low FCE of lucerne grazing lambs also indicated that lambs grazing lucerne pasture were more efficient in utilising dietary nutrients than lambs grazing CFP pasture. The higher change in WH and BCS of lucerne grazing lambs in comparison to CFP grazing lambs may have resulted from increased fat thickness.

4.4. Carcass Characteristics

Lambs grazing lucerne pastures in this study had higher carcass weight, fat thickness and body wall thickness than lambs grazing CFP. This result could be due to increased protein intake in the lambs grazing legume pastures than lambs grazing on grass only [7]. In an indoor management system, Estrada-Angulo et al. [42] demonstrated that lambs fed with increasing amounts of protein in isocaloric diets had linear increases in protein intake, carcass weight and fat thickness. The findings of the present study are in line with the results of Turner et al. [43] who reported that goat kids grazing on legumes (alfalfa or red clover pastures) produced heavier carcasses than goat kids grazing orchard grass (*Dactylis glomerata* L.). The heavier carcasses of lucerne grazing lambs in our study compared with lambs grazing CFP resulted in higher OTH trade of these lambs.

5. Conclusions

Some of the advantages from this study include the fact that carcasses of lambs grazing on lucerne pasture or CFP pasture with pellet supplementation were over 22 kg, implying suitability for meeting local and export market requirements. Lambs grazing lucerne pasture had higher performance and carcass traits than lambs grazing CFP pasture. Although pellet supplementation did not change the final LWT, ADG, BL, WH and CG of grazing lambs, it was apparent that cocksfoot grazing lambs with pellet supplementation and lucerne grazing lambs with RBO supplementation had higher dressing percentages than lambs grazing on pasture only. Furthermore, supplementation with NOP significantly increased rib eye area of grazing lambs. Therefore, supplementation of CFP grazing lambs with CO can be utilised as a strategic nutritional tool to increase the carcass weight and OTH trade of lambs with low FCE. The key advantage emanating from this study is the practical applicability and flexibility with which lamb producers can apply the results of this feeding trial to their sheep farms depending on available feed ingredients in their localities. However, it is also pertinent to interpret the results with caution, because this study was a small-scale experimental trial with limited number of grass and legume species under Tasmanian grazing conditions that may not be generalized elsewhere. Further studies with large-scale sheep grazing and pastoral enterprises with a larger variety of grasses and legumes currently being used to fatten prime lambs by farmers are suggested. Future research with other grasses and legumes in different regions will also widen the scope of the investigation and give lamb producers more options in the improvement of lamb production.

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