Animal performance, beef lipid profile, and beef quality of finishing crossbred steers (Hereford x Angus) grazing two contrasting pastures.

Respuesta productiva, perfil de ácidos grasos y calidad de la carne de novillos híbridos (Hereford x Angus) finalizados en dos praderas contrastantes.

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ABSTRACT

Pastoral systems provide the basis for sustainable systems in southern Chile, which is the cheapest source of nutrients for cattle and receives a better perception by consumers. However, there is a great variability in animal performance and beef quality. This study aimed to assess animal performance, as well as fatty acid profile and beef quality from steers grazing grassland of mainly grass or legume species as a main source of feed. Steers were allocated into two grazing groups, either tall fescue (TF) or red clover (RC). For 97 days, steers on the RC pasture showed a higher LWG than the TF steers ($p<0.05$) and had higher marbling and flavor scores than those on the TF pasture ($p<0.05$). Both groups showed soft meat with low WBSF values (2.6 for both groups) and high sensorial tenderness (over 6 in the 1 to 7 scale). Due to the low levels of cholesterol and saturated fat, both were classified as extra lean. Likewise, a similar beef lipid profile was observed in beef from both pastures. Developing finishing strategies on pastoral-based systems is crucial to improving production characteristics, such as growth, without compromising the nutritive value of beef.

RESUMEN

La mayor población de ganado bovino se concentra en el sur de Chile y su producción se basa en sistemas pastoriles dado su menor costo como fuente de su alimentación. De esta forma, los productores tienen posibilidades de diferenciar su producción con relación a sistemas más intensivos. El objetivo de este estudio fue evaluar la respuesta animal, la calidad de la carne y el perfil lipídico de novillos a pastoreo como principal fuente de alimentación. Los animales se dispusieron en dos grupos de praderas: un grupo en pastoreo de festuca (FA) y el otro, en trébol rosado (TR). El estudio tuvo una duración de 97 días y los animales se mantuvieron a pradera con cambios de potrero en cada tratamiento, según la disponibilidad de materia seca a la entrada y salida, de acuerdo con la altura de esta. Los novillos en el grupo TR presentaron ganancias de peso vivo significativamente mayores ($p<0,05$) que el grupo FA. Además, el grupo TR presentó mayor marmoleo y mejor sabor de la carne que los novillos del grupo FA. Ambos grupos presentaron una carne blanda, mostrando bajos valores WBSF (2,6 kgf para ambos grupos) y alta terneza a nivel sensorial (sobre 6 en una escala de 1 a 7). Bajos niveles de colesterol como también de grasa saturada, clasificaron la carne de estos tratamientos como extra-magra. Los dos sistemas mostraron carne con un perfil lipídico similar. Desarrollar sistemas de producción de carne basados en sistemas a pradera es relevante para sostener crecimiento y establecer características diferenciadoras en la carne sin comprometer su valor nutritivo.

Palabras clave: Carnes a pradera, calidad de carne, sistemas pastoriles, ganado de carne, trébol rosado, festuca.

INTRODUCTION

Beef production in southern Chile is based on grasslands, matching the growth curve of pastures, with cattle requirements. Usually, many producers include conserved forage (hay/silage) for critical periods of the year when pastures are unable to fulfill the requirements, as well as different levels of grains (mostly cereals) to attain enough fat cover and beef quality for human consumption. However, in recent years an increasing concern about food quality, particularly beef, and its association with saturated fat content. Altogether, this resulted in reviewing the way to produce beef cattle. In fact, the animal industry is increasing the number of organic and naturally finished beef animals rather than finishing them on grains (Dierking *et al.*, 2010). The fatty acid composition of grass-fed beef has been seen as an opportunity for market advantages (Howes *et al*., 2015) and its nutritional value is an increasingly important factor influencing consumer preferences (Scollan *et al*., 2017). Several researchers highlighted that ruminants fed on high grass-based diets provide milk and meat with a higher concentration of nutraceutical compounds (Elgersma *et al*., 2013). Beef from pasture-finished animals has greater amounts of n-3 fatty acids (FA) and elevated levels of conjugated linoleic acid (CLA) (French *et al*., 2000). Both n-3 FA and CLA fats have been shown to lower the risk of heart disease, diabetes, and obesity as well as contain anticarcinogenic properties (Sumeca and Miller, 2000; Weiss *et al*., 2004). The FA composition of forage lipids is dominated by high proportions of polyunsaturated linolenic and linoleic acids (Harfoot and Hazlewood, 1988), but also small amounts of oleic acid. Bouafied *et al*., (2003) found the alfa-linolenic, linoleic and palmitic acids were the most abundant FA in all the forage species studied averaging 51, 18, and 19% of TFA, respectively (Whetsell and Rayburn, 2022).

The amount of lipid and the specific fatty acids available to the cattle will depend on the amount of leafy tissue consumed. The variations in available FA in feeds cause variations in the content of bioactive lipid components that accumulate in the tissues of the ruminants that consume these forages (Mir *et al*., 2006). Several authors (*i.e.* Duckett *et al*., 2007, 2009; Neel *et al*., 2007), have shown that finishing steers on forages instead of concentrates results in leaner carcasses with greater concentrations of n-3 fatty acids and CLA when finished at similar animal ages.

Moreover it has been pointed out the increased phytochemical richness of the diets of animals grazing botanically diverse pastures results in higher anti-oxidant capacity in meat and milk (van Vliet *et al.,* 2021). Forage fatty acid content is variable among species, variety, harvest time, and growing season (Dewhurst *et.al*., 2001; Clapham *et al.*, 2005), and influences meat and milk fatty acids of grazing animals (Dewhurst *et al*., 2003). In southern Chile, the challenges imposed by climate change have made it necessary to identify forage species that can thrive in this new scenario and have good performance in terms of animal response and product quality. For example, Povolo *et al*., (2013), found variations in plant fatty acids and secondary plant metabolites. In addition, grasslands with different botanical compositions can confer specific intrinsic sensory and chemical attributes on dairy and meat products. In this context, red clover has higher levels of isoflavones and other secondary compounds, such as polyphenol oxidase (PPO) enzyme (Van Rast et al., 2011; Mikulic et al., 2024). In red clover, PPO has been suggested to protect lipids against degradation in the rumen leading to a higher output of PUFA in meat and milk products (Van Rast et al., 2011). The objective of this study was to assess the animal performance and fatty acid profile of beef from finishing steers grazing either red clover or tall fescue pastures.

MATERIAL AND METHODS

Treatments and Animals

The experiment was carried out at the Instituto de Investigaciones Agropecuarias, INIA Carillanca Research Station (38°41'S, 72°25'O, 200 m.a.s.l.) located at La Araucanía region in Chile. The study was conducted under requirements of the Chilean Law 20,380 on Animal Protection and with the approval of the INIA Bioethics Committee. A total of 20 crossbreed steers (Hereford x Angus) of 14 months of age and with 293±18 kg live weight on average were randomly allocated into two feeding groups (n=10 per treatment), based on their live weight (LW). One group grazed a pasture of red clover (*Trifolium pratense* L.) cv. Superqueli, (RC), and the other group grazed a permanent pasture of tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.) cv. Manade, (TF). Grazing management was made by an electric fence, rotating the animals when dry matter availability reached an average of 2500 kg DM ha^{-1} and leaving the paddock when the residual, measured by Rising Plate Meter (Jenquip, NZ), was approximately 1450 kg DM ha^{-1}. There was a 14 days pre-experimental period to accustom animals to the two grazing systems and management conditions. Steers were weighed fortnightly during the experiment and individual intake was not measured. At the beginning of the experiment, steers were treated against parasites and free access to watering was always provided. Animals were kept in experimental paddocks throughout the study, and no anabolic implants were used. The experiment lasted for 97 days, from 03 October 2016 to 09 January 2017.

Samples of RC and TF were collected for chemical analysis at two phenological stages during the grazing

period. Dry matter (DM), crude protein (CP), and crude fiber (CF) were determined through AOAC (1996). Metabolizable energy (ME) was estimated following digestibility *in vitro* analysis (Tilley and Terry, 1963). Fatty acid content was determined from samples, of both pastures, collected from the allowance pasture strip that was lyophilized at INIA Remehue laboratory.

Steers were slaughtered when they attained 400 kg LW on average, at a slaughter plant located 40 km from the research center. Although the animals were leaner and with limited fat cover, this LW was considered adequate for the internal market and type of beef breed utilized. Carcasses were identified and cooled for 24 h at 2°C. The pH24 (pH 24 h postmortem) was measured three times with a pH penetration electrode (Hanna FC232) of a portable pH-meter (Hanna 99163, Hanna Instruments, Woonsocket, Rhode Island, USA). In the quartering, 200 g of *Longissimus thoracis* was collected from the 8th to the 9th vertebra and transported to the Meat Science Laboratory of the Remehue Regional Research Centre (INIA) in Osorno, Chile. Muscle samples were vacuum packaged and stored at 4 ± 2 ° C until analyses.

Colour, pH, and texture

The *Longissimus* muscle samples were thawed for analysis for 48 h at 4± 2° C, after which instrumental color was measured. Samples were then kept at room temperature for 30 min before measuring pH levels with a pH meter (HI 99163, Hanna Instruments, Madrid, Spain) with a penetration electrode (FC 232, Hanna Instruments). Instrumental color measurements were recorded for L*, (lightness; 0: black, 100: white), a* (redness/greenness; positive values: red, negative values: green), and b* (yellowness/blueness; positive values: yellow, negative values: blue) using a Minolta chromameter (CR-400, Minolta, Osaka, Japan) with illuminat D65 and 2° viewing angle. Readings were taken from three locations of the upper surface of randomly selected samples to be representative of surface color. Subsequently, all external fat from the steaks was removed, and the samples were ground, and intramuscular fat (IMF) was measured by the Soxhlet extraction 920.39 method (AOAC, 1996). Shear force was estimated from samples cut into 3 cm and after the external fat was removed. Samples were cooked in an oven at 170 °C until reaching a central temperature of 73 ± 1 °C (approximately 15 min) and then chilled at 4 ± 2 °C for 24 h. Six to 10 cores, 1.3 cm circular, were extracted with a hollow punch to measure the shear force with a texture analyzer (TA-XT2i, Stable Micro Systems, Godalming, UK) using the Warner–Bratzler method (WBSF) at a crosshead speed of 1 mm s^{-1}, yielding the shear force (kgf). The remaining samples were vacuum-packed and stored at -18 ± 2 °C until fatty acid analysis. To determine marbling score a section of the *Longissimus thoracis* muscle was removed from the ninth thoracic vertebrae until the last lumbar vertebrae of each carcass. This section was cut into three equal parts that were vacuum packaged and aged for 21 days at 4 ± 2°C and then stored frozen at -18 ± 2°C until analysis.

Fatty Acid Composition

Samples of 10 g were used for the fatty acid analysis of meat according to Lumley and Colwell (1991). Samples were thawed, and fat was extracted with methanol, chloroform, and water (40:25:16 mL). The samples were then homogenized for 30 min. and passed through filter paper in a glass funnel. Water was added until biphasic separation was observed. The fat was concentrated in the chloroform layer. The chloroform phase was collected and removed by evaporation, and 2.0 mL of n-hexane was added to the extract, which was then stored at -18 ± 2 °C until analysis. Approximately 0.2 g of fat was obtained with this extraction. Transmethylation was carried out according to the method described by Ichihara *et al*. (1996). One hundred mL of KOH in 2-n methanol was added, and the mixture (sample + 2.0 mL) was agitated for 3 min at room temperature. After phase separation, the supernatant was collected and analyzed by gas chromatography. The fatty acid profile was determined in a gas chromatograph (GC-2010 plus Shimadzu®, Kyoto, Japan) equipped with a flame ionization detector (FID). A capillary column SP-2560™ (Sigma-Aldrich Co., Bellefonte, PA, USA) of 100 m × 0.25 mm × 0.25 µm film was used. Helium was used as the carrier gas at 1.0 mL min^{-1} with an inlet pressure of 15 psi, using the split injection method (100:1). The injector temperature was fixed at 250 °C, and the detector temperature at 260 °C. The injected sample volume was 1.0 µl, and the oven temperature was programmed to increase from 140 °C (held for 5 min) to 240 °C (held for 15 min) at 4 °C min^{-1}. Fatty acids were identified by comparing the retention times of the chromatograph peaks to those of the methyl esters from a mixture prepared with a 37-component FAME mix standard (Standard: 47885-U, Sigma Aldrich Co, St. Louis, USA), C18:1 t-11 methyl ester standard (Standard: 46905-U, Sigma Aldrich Co, St. Louis, MO, USA) and c-9, t-11 octadecadienoic conjugated methyl acid (Standard: 10-1823-7, Larodan AB, Malmo, Sweden).

Sensory Analysis by Trained Panel

An 11-member trained panel participated in the sensory analysis. The panelists were selected from a group of 30 people without previous experience in sensory evaluation. The training and testing sessions were conducted at the Sensory laboratory of INIA Remehue. The panelists completed 48 h of training sessions on

the evaluation of a set of selected steer beef attributes (flavor, tenderness, and juiciness). The sensory laboratory was designed according to ISO standards with separate booths, and samples were evaluated in a sequence established to avoid the effect of sample order presentation, first-order, or carry-over effects (Mac Fie *et al*., 1989). The panelists evaluated the two types of beef in duplicate. Cooked steaks were cut into dice of 20 mm x 20 mm x 25 mm (length/width/height) and kept warm. Subsequently, samples were placed in coded trays and served. The descriptors were quantified using a hybrid scale ranging from 0 (absence) to 10 (maximum intensity) (Villanueva *et al*., 2005).

Statistical analysis

The data were subjected to ANOVA to examine the effect of pasture on steers' performance, under a complete randomized block design with ten replicates, where the block corresponded to steers initial live weight. For beef chemical and physical characteristics and FA composition, comparisons were made between the two pastures, data were analyzed using the General ANOVA procedure in InfoStat Software (Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Argentina), considering a completely randomized design, treatment differences were tested for significance at the 0.05 probability level based on the Fisher's least significant difference (LSD) method. The ANOVA for sensory data (tenderness, juiciness, and flavor) was performed with the General Linear Model (GLM) procedure of the SAS system (SAS Inst. Inc., Cary, NC, USA). Treatments were used as fixed effects and differences among effects were tested using Tukey's test

RESULTS AND DISCUSSION

Chemical analysis in Tall Fescue and Red Clover

The chemical analysis and fatty acid content of both forage species are presented in Table 1. The results reflect the better quality of red clover throughout the grazing period with tall fescue showing an important decrease in quality. It has been long generally recognized that the feeding value of legumes is superior to that of most grasses (Dewhurst *et al*., 2009). In the present study, the D value in tall fescue of 50.7% in December represented a nutritional limitation for the maximum daily gain of steers. During the stage of plant maturation yield increases and the forage quality rapidly decreases (Tucak *et al*., 2023)

Fatty acid composition of Tall Fescue and Red Clover

It has been reported (Wyss *et al*., 2006) that linolenic acid (C18:3) is the dominant fatty acid observed on temperate grass + clover mixtures with an average fatty acid of over 60%, which agrees with this study, that averaged 57.8%. As observed in Table 2, there were no significant differences ($P > 0.05$) in the fatty acid composition of both species, except for stearic acid (C18:0) which was higher in red clover ($P<0.05$). As previously reported by Schmidt *et al.,* (2013), in the current study, the RC showed a higher (P<0.05) content of stearic acid (C18:0) than TF. It has been suggested that the polyphenol oxidase (PPO) enzyme activity present in RC might influence the n-3 fatty acid content in this species (Dierking *et al*., 2010), although this was not observed in this study.

Table 1. Bromatological composition of the pasture consumed in the experiment during the grazing period.

Cuadro 1. Composición bromatológica de las praderas consumidas en el experimento durante el periodo de pastoreo.

Bromatological analysis	Tall Fescue	Red Clover
CP Cut 02/11/16, %	14.9	25.6
CP Cut 17/12/16, %	9.5	22.7
ME Cut 02/11/16, Mcal/kg	2.35	2.33
ME Cut 17/12/16, Mcal/kg	1.93	2.32
D value 02/11/16, % (*)	63.8	63.0
D value 17/12/16, % (*)	50.7	62.9

*Dry Matter (DM) digestibility

Animal performance

The effects of pasture on steer LW gain for the two feeding groups, RC and TF, are presented in Table 3. Animal LW gain was higher ($P < 0.05$) in steer grazing RC compared to those grazing TF, averaging 36 kg more.

In the present experiment, steers grazing on RC reached a higher final LW than those grazing on TF, as previously mentioned in the literature (Thomas *et al*., 1981; Fraser *et al*., 2004). For example, Dewhurst *et al*., (2009), pointed out that the chemical and physical compositions of forage legumes, particularly red and white clover, confer many benefits in terms of nutritive value. These legumes lead to enhanced growth rates in comparison with grass, whether grazed or fed as silage. Increased feed intake, related to more rapid fermentation and physical breakdown in the rumen, is a major source of this advantage.

Higher voluntary intake is attributed to higher concentration of cell contents in RC than in grasses resulting in faster rates of particle breakdown in the rumen and more rapid clearance of particles from the rumen (Frame *et al*., 1998). The higher activity of PPO and

Table 2. The Fatty acid content of red clover and tall fescue used in the study.
Cuadro 2. Contenido en ácidos grasos del trébol rojo y festuca utilizados en el estudio.

Fatty acid composition (%/100 mg fat)	Red Clover	Tall Fescue	RMSE	P	Significance of *p-*value
Palmitic *16:0*	12.6	14.84	1.194	0.209	Ns
Estearic *18:0*	1.93 [a]	0.98 [b]	0.024	0.001	***
Linoleic *18:2n-6*	16.17	13.02	0.757	0.053	Ns
Linolenic 18:3*n-3*	56.61	59.02	2.993	0.504	Ns
Other fatty acids	12.61	12.11	1.383	0.751	Ns
Total saturated	20.69	21.38	1.986	0.762	Ns
Total MUFA	4.99	4.88	0.256	0.696	Ns
Total PUFA	73.49	73.03	2.222	0.856	Ns
Total *n6*	16.17	13.02	0.757	0.053	Ns
Total *n3*	57.32	60.01	2.976	0.462	Ns

RMSE = Root Mean Square Error; Ns = not significant. [a, b] Values within rows without common superscript letters differ (at least p<0.05).

Table 3. Effects of pasture type on steers performance.
Cuadro 3. Efectos del tipo de pradera en el rendimiento de los novillos.

Variable	Red Clover	Tall Fescue	RMSE	P	Significance of *p-*value
Initial live weight (kg)	291.2	295.3	3.29	0.750	Ns
Live weight gain (kg d^{-1})	1.37 [b]	0.96 [a]	0.296	0.009	***
Final weight (kg)	424.4[b]	388.5[a]	5.87	0.121	***

RMSE = Root Mean Square Error; Ns = not significant. [a, b] Values within rows without common superscript letters differ (at least p<0.05).

higher DM intake of red clover could improve animal performance on this treatment. High PPO activity reduces proteolysis and lipolysis, which is the likely mechanism for improved conversion of feed N into product N and to higher transfer of polyunsaturated fatty acids from feed to product (Steinshamn, 2008). Locally, no information about the PPO contents is available for the cultivar used in the study (Fernando Ortega, personal communication). The results indicate that RC can be used as grazed forage to finish beef steers at an early age (18 months) with an LW of 424 kg per animal. Likewise, allows the animals a permanent dry matter availability intake and regrowth in the leafy stage. On the contrary, TF pasture, although it was also managed with rotational grazing, was not enough to maintain a leafy nutritional stand showing a decrease in digestibility, probably limiting the dry matter intake and consequently, the average daily gain (ADG). Steers finished at RC had a greater range of nutrients (Table 1) with more protein than those on TF. Therefore, it is suggested that, in this experiment, when grazed on TF, the lower nutrient consumption would be reflected in a lower ADG, especially in the early summer months, showing a better tolerance of RC to the rainfall drop of the summer months.

Chemical and Physical Characteristics of meat of steers finished on two contrasting pastures

The chemical and physical characteristics of the steers fattened on different pasture systems are presented in Table 4.

In the present study there were no significant effects (p>0.05) on finishing production systems on these parameters. These results corroborate with the findings of Nogalski *et al.,* (2023), who, with more contrasting steers finishing diets, did not note significant effect of silage type nor feeding intensity on the physicochemical properties of the meat.

Regarding the measures in color, it is worth mentioning that longissimus *a** values, in this study averaging 23.9 between both treatments. It has been found that

the degree of redness (*a**) provided the most simple and robust prediction of beef colour acceptability (*i.e.* Glitsch, 2000; Zamuz *et al*.,2022). According to Holman *et al*., (2017), beef colour was considered acceptable when *a** values were ^{3}14.5.

Destefanis *et al*., (2008) indicated that for beef, consumers accept WBSF values < 4.37 kgf were perceived by most consumers as "tender", but if the value is > 5.37 kgf it is considered "tough". Overall, the shear force recorded for both groups of steers were well below these values for this parameter.

Sensory panel

The effects of the two contrasting pastures on three sensory traits are presented in Table 5. Steers finished on red clover presented a higher (P < 0.05) flavor score than steers finished on tall fescue.

However, there were no differences (P>0.05) between the two contrasting pastures for tenderness, juiciness and marbling. Grazing of legumes, white clover (Shorland *et al*., 1970), or alfalfa (Park *et al*., 1972) before slaughter increased odor and off-flavor scores in lamb. The current study showed that animals finished on TF, resulted in a lower flavor score, in comparison to steers finished on red clover.

Fat Content and Fatty Acid Composition

The results on fat content and fatty acid composition are presented in Table 6. There were no differences in the fat and fatty acid composition between treatments, except for palmitic acid (16:0) and Branch fatty acids (BCFAs). The 16:0 was higher (P< 0.05) in the beef from steers grazing RC. On the contrary, no differences were recorded among forage species on the 16:0 content of the *Longissimus* muscle, according to Schmidt *et al*., (2013). Regarding BCFAs, beef from steers grazing TF showed higher values than those grazing RC. BCFAs are an emerging group of bioactive FAs, sparking growing research interest within the scientific community due to their biological effects and potential

Table 4. Chemical and physical characteristics of *Longissimus* muscle from steers finished on two contrasting pastures.
Cuadro 4. Caracteristicas quimicas y fisicas del musculo *Longissimus* de novillos terminados en dos praderas constrastantes.

	Red Clover	Tall Fescue	RMSE	P	Significance of *p*-value
Dry matter (%)	24.4	24.1	1.302	0.609	Ns
Protein (%)	81.8	80.7	4.435	0.629	Ns
Ash (%)	4.2	4.1	0.310	0.582	Ns
Ether extract (%)	13.6	15.16	4.714	0.492	Ns
pH	5.9	5.8	0.216	0.375	Ns
*L**	38.7	37.4	1.863	0.372	Ns
*a**	23.1	24.7	2.449	0.134	Ns
*b**	12.0	11.8	1.671	0.841	Ns
Shear force (kgf)	2.6	2.6	0.653	0.799	Ns

RMSE = Root Mean Square Error; Ns = not significant. [a, b] Values within rows without common superscript letters differ (at least p<0.05).

Table 5. Sensory attributes of *Longissimus* muscle from steers finished on two contrasting pastures.
Cuadro 5. Atributos sensoriales del músculo *Longissimus* de novillos terminados en praderas contrastantes.

	Red Clover	Tall Fescue	RMSE	P	Significance of *p*-value
Tenderness	6.14	6.67	0.990	0.798	Ns
Juiciness	4.08	4.40	1.051	0.549	Ns
Flavor	5.87 [a]	5.28 [b]	0.512	0.004	***
Marbling	4.14	3.42	1.202	0.254	Ns

RMSE = Root Mean Square Error; Ns = not significant. [a, b] Values within rows without common superscript letters differ (at least p<0.05).

Table 6. Fatty acid content (%/100 mg fat) of *Longissimus* muscle in the two production systems.
Cuadro 6. Contenido en ácidos grasos (%/100 mg de grasa) del músculo *Longissimus* en los dos sistemas de producción.

	Red Clover	Tall Fescue	RMSE	P	Significance of *p*-value
Palmitic 16:0	25.72 [b]	24.36 [a]	1.323	0.047	*
Stearic 18:0	16.63	17.44	1.506	0.272	Ns
10 t-18:1	0.195	0.194	0.025	0.893	Ns
Trans-vaccenic 11t-18:1	2.02	1.99	0.279	0.832	Ns
Oleic 9c-18:1n-6	29.8	29.23	2.093	0.550	Ns
Linoleic 18:2n-6	2.42	2.75	0.591	0.267	Ns
α linolenic 18:3n-6	1.11	1.22	0.215	0.290	Ns
CLA Rumenic 9c,11t-18:2	0.600	0.653	0.101	0.289	Ns
EPA 20:5n-3	0.32	0.32	0.141	0.955	Ns
DHA 22:6n-3	0.004	0.04	0.021	0.723	Ns
DPA 22:5n-3	0.48	0.49	0.167	0.920	Ns
Total saturated	49.98	49.96	2.399	0.990	Ns
Total Branch fatty acids	2.07	2.39	0.254	0.015	***
Total monounsaturated	41.85	41.29	2.109	0.589	Ns
Total polyunsaturated	5.45	5.92	1.404	0.489	Ns
n-6	3.21	3.57	0.280	0.807	Ns
n-3	2.09	2.22	0.530	0.619	Ns
n-6/n-3	1.53 [b]	1.61 [a]	0.069	0.035	***
P/S	0.11	0.12	0.033	0.555	Ns
t11/t10-18:1	10.47	10.27	1.409	0.771	Ns
Cholesterol	35.65	31.02	9.205	0.331	Ns
Total CLA	0.79	0.81	0.111	0.704	Ns

RMSE = Root Mean Square Error; Ns = not significant. [a, b] Values within rows without common superscript letters differ (at least p<0.05).

pro-health benefits (Taormina *et al.,* 2020). Because BCFAs are principally derived from rumen bacteria, ruminant products pose unique dietary sources of BCFAs (Vahmani *et al*., 2020). Nutritional modulation of BCFA in beef and dairy products published is limited.

Although there was a significant difference in the P:S ratio of 0.12 vs. 0.11 for TF and RC finishing groups, respectively (P<0.05), the overall ratio of this parameter for both finishing systems is in line with grass-fed beef, as mentioned earlier by Enser *et al*., (1998). Concerning the ratio n-6: n-3, although no significant differences were observed between pastures, on average, the ratio n-6: n-3 observed in the current study was 1.57. According to Simopoulos (1999), it should be considered essential to use a ratio *n*-6: *n*- 3 PUFAs of between 1-2:1 to keep saturated fat intake low. Thus, both grazing finishing systems exhibit a favorable ratio for human health. Nevertheless, typical values for grass-fed beef are no greater than 2:0. Values for the omega 6: 3 ratios of 1,61 and 1,53 were found for TF and RC, respectively, which are similar to those reported previously (Duckett *et al*.,2009; Schmidt *et al*.,2013).

Nevertheless, typical values for grass-fed beef are no greater than 2:0. Values for the omega 6/ omega 3 ratio of 1.61 and 1.53 were found for TF and RC, respectively, which are similar to those reported previously in the literature (*i.e.* Duckett *et al*.,2009; Schmidt *et al*.,2013).

The results of the lipid profile are comparative with those obtained with dairy steers which were finished at permanent pastures in the Region de Los Lagos (Morales *et al*., 2012; Morales *et al.*, 2015; Subiabre *et al*., 2024). However, the beef steers of the present study finished on TF or RC pastures presented higher values

of 18: 2*n*-6 y 18:3*n*-3 and a lower *n*-6: *n*- 3 PUFAs ratio than the dairy steers which presented a value of 1.75 in the intramuscular fat. The low levels of cholesterol found in the two systems studied, along with low levels of total fat and saturated fat, classified these cuts of meat as "extra lean", according to the Chilean legislation (MINSAL, 2024).

CONCLUSIONS

Finishing steers grazing RC had significant higher LWG compared to those grazing tall fescue, also showing a higher score on marbling and flavor but without differences in the fatty acid profile. Because the concern and demand for healthy foods in Chile are increasing, and grass-based feeding systems are perceived by consumers as more natural and friendly, the outcomes of this study are important for the marketing of grass-fed beef. In addition, the pasture did not affect the shear force, producing acceptable sensory traits and beef low in fat and cholesterol, classified as lean meat according to Chilean standards. Overall, the beef produced in pastures in Chile is considered safe and healthy for humans.

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REFERENCES

AOAC. 1996. Association of Official Analytical Chemists. 1.015 p. 18thEd. William Horwist (ed). Washington D.C., USA.

Boufaïed H., Chouinard P.Y., Tremblay G.F., Petit H.V., Michaud R. and Belanger G. 2003. Fatty acids in forages. I. Factors affecting concentration. Canadian Journal of Animal Science, 83: 501-511

Clapham, W.M., Foster, J.G., Neel, J.P.S. and Fedders, J.M. 2005. Fatty acid composition of traditional and novel forages. Journal of Agricultural and Food Chemistry, 53:10,068–10,073.

Destefanis, G., Brugiapaglia, A., Barge, M.T. and Dal Molin, E. 2008. Relationship between beef consumer tenderness perception and Warner–Bratzler shear force. Meat Science, 78:153–156.

Dierking, R.M., Kallenbach, R.L. and Grün, I.U. 2010. Effect of forage species on fatty acid content and performance of pasture-finished steers. Meat Science, 85: 597–605.

Duckett, S.K., Neel, J.P.S., Sonon Jr. R.N., Fontenot, J.P., Clapham, W.M. and Scaglia, G. 2007. Effects of winter stocker growth rate and finishing system on: II. Ninth-tenth-eleven thrib composition, muscle color and palatability. Journal of Animal Science, 85:2691–2698.

Duckett, S. K., Neel, J.P.S., Fontenot, J.P. and Clapham, W.M. 2009. Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin, and cholesterol content. Journal of Animal Science, 87:2961–2970.

Dewhurst, R. J., Scollan, N.D., Youell, S.J., Tweed, J.K.S. and Humphreys, M.O. 2001. Influence of species, cutting date, and cutting interval on fatty acid composition of grasses. Grass Forage Science, 56:68–74.

Dewhurst, R. J., Scollan, N.D., Lee, M.R., Ougham, H.J. and Humphreys, M.O. 2003. Forage breeding and management to increase the beneficial fatty acid content of ruminant products. Proceedings of the Nutrition Society, 62:329–336.

Dewhurst, R. J., Delaby, L., Moloney, A., Boland, T. and Lewis, E. 2009. Nutritive value of forage legumes used for grazing and silage. Irish Journal of Agricultural and Food Research, 167-187.

Elgersma, A., Soegaard, K., Jensen, S.K. 2013. Fatty acids, α-tocopherol, β-carotene, and lutein contents in forage legumes, forbs, and a grass—Clover mixture. Journal of Agricultural and Food Chemistry, 61, 11913–11920.

Enser, M., Hallett, K. G., Hewett, B., Fursey, G. A. J., Wood, J. D., & Harrington, G. (1998). Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. Meat Science, 49 (3), 329-341.

Frame J., Charlton J.F.L., Laidlaw A.S. 1998. Temperate forage legumes. CAB International, Wallingford. UK. 327 p.

Fraser M. D., Speijers M.H.M., Theobald V.J., Fychan R., Jones R. 2004. Production performance and meat quality of grazing lambs finished on red clover, lucerne or perennial ryegrass swards. Grass and Forage Science, 59:345-356.

French, P., Stanton, C., Lawless, F., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J. 2000. Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate-based diets. Journal of Animal Science, 78: 2849–2855.

Glitsch, K. 2000. Consumer perceptions of fresh meat quality: cross-national comparison. British Food Journal, 102(3), 177-194.

Harfoot, C.G. 1981. Lipid metabolism in the rumen. Pages 21–55.in W. W. Christie, (ed). Lipid metabolism in ruminant animals. Pergamon Press, Oxford, UK.

Harfoot, C.G. and Hazlewood, G.P. 1988. Lipid metabolism in the rumen. Pages 285–322 in P. N. Hobson, (ed). The rumen microbial ecosystem. Elsevier Applied Science, New York, NY.

Hawke, J. C. 1973. Lipids. In: G. W. Butler and R.W. Bailey, (Eds). Chemistry and biochemistry of herbage. Vol. 1, Academic Press, New York, NY p. 213–263

Holman, B.W., van de Ven, R. J., Mao, Y., Coombs, C. E., and Hopkins, D.L. 2017. Using instrumental (CIE and reflectance) measures to predict consumers' acceptance of beef colour. Meat Science, 127, 57-62.

Howes, N.L., Bekhit, A.E.A., Burrit, D.J., Campbell, A.W. 2015. Opportunities and implications of pasture-based lamb fattening to enhance the long chain fatty acid compo-

sition in meat. Comprehensive Review in Food Science and Food Safety, 14, 22–36.

Ichihara, K.; Shibahara, A.; Yamamoto, K.; Nakayama, T. 1996. An improved method for rapid analysis of the fatty acids of glycerolipids. Lipids, 31, 535–539.

Lumley, I.D., Colwell, R.K. 1991. Extraction of fats from fatty foods and determination of fat content. In *Analysis of Oilseeds, Fats and Fatty Foods*; Rossell, J.B., Pritchard, J.L.R., Eds.; Elsevier Applied Science: London, UK, pp. 227–245.

MacFie, H.J.H., Bratchell, N., Greenhoff, H., Vallis, L.V. 1989. Designs to balance the effect of the presentation and first-order carry-over effect in hall test. Journal of Sensory Studies, 4: 129–149.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. 1988. Lipids. In: Animal Nutrition. 4th ed. Longman Scientific and Technical, New York, NY. P. 26 – 41.

Mikulić, M., Atanacković Krstonošić, M., Kladar, N., Vasiljević, S., Katanski, S., Mamlić, Z., Rakić, D., Cvejić, J. 2024. Phytochemical Composition of Different Red Clover Genotypes Based on Plant Part and Genetic Traits. Foods, 13(1), 103.

Ministerio de Salud de Chile. Reglamento Sanitario de los Alimentos; MINSAL. 2024. Santiago, Chile. Available online: https://www.minsal.cl/reglamento-sanitario-de-los-alimentos

Mir, P.S., Bittman S., Hunt D., Entz T., and Yip B. 2006. Lipid content and fatty acid composition of grasses sampled on different dates through the early part of the growing season. Canadian Journal of Animal Science, 86:279-290.

Morales, R., Folch, C., Iraira, S., Teuber, N., and Realini, C.E. 2012. Nutritional quality of beef produced in Chile from different production systems. Chilean Journal of Agricultural Research, 72(1):80-86.

Morales, R., Subiabre, I., Parga, J., and Realini, C.E. 2015. Finishing strategies for steers based on pasture or silage plus grain and time on feed and their effects on beef quality. Ciencia e Investigación Agraria, 42(1), 5-18.

Neel, J.P.S., Fontenot, J.P., Clapham, W.M., Duckett, S.K., Felton, E.E.D., Scaglia, G. and Bryan, W.B. 2007. Effects of winter stocker growth rate and finishing system on: I. Animal performance and carcass characteristics. Journal of Animal Science, 85:2012–2018.

Nogalski, Z., Modzelewska-Kapituła, M., and Tkacz, K. 2023. Effects of silage type and feeding intensity on carcass traits and meat quality of finishing Holstein–Friesian bulls. Animals, 13(19), 3065.

Park, R.J., Corbett, L. and Furnival, E.P. 1972. Flavour differences in meat from lambs grazed on Lucerne (Medicago sativa) or Phalaris (Phalaris tuberosa) pastures. Journal of Agricultural Science, 78:47–52.

Povolo, M.; Pelizzola, V.; Passolungo, L.; Biazzi, E.; Tava, A.; Contarini, G. 2013. Characterization of two Agrostis-Festuca alpine pastures and their influence on cheese composition. Journal of Agricultural and Food Chemistry, 61, 447–455.

Schmidt, J.R., Miller, M.C., Andrae, J.G., Ellis, S.E. and Duckett, S.K. 2013. Effect of summer forage species grazed during finishing on animal performance, carcass quality, and meat quality. Journal of Animal Science, 91(9), 4451-4461.

Scollan, N.D., Eleri, M.P., Morgan, S.A., Huws, S.A. and Shingfield, K.J. 2017. The future of animal products in the human diet: Health and environmental concerns. Symposium 1: Meat, health and sustainability. Can we improve the nutritional quality of meat? Proceedings of the Nutrition Society, 76: 603–618

Simopoulos, A.P. 1999. Essential fatty acids in health and chronic disease. The American Journal of Clinical Nutrition, 70(3), 560S-569S.

Shorland, F.B., Czochanska, Z., Moy, M., Barton, R.A. and Rae, A.L. 1970. Influence of pasture species on the flavor, odor, and keeping quality of lamb and mutton. Journal of the Science of Food and Agriculture, 21:1–4.

Steinshamn, H. 2008. The unique properties of red clover in the diet of ruminants. 1st Scientific Conference within the framework of the 8th European Summer Academy on Organic Farming, Lednice na Moravě, Czech Republic, September 3–5.

Subiabre, I., Rodríguez, R. A., Aldai, N., Allende, R., Morales, R. 2024. Pasture type effects over beef quality: A comparison. Chilean Journal of Agricultural Research, 84(5) 620-631.

Sumeca, J. A., and Miller, G. D. 2000. Potential health benefits of conjugated linoleic acid. Journal of the American College of Nutrition, 19: 472–506.

Taormina, V.M., Unger, A.L., Schiksnis, M.R., Torres-Gonzalez, M., Kraft, J. 2020. Branched-Chain Fatty Acids—An Underexplored Class of Dairy-Derived Fatty Acids. Nutrients, 12(9), 2875.

Thomas, C., Gibbs, B.G. and Tayler, J.C. 1981. Beef production from silage 2. The performance of beef cattle given silages of either perennial ryegrass or red clover. Animal Science, 32(2), 149-153.

Tilley, J.M., and Terry R.A. 1963. A two-stage technique for the in vitro digestion of forage crops. Journal of the British Grassland Society, 18:104-111.

Tucak, M., Čupić, T., Horvat, D., Ravlić, M., Krizmanić, G., Maćešić, D. and Meglič, V. 2023. Changes in agronomic and forage nutritive values of red clover in response to different development stages. Romanian Agricultural Research, 40, 215-224.

Ulyatt, M.J., Lancashire, J.A., and Jones, W.T. 1976. The nutritive value of legumes. In: Proceedings of the New Zealand Grassland Association (pp. 107-118).

Vahmani, P., Ponnampalam, E. N., Kraft, J., Mapiye, C., Bermingham, E. N., Watkins, P.J., Spencer Proctor, S.P. Dugan, M. E.R. 2020. Bioactivity and health effects of ruminant meat lipids. Invited Review, Meat Science, 165, 108114.

Van Ranst, G., Lee, M.R.F., Fievez, V. 2011. Red clover polyphenol oxidase and lipid metabolism. Animal, 5(4), 512-521.

Van Vliet S., Provenza F.D., and Kronberg K.L. 2021. Health-promoting phytonutrients are higher in grass-fed meat and milk. Frontiers in Sustainable Food Systems, 4: 555426

Villanueva, N.D.M., Petenate, A.J., Da Silva, M.A.A.P. 2005. Performance of the hybrid hedonic scale as compared to the traditional hedonic, self-adjusting and ranking scales. Food Quality and Preference, 16: 691–703.

Weiss, M.F., Martz, F.A., and Lorenzen, C.L. 2004. Conjugated linoleic acid: Implicated mechanisms related to cancer,

atherosclerosis, and obesity. Professional Animal Science, 20: 127–135.

Whetsell, M. and Rayburn, E. (2022). Variation in fatty acids concentration in grasses, legumes, and forbs in the allegheny plateau. Agronomy, 12(7), 1693.

Wyss, U., Morel, I., and Collomb, M. 2006. Fatty acid content of three grass/clover mixtures. Grassland Productivity, 11: 348-350.

Zamuz, S., García-Torres, S., de Vaca, M. C., Tejerina, D., Ortiz, A., Oliván, M., and Franco, D. 2022. Impacto del modo de transporte al matadero (mezcla o no mezcla con animales extraños) de terneros de las razas Asturiana de los Valles y Retinta en los atributos físico-químicos y organolépticos de carne madurada. Aceptabilidad y preferencia de los consumidores. *ITEA* Información Técnica Económica Agraria.