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REGULAR ARTICLES

Effects of dietary supplementation with organic selenium-enriched yeast on growth performance, carcass characteristics, and meat quality of finishing lambs

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Abstract

This study was aimed to assess the impact-enriched *Saccharomyces cerevisiae* with organic selenium addition in finishing lambs on fatty acid composition and physicochemical meat characteristics. Eighteen five-month-old Pelibuey female lambs were fed the same diet for 60 days. Animals were assigned a completely random design of three treatments, control (Se0) without the addition of selenium-yeast or supplemented with 0.35 ppm of selenium-yeast (Se35) and with 0.60 ppm of selenium-yeast (Se60). Lambs were slaughtered at an average weight of 39.5 ± 4.41 kg. Feed intake and meat water holding capacity were decreased ($P = 0.001$) in Se35 lambs, whereas meat moisture and fat were decreased ($P = 0.002$) in Se60 lambs. However, meat carbohydrates were increased ($P = 0.001$) in Se60 lambs. It is concluded that consumption of selenium-yeast in lambs did not alter the productive variables nor the fatty acid composition, though, the fat content is lower, and the carbohydrates are higher in physicochemical meat characteristics.

Keywords Selenium enriched yeast · Meat quality · Lambs

Introduction

Selenium is involved in several biological functions, they bind to protein and many of them are involved in enzymatic functions, thus their supplementation is necessary for farm animals (Taheri et al. 2018). Despite the importance of selenium in farm animals, it could also be toxic. The inorganic form of selenium has less retention compared to organic. Organic Se usually has higher absorption and retention in muscle tissues more than inorganic Se. For example, organic Se of the yeast origin showed greater Se levels in liver and breast tissues compared to inorganic (Wood et al. 2020) and these generate better assimilation and retention in the muscle. Organic forms like selenium-enriched yeast are utilized in many countries as a safer and better source of Se in animal feed, and they are high bioavailability and have the ability to improve meat quality as well as production of Se-enriched meat (Wu et al. 2011). It is important to consider that selenium effectiveness depends, in part, on the supply level, so it is important to determine the optimal levels because the dietary requirement is 0.5 mg/kg LWG/AC (NRC 2007) in small ruminants. Selenium is used as a feed additive and provided in different chemical forms to enhance feed efficiency and to improve growth, carcass traits, and meat quality (Juniper et al. 2009; Issakowicz et al. 2013). The feed of animals is of great importance for adequate growth performance and modifies the composition and physicochemical properties of meat (Vasta et al. 2008; Santos-Silva et al. 2002). However, the excess of selenium in

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the diet could have negative effects and could be even toxic especially the inorganic selenium which may affect growth and meat quality (Hefnawy and Tortora-Perez 2010). Due to the less toxic nature of organic selenium (Markovi'c et al. 2018), there is a need to investigate its impact on the growth performance and meat quality on lamb and different concentrations to ascertain its appropriate level. The aim of this study was to evaluate the effect of addition of the enriched *Saccharomyces cerevisiae* yeast with organic selenium to the diet of finishing sheep on the productive variables and physicochemical meat characteristics and these generate better assimilation and retention in the muscle.

Materials and methods

Animal handling

Eighteen five-month-old lambs (female), Pelibuey breed, with an average initial weight of 27.75 ± 3.37 kg, were enrolled in the study. Animals were randomly allocated to one of three experimental treatments, whereas 6 animals in each. Sheep were fed individually with the same diet (Table 1) twice a day, and selenium yeast was provided to each sheep using 20 g of ground sorghum. The first group considered control Se0 free diet enriched yeast with organic selenium, the second group (Se35–was given 0.35 ppm of selenium-enriched yeast), whereas the third Se60 was 0.60 ppm, considering selenium from the basal diet in Se35 and Se60 groups, for 60 days. Feed and water were provided *ad libitum*. The diet was balanced according to NRC (2007) requirements, with 3.1 Mcal/kg for energy and 13.36% of crude protein per day (Table 1). Organic selenium was obtained from *Saccharomyces cerevisiae*, through a commercial product distributed by Selyest (3000 ppm).

Table 1 Ingredients and chemical composition of basal diet

Ingredient	kg
Whole sorghum	295
Ground corn	100
Ground cookies	200
Rolled corn	100
Distillers dried grains	100
Bran	100
Molasses	80
Minerals and vitamin premix[*, a]	25
Chemical composition (g/kg DM)	
Crude protein	133.9
Ether extract	44.6
Neutral detergent fiber	330.4
Metabolizable energy Mcal/kg	3.1

[*]Selenium free; [a]Minerals and vitamins (per kg). Cu, 60 mg; Fe, 853.44 mg; Mn, 1488 mg; Co, 3.7 mg; I, 19.84 mg; Zn, 2000.16 mg; Mg, 6479.76 mg; $CaCO_3$, 499 mg; Na, 6894.40 mg; K, 5540 mg; Vit. A, 240 KUI; Vit. D_3, 30 KUI, Vit E 1000 mg

A selenium-free mineral mixture was provided for the base diet. At the beginning of the experiment, sheep were de-wormed with ivermectin at a dose of 2 μg/kg of weight and supplemented with a total dose of 0.5 mL of vitamins A, D, and E.

Growth and carcass characteristics

Animal bodyweight gain was recorded every 15 days during the experimental period. Daily feed intake was recorded and lambs were slaughtered at an average body weight of 39.5 ± 4.4 kg. Sheep arrived 12 h before slaughtering, loading, and unloading weight were recorded.

Lambs were slaughtered considering fasting, lairage, and use of numbing according to Mexican Official Standard NOM-033-ZOO-1995. Carcass weight was recorded immediately after slaughtering and 45 min postmortem, pH (pH45) and temperature, both using a potentiometer HANNA INSTRUMENTS, model HI 99,163 (Honikel 1998), the measurements were taken at the 10th rib, and refrigerated at 4 °C for 24 h, time in which was recorded carcass weight, pH (pH24) and temperature.

Meat quality

Color, tenderness, water holding capacity, and chemical composition

Longissimus lumborum muscle samples were taken at 24 h postmortem, color (lightness (L*), redness (a*), and yellowing (b*) at the 10th rib was registered with a Minolta Chroma Meter CR-400 (Minolta, Osaka, Japan). Saturation or chroma (C*) and angle of color hue (H*) values were calculated according to Ripoll et al. (2011).

Tenderness was measured with the Warner-Blatzler blade according to AMSA (1995) (Mecmesin Basic Force Gauge-BFG 500 N) and water holding capacity (WHC) at 24 h postmortem by compression between two plates of glass (Cañeque and Sañudo 2005).

Moisture was determined by AOAC 950.46; fat by Soxhlet extraction method, extraction with hexane (AOAC 991.36); protein by the method of micro Kjeldahl (AOAC 976.05); ashes (AOAC 900.02) and total carbohydrates by difference: % carbohydrate = 100 − (% moisture + % protein + % fat + % ash) (AOAC, 2007; AOAC 2000; AOAC 1990).

Fatty acid profile analysis

Intramuscular fat of Longissimus lumborum was extracted according to the Soxhlet method with hexanes ACS (AOAC, 2000). Fatty acid methyl esters (FAMEs) were determined by a direct method using the method described by of O'Fallon et al. (2007). Fat was reacted with 0.5 N methanolic NaOH solution in a water bath for 30 min and then esterified with a 0.5 N methanolic H_2SO_4 solution and maintained another 30 min in a water bath. The obtained FAMEs were diluted in hexane for analysis. The FAMEs were then analyzed by a gas-chromatography Perkin-Elmer Autosystem XL (Perkin-Elmer, USA), equipped with a flame ionization detector (FID), split/splitless, capillary column Supelco SPTM-2560 (100 m × 0.25 mm × 0.2 µm), injecting 1.5 µl of the sample. The initial oven temperature was 40 °C/7 min increments were made and finally adjusted to 230 °C/20 min (Martínez-Gómez et al. 2012). Injector temperature was 200 °C and detector temperature was 220 °C and the carrier gas used was helium at a flow rate of 30 psi. Fatty acids were identified by comparison of their retention times with those of a standard FAMEs mixture (Supelco® 37 Component FAME Mix, Sigma Aldrich). Fatty acids were expressed as a percentage of total fatty acids identified, and the sum of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) were reported.

Statistical analysis

A completely randomized design was used, and ANOVA was obtained with Statgraphics version 5.0 plus, and the variables referring to growth, the initial body weight were taken as covariate. It was performed a Shapiro–Wilk ($P \leq 0.05$) normality of the variable through the Statgraphics 5.0 plus program. However, differences among experimental groups and days of evaluation were determined by the Tukey test was applied with a 95% confidence level and standard error of means (SEM). Linear and quadratic effects of selenium-yeast are reported. Significant differences were accepted when $P \leq 0.05$.

Results

Productive performance

No differences were observed ($P > 0.05$) for final weight, average daily gain, and feed conversion (Table 2). The feed intake of Se60 lambs was quadratically ($P = 0.001$) higher than Se30 and Se0 lambs which was the lowest.

Carcass meat characteristic

The parameters of pH45, pH24, temperature, color, and tenderness have not differed among treatments ($P > 0.05$) (Table 2). For water holding capacity (WHC), significant differences were found between treatments ($P < 0.05$), however, the WHC increased for Se35 and decreased for Se0 and Se60. No differences ($P > 0.05$) among treatments were observed for loading and unloading weight, transport loss, weight before slaughtering, fasting loss, and hot and cold carcass weight and carcass shrinkage at 24 h.

Carcass meat chemical composition

Selenium supplementation had no significant ($P > 0.05$) effect on meat protein and ash. However, selenium had a linear and quadratic effect on moisture ($P = 0.0315$; $P = 0.0163$) and carbohydrate ($P < 0.0001$; $P < 0.0001$) while it only had linear effect on fat ($P = 0.0002$). Among the selenium supplementations, moisture and fat decreased in a dose-dependent manner while carbohydrate increased. The Se35 and Se60 supplementation decreased the fat by about 25%, while the carbohydrate in Se60 was about 79% higher than Se35 and Se0.

Meat fatty acid profile

Neither saturated, unsaturated, nor polyunsaturated fatty acid affected by the treatments (Table 3), but it was a quadratic effect in MUFA and PUFA ratios. The highest percentage of oleic, then palmitic, and stearic was in Se-yeast lambs.

Discussion

Selenium supplementation improves feed intake in sheep despite their lower initial weight. This indicates that selenium addition can increase appetite in ruminants to enhance intake. The improvement in feed intake is also reflected in the average daily gain and feed conversion ratio of the sheep. This effect agrees with the report of Taheri et al. (2018) where selenium improved feed intake in goats. However, final weight, daily weight gain, and feed conversion did not present significant differences which coincided with the results found by Dominguez-Vara et al. (2009), who fed lambs with a supplement of selenium (0 and 0.3 mg per day per head) and combinations with chromium (0, 0.25, and 0.35 mg) both from yeast did not affect final weight, daily gain, and feed conversion ratio.

Although no difference was found for the pH of the muscle, the decrease in this study from 7.03–7.15 to 5.53–5.59 is similar to the result of Savell et al. (2005) who reported

Table 2 Results of Pelibuey lambs fed on diets with different levels of enriched yeast with organic selenium

Characteristics	Levels of Se*			SEM	Linear	Quadratic
	Se0	Se35	Se60			
Intake and growth performance						
Final body weight (kg)	41.5	39.0	38.0	1.7996	0.1763	0.7691
Intake (g/d)	1130.6	1070.0	1184.1	0.0001	0.0521	0.0001
Average daily gain (g/d)	190	189	208	0.0187	0.4973	0.8600
Feed conversion	6.087	6.127	5.895	0.5811	0.8130	0.8788
Carcass characteristics (kg)						
Load weight	41.5	39.0	38.0	1.7996	0.1763	0.7691
Unload weight	40.10	37.63	37.00	1.7435	0.2277	0.6737
Transport loss	1.40	1.37	1.00	0.2336	0.2430	0.5674
Weight before slaughtering	39.23	36.77	35.90	1.6631	0.1768	0.7000
Fasting loss	0.87	0.87	1.10	0.1303	0.2245	0.4758
Hot carcass weight	21.17	20.27	19.77	0.9972	0.3368	0.8722
Cold carcass weight	20.60	19.77	19.30	1.0464	0.3938	0.8882
Carcass shrinkage	0.57	0.50	0.47	0.1021	0.5011	0.8962
Carcass physical parameters						
pH_{45}	7.06	7.03	7.15	0.1593	0.6895	0.7089
pH_{24}	5.63	5.59	5.53	0.0652	0.3305	0.8865
T 45 min (°C)	20.98	21.15	20.6	1.2704	0.8339	0.8209
T 24 h (°C)	13.52	12.78	12.95	0.5521	0.4794	0.5176
*L**	37.07	37.51	37.63	0.9683	0.6883	0.8966
*a**	14.84	13.48	14.14	0.9270	0.5988	0.3883
*b**	6.18	5.59	6.27	0.5948	0.9130	0.4003
*C**	16.10	14.60	15.47	1.0707	0.6824	0.3794
*H**	21.90	22.43	23.82	1.1000	0.2363	0.7587
WHC (% juice released)	11.65	8.62	11.96	1.0612	0.8408	0.0270
Tenderness (Kg_f)	3.29	3.95	4.41	0.3625	0.0458	0.8302
Meat chemical composition (g/100 g)						
Moisture	68.227	69.672	69.198	0.2892	0.0315	0.0163
Crude protein	20.515	21.19	20.96	0.2527	0.2346	0.1621
Fat	9.840	7.863	7.363	0.3449	0.0002	0.1044
Carbohydrates	0.588	0.415	1.644	0.0953	< 0.0001	< 0.0001
Ash	0.830	0.860	0.835	0.0332	0.9149	0.5154

Selenium supplementation expressed as ppm. Se0, free diet enriched yeast with organic selenium, Se35—was given 0.35 ppm of selenium-enriched yeast, Se60 was 0.60 ppm; pH_{45} (recorded immediately after slaughtering and 45 min postmortem), pH_{24} (Refrigerated at 4 °C for 24 h); T 45 min (°C) (recorded immediately after slaughtering and 45 min postmortem), T 24 h (°C) (refrigerated at 4 °C for 24 h); L: lightness, *a**: redness, *b**: yellowing, *C**: saturation or chroma, *H**: angle of color hue; *WHC*: water holding capacity; *SEM*, standard error of means

that muscle pH decreased from about 7.0 to the range of 5.3–5.8 after slaughtering. This pH falls to the range suitable for acceptable meat characteristics by consumers with better flavor and color (Braggins 1996; Abril et al. 2001; Viljoen et al. 2002). The color of the flesh is a feature that influences directly consumers purchase decisions; due to it is an indicator of freshness and quality (Faustman and Cassens 1990). Organic selenium did not affect the values of color, L*, a*, b*, hue, and chroma, coinciding with Vignola et al. (2009) in lambs and Ripoll et al. (2011). Meat lambs of Se35 presented a higher water holding capacity (WHC), however, this decreased in Se60 (Table 2). This increase in water holding capacity is due to the ability of organic Se to enhance water retention in the tissues (Choct et al. 2004). These results are consistent with those found in pigs by Li et al. (2011) at a concentration of 0.3 ppm from selenium yeast, as it increases the concentration of selenium reduced juiced released, however, the result of this research contrasts with Li et al. (2011) at 3 and 0.6 ppm selenium which decreased water holding capacity. The largely decreased fat content in meat from sheep that received enriched selenium-yeast may be able to modify lipid metabolism, thereby

Table 3 Meat fatty acid profile (g/100 g total fatty acids) of Pelibuey lambs fed on diets with different levels of enriched yeast with organic selenium

	Levels of Se*			SEM	Linear	Quadratic
	Se0	Se35	Se60			
Saturated						
C10:0 capric	0.18	0.20	0.19	0.21	0.4712	0.3899
C12:0 lauric	0.19	0.20	0.19	0.22	0.8764	0.4780
C14:0 myristic	3.18	3.22	3.23	2.69	0.7200	0.7415
C16:0 palmitic	27.75	26.96	27.49	16.61	0.9017	0.9950
C18:0 stearic	18.68	17.78	17.35	5.17	0.1007	0.6842
Unsaturated						
C16:1n-7 palmitoleic	1.67	1.71	1.68	1.14	0.7643	0.4755
C18:1 n-9 oleic	38.18	39.72	39.62	14.09	0.1938	0.2092
Polyunnsaturated						
C18:2 n-6 linoleic	5.35	5.33	5.40	0.81	0.1356	0.3163
C18:3 n-3 α-linolenic	2.37	2.52	2.44	1.64	0.4935	0.2462
C20:4 n-6 arachidonic	2.45	2.38	2.41	0.32	0.9242	0.9158
SFA	49.97	48.35	48.45	15.34	0.1854	0.1969
MUFA	39.85	41.42	41.30	14.55	0.7752	< 0.0001
PUFA	10.17	10.22	10.25	1.76	0.0909	< 0.0001
P/S	0.204	0.211	0.212	0.01	0.3605	0.7432
n-6:n-3	3.3	3.1	3.2	0.17	0.8182	0.2988

*Selenium supplementation expressed as ppm. Se0, free diet enriched yeast with organic selenium, Se35 was given 0.35 ppm of selenium-enriched yeast, Se60 was 0.60 ppm

P, probability; *SEM*, standard error of means; *SFA*, C10:0 + C12:0 + C14:0 + C16:0 + C18:0; *MUFA*, C16:1 + C 18:1; *PUFA*, C18:2 + C18:3 n − 3 + C20:4; *P/S*, PUFA/SFA; *n-6*, omega-6

n-3, omega-3

affecting fat accumulation in the meat or indirect effect of Se on thyroid hormone which plays an important role on lipid metabolism which result in low-fat accumulation in muscle (Wiernsperger and Rapin 2010; Ahmad et al. 2012; Rayman and Stranges 2013). There are few researches in sheep but there are in other animals, Taylor et al. (2008) in beef did not find differences for moisture, and fat, whereas, in pigs Zhan et al. (2007) no differences were found for fat. It is possible because, in these experiments, a lower dose of selenium was provided, 0.068 mg Se/kg and 0.3 mg Se/kg, respectively, than those used in the current research.

Selenium intakes decrease fat, but quadratically improve meat MUFA and PUFA, and this results are depends on the breed, feeding, and management (Bessa et al. 2008; Bernes et al. 2012). However, female lambs deposit fat differently than male lambs, which could be another factor to be considered, however, most of the studies use female lambs and, in some cases, it is not specified. It was identified saturated fatty acid as capric, lauric, myristic, palmitic, and stearic. For unsaturated, oleic acid is found in large quantities, but there were no differences between treatments and the values were similar to those reported by Wood et al. (2008). The nonlinear effect of selenium on fatty acid compositions is consistent with the report of (Liu et al. 2011) who found that selenium (Se, 2.5 mg/kg diet) did not affect fatty acid concentrations in the muscles. The n-6 (omega-6) and n-3 (omega-3) series of polyunsaturated fatty acids (PUFA) are defined as “essential” fatty acids, and their appropriate ratio is essential for human health (Russo, 2009). The inappropriate ratio of n-6: n-3 PUFA is also a risk factor in cancers and coronary heart disease, and it is recommended that a ratio less than 4 in meat is healthy for human consumption (Simopoulos 2002). Thus, the ratio of 3.3 obtained in this study aligns to suggest that it is healthy for human consumption.

Conclusions

The inclusion of organic selenium in the diet improved feed intake and modified the physicochemical meat characteristics. Se60 inclusion decreased meat fat, increased meat moisture, carbohydrate, and water holding capacity. Selenium inclusion quadratically increased the monounsaturated and polyunsaturated in the muscle of a finishing lamb. Thus, the inclusion of Se60 may be included in animal diets without having a negative effect on meat quality.

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Author contribution MDM, MAM, and YLJ conceived and designed the experiment; YLJ, MDM, and JL conducted the experiment; MDM and MAM supervised the experiment; JL, YLJ, and MGF sample analysis; MDM, and AZM prepared the manuscript. All Authors approved of the manuscript.

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Data Availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to, and the appropriate ethical review committee approval has been received. The authors confirm that they have followed official Mexican standards of animal care (NOM-051-ZOO-1995) for the protection of animals used for scientific purposes.

Consent to participate All authors agree to participate in the current work.

Consent for publication All authors agree to publish the findings of current research.

Conflict of interest The authors declare no competing interests.

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