

Evaluation of polyherbal with vitamin C activity on lamb performance and meat characteristics

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ABSTRACT - We conducted an experiment to evaluate the effect of a polyherbal additive with metabolites such as antioxidants, vitamins, and small hydrolysable tannoids oils on productive parameters and blood metabolites in finishing lambs. Forty male Hampshire × Suffolk lambs (23.79±2.24 kg) were used in a completely randomized experimental design. Treatments consisted of dietary inclusion of a polyherbal additive based on *Emblica officinalis* and *Ocimum sanctum* at 0, 5, 10, and 15 g/kg dry matter for 60 d. There were no effects on daily gain, dry matter intake, feed conversion, back fat thickness, and *Longissimus dorsi* area; however, hot carcass dressing improved linearly as the level of herbal additive supplementation was increased. The antioxidants of the polyherbal additive linearly inhibited lipid oxidation of the meat (24 h; day 10) and improved its water-holding capacity (24 h). Meat lightness after 1 d was reduced linearly, but no changes were detected in other color parameters. Metabolites (glucose, urea, cholesterol) related to energy or protein metabolism were not affected by the herbal additive. Lymphocytes and basophiles were reduced linearly whereas monocytes and segmented neutrophils increased linearly for polyherbal additive. The inclusion of the polyherbal additive does not improve daily gain or feed efficiency in finishing lambs but improves the carcass dressing and antioxidant capacity of the meat.

Keywords: antioxidant, finishing, lambs, meat quality

1. Introduction

Although ruminants, as other mammals, can synthesize vitamin C from D-glucose (Akbari et al., 2016), various stress conditions and the metabolic needs of high-performance animals have led researchers to assess the importance of ascorbic acid in ruminants. Some studies have shown that vitamin C supplementation can reduce diarrhea in calves (Sahinduran and Albay, 2004) and reduce mastitis problems in dairy cattle (Weiss and Hogan, 2007), and it has been suggested that it may improve meat marbling (Matsui, 2012) based on some experiences with fattening Japanese Black cattle receiving vitamin C (Oohashi et al., 2000; Mori et al., 2006).

Feedlot diets cause chronic stress by reducing ruminal pH, with daily weight gains below the potential of metabolizable energy consumed (Hernández et al., 2017), and the use of phytogenic additives has been recommended in cows to attenuate the stress caused by ruminal subacute acidosis (Humer et al., 2018b), an area that has been unexplored in feedlot lambs.

Despite the potential benefits of this nutrient, the most important water-soluble antioxidant in mammals is not included in ruminant rations because supplemental forms of vitamin C (crystalline ascorbic acid or ascorbyl-2-polyphosphate) are rapidly degraded in the rumen (MacLeod, 1996) and are relatively unstable; therefore, some rumen-protected products have been evaluated experimentally or tested in commercial farms (Mori et al., 2006; Guo et al., 2017). Some herbs and spices used as feed plant additives (Bodas et al., 2008; Frankič et al., 2009) have been used as a source of natural vitamins for ruminants, providing metabolites with vitamin C activity that allow the replacement of synthetic vitamins (Godinez-Cruz et al., 2015; Crosby et al., 2017; Mendoza et al., 2019). A polyherbal based on *Phyllanthus emblica* has shown the same potential as ascorbic acid to ameliorate heat stress in dairy cattle and heat-stressed buffaloes (Haq et al., 2013; Lakhani et al., 2017).

In feedlot conditions, vitamin C could help maintain lamb welfare and improve meat oxidative properties, and possibly lamb performance. Therefore, the objective of this experiment was to test the hypothesis that supplementation with a polyherbal with vitamin C activity in lamb feed consisting of a high-grain diet would improve lamb performance and the physical and chemical characteristics of the meat, and various changes in blood biochemistry and biometry would be detected due to its antioxidant potential and the immune functions of vitamin C.

2. Material and Methods

The experiment was authorized by the Animal Well-being Committee. At the end of the experiments, animal transport and slaughter were carried out according the specifications of Mexican approved legal norms for humanitarian slaughter of domestic and wild animals (NOM-033-SAG/ZOO-2014). The experiment was carried out in Montecillo, State of Mexico, Mexico located at 98°54'11" W, 19°27'38" N, and 2250 m altitude. The mean annual temperature at this site is 15.9 °C.

2.1. Animal performance, carcass characteristics, and meat quality

Forty male Hampshire × Suffolk lambs with an initial weight of 23.79±2.24 kg and three months of age were housed in individual pens (1.00 × 1.80 m) and allotted in a completely randomized experimental design considering each lamb as an experimental unit. Treatments consisted of dietary inclusion of Power C® (Nuproxa Mexico, Querétaro, México) at 0, 5, 10, and 15 g/kg dry matter (DM) for 60 d (n = 10 lambs/treatment) in a basal diet formulated for a 30-kg lamb gaining 300 g/d (NRC, 2007; Table 1). The polyherbal mixture was based on *Emblica officinalis* and *Ocimum sanctum* and contained small hydrolysable tannins (12%) and gallic acid (5.1%) quantified HPTLC in certified laboratories (Indian Herbs Research & Supply Co. Ltd.). A sample of the polyherbal was analyzed with the microhistological procedures (Holechek, 1982) and, based on vitamin C contents reported in *Emblica officinalis* and *Ocimum sanctum* (Khopde et al., 2001; Scartezzini et al., 2006; Hussain et al., 2017; Pattanayak et al., 2010), the calculated vitamin C in the polyherbal is 0.96%.

Before starting the experiment, lambs were dewormed with closantel (Closantil 5%, 20 mg/kg BW orally) and immunized against *Clostridium chauvoei*, *C. septicum*, *C. novyi*, *C. sordellii*, *C. perfringens*, *Pasteurella multocida* type A, *P. multocida* type D, and *P. haemolytica* (Bobact 8, 2.0 mL/animal, intramuscularly). Lambs were gradually adapted to the experimental diet from a 50% forage diet for 15 d, and the experimental phase lasted 60 d.

Feeds were ground (1.25 cm screen) and mixed in a grinder-mixer (Azteca No. 24, Mexico), and total mixed rations were provided *ad libitum* in individual feeders (50 cm bunk space/lamb), offered in two meals (08:00 and 15:00 h), ensuring a daily refusal of 100 g per kg of feed offered. Lambs were weighed on two consecutive days at the beginning (days 0 and 1) and end of the experiment (days 59

Table 1 - Formulation and nutritional composition of the experimental diets

Ingredient (g/kg DM)	Polyherbal (g/kg DM)			
	0	5	10	15
Sorghum grain	544.40	542.60	540.80	539.00
Soybean meal	190.90	192.60	194.20	195.90
Oat hay	100.00	100.00	100.00	100.00
Alfalfa hay	100.00	95.00	90.00	85.00
Cane molasses	50.00	50.00	50.00	50.00
Mineral premix ¹	10.00	10.00	10.00	10.00
Sodium chloride	3.00	3.00	3.00	3.00
Calcium carbonate	1.70	1.80	2.00	2.10
Power C ²	0.00	5.00	10.00	15.00
Chemical composition (g/kg DM)				
Crude protein	174.90	174.90	174.80	174.80
Neutral detergent fiber	411.10	407.50	404.00	400.50
Acid detergent fiber	259.10	256.50	253.90	251.40
Ether extract	25.45	25.39	25.33	25.27
Calcium	11.45	11.45	11.35	11.34
Phosphorus	4.53	4.53	4.51	4.51

DM - dry matter.

¹ Mineral premix: P, 10.0 g/100 g; Ca, 12.0 g/100 g; Fe, 0.5 g/100 g; Mg, 0.1 g/100 g; Cu, 0.15 g/100 g; Zn, 0.12 g/100 g; Mn, 0.055 g/100 g; Co, 0.05 g/100 g; I, 0.02 g/100 g; Se, 200 ppb/100 g.² Polyherbal additive based on *Embllica officinalis* and *Ocimum sanctum*.

and 60). Intake was recorded daily, and samples of the feed and the refusals were collected daily and composited every 15 d; they were analyzed for DM, crude protein, ether extract, calcium, and phosphorous (AOAC, 2005), NDF (Mertens, 2002), and ADF (Van Soest, 1973).

Lamb performance was evaluated with daily feed intake, average daily gain, feed conversion ratio, and variation in daily feed intake between days as an indicator of stability and welfare (Díaz Galván et al., 2021). Lambs were fasted (16 h) and weighted on two consecutive days at the beginning and at the end of the experiment. Ultrasound back fat and *Longissimus dorsi* muscle area were measured by real time ultrasound (Silva et al., 2005) using a Sonovet 600 (Medison, Inc., Cypress, CA, USA) with a 7.5 MHz transducer between the 12th and 13th rib, on day 60 of the experiment. Before the examination, wool overlying the area was shaved off for the skin to have contact with the transducer to improve image resolution.

Meat quality was assessed in *Longissimus dorsi* samples obtained from five animals per treatment following slaughter in a commercial facility where hot carcass dressing was recorded. Measurements were made in triplicate at 24 h (1 d) and 7 d after in samples kept in polystyrene trays covered by oxygen-permeable polyethylene film and stored at 4 °C (Honikel, 1998). Meat pH values were recorded using a pH meter (Hanna HI 99163) with the probe inserted into the muscle to a depth of approximately 3 cm. Water-holding capacity was measured with the pressure paper filter method (Cañeque and Sañudo, 2005). Texture was determined using a texture analyzer (Model TA-XT plus Stable Micro Systems Brand, Vienna Court, England) with a Warner-Bratzler blade and Texture Expert software (Warner et al., 2010). Meat color was measured using a Minolta CR-200 Chroma-Meter (Konica Minolta Optics, Inc., Tokyo, Japan) recording L* (luminosity), a* (redness), and b* (yellowness) (Warner et al., 2010). Antioxidant capacity was measured using the ferric reducing/antioxidant power (FRAP) assay (Benzie and Strain, 1999) using Trolox (6-hydroxy-2-5-7-8-tetramethyl-chroman-2-carboxylic acid) as standard.

2.2. Blood biochemistry and biometry

Blood samples (5 mL; preprandial 08:00 h) were collected on day 59, from the jugular vein by puncture, using vacutainer tubes without anticoagulant, and put immediately under refrigeration

(4 °C); then, they were centrifuged (Sigma 2-16 k, Germany) at $3500 \times g$ for 20 min to obtain blood serum, which was stored in Eppendorf tubes and kept in a freezer (Sanyo MDF-436, USA) at -20 °C until analysis for total cholesterol, glucose, total protein, albumin, and high- and low-density lipoproteins using a Kontrolab 2017 autoanalyzer. A second blood sample (2.5 mL) was collected in disodium-EDTA used for complete blood count (CBC), and 7.5 mL were transferred to plane tubes for serum separation, placed immediately on ice, and transferred to the laboratory. The CBC, leukocyte differential count, and hematocrit analysis was performed with an automatic hematology analyzer (QS Kontrolab EasyVet).

2.3. Statistical analysis

Data were analyzed as a completely randomized design, and normality was verified with Shapiro-Wilk test. To evaluate the effect of the polyherbal dietary concentration, linear and quadratic contrasts were tested. Each lamb was used as an experimental unit. Data were analyzed with Proc GLM in SAS (Statistical Analysis System, version 9.1) with the following model:

$$Y_{ij} = \mu + \tau_i + e_{ij}, \quad (1)$$

in which Y_{ij} is observation j in treatment i , μ represents the mean value, τ_i is the fixed treatment effect, and e_{ij} is the random error term.

3. Results

3.1. Animal performance, carcass characteristics, and meat quality

There were no effects of herbal C on daily gain, DM intake, feed conversion, or *Longissimus dorsi* area. However, hot carcass weight tended to be improved (linear $P < 0.10$), and hot carcass dressing improved linearly up to 7% ($P < 0.05$), and there was a numerically substantial reduction in the variation of feed intake as herbal C was augmented (Table 2).

Meat pH and Warner-Bratzler shear force were not affected, but herbal C tended to improve the water-holding capacity after 1 d (linear $P < 0.10$), and the antioxidants of the polyherbal additive inhibited lipid oxidation of the meat linearly after 1 d ($P < 0.01$), maintaining the effect in samples after 7 d ($P < 0.10$). Lightness after 1 d was reduced linearly ($P < 0.05$), and no changes were detected in other color parameters (Table 3).

Table 2 - Effect of polyherbal additive with vitamin C activity supplementation on lamb performance

	Polyherbal (g/kg DM) ¹				SEM	P-value	
	0	5	10	15		Linear	Quadratic
Initial weight (kg)	23.70	23.90	23.80	23.70	0.74	0.93	0.83
Final weight (kg)	44.20	44.60	43.50	44.80	1.27	0.90	0.73
Average daily gain (kg/d)	0.35	0.35	0.33	0.36	0.02	0.83	0.53
Dry matter intake (kg/d)	1.569	1.575	1.487	1.542	0.5582	0.50	0.67
Feed intake variation (%) ²	26.40	27.00	19.10	16.30	7.00	0.22	0.80
Feed conversion	4.54	4.59	4.55	4.35	0.22	0.54	0.56
Back fat thickness (mm)	0.22	0.22	0.23	0.23	0.01	0.39	0.71
<i>Longissimus dorsi</i> muscle area (mm ²)	1015	1318	1000	1030	150.30	0.68	0.37
Hot carcass dressing (%)	43.40	44.70	43.40	46.60	0.87	0.05	0.25
Hot carcass weight (kg)	19.22	19.91	19.03	20.99	0.564	0.10	0.30

SEM - standard error of the mean.

¹ Polyherbal additive based on *Emblica officinalis* and *Ocimum sanctum*.

² Variation in daily feed intake among individuals between days.

Table 3 - Effect of polyherbal additive with vitamin C activity supplementation on meat characteristics

	Polyherbal (g/kg DM) ¹				SEM	P-value	
	0	5	10	15		Linear	Quadratic
pH Day 1	5.72	5.68	5.86	5.67	0.13	0.94	0.56
Day 7	5.74	5.73	5.89	5.66	0.10	0.85	0.28
WBSF (N)	3.80	2.89	2.98	3.22	0.41	0.38	0.18
Day 7	2.01	2.36	2.77	2.52	0.32	0.74	0.54
FRAP (mmol Trolox/g DM)							
Day 1	1.53	1.00	0.53	0.53	0.17	0.0008	0.15
Day 7	1.66	0.82	1.66	0.98	0.23	0.10	0.12
Color							
L* Day 1	40.96	39.83	37.81	38.26	0.98	0.03	0.43
Day 7	41.88	41.04	39.94	40.19	1.20	0.26	0.65
a* Day 1	9.45	9.80	8.89	9.31	0.53	0.57	0.93
Day 7	9.51	9.82	8.84	9.89	0.46	0.93	0.42
b* Day 1	10.79	10.75	9.81	9.82	0.69	0.23	0.97
Day 7	11.34	11.20	10.51	10.73	0.58	0.34	0.75
WHC Day 1	0.10	0.11	0.12	0.10	0.01	0.09	0.08
Day 7	0.08	0.07	0.09	0.10	0.01	0.03	0.52

DM - dry matter; SEM - standard error of the mean; WBSF - Warner-Bratzler shear force; FRAP - ferric reducing/antioxidant power assay; L* - lightness; a* - redness; b* - yellowness; WHC - water-holding capacity.

¹ Polyherbal additive based on *Emblica officinalis* and *Ocimum sanctum*.

3.2. Blood biochemistry and biometry

Most of the metabolites related to energy or protein metabolism were not affected by the herbal C (Table 4), and there was a linear increase in serum phosphorus ($P < 0.01$) and a tendency of quadratic response ($P < 0.10$) in serum calcium. Herbal C tended to reduce alkaline phosphatase values linearly ($P = 0.11$); total protein tended ($P < 0.10$) to be reduced linearly by herbal C and was associated with a tendency for reduced globulins ($P = 0.13$ linear); albumin tended to show a quadratic response ($P < 0.10$) resulting in a quadratic albumin:globulin ratio ($P < 0.10$).

Table 4 - Effects of polyherbal additive with vitamin C activity supplementation on biochemical profile of lambs

	Polyherbal (g/kg DM) ¹				SEM	P-value	
	0	5	10	15		Linear	Quadratic
Glucose (mg/dL)	93.80	94.60	92.33	93.40	1.74	0.65	0.90
Urea (mg/dL)	24.00	23.30	25.11	25.10	1.31	0.38	0.79
Uric acid (mg/dL)	0.99	1.01	1.00	1.00	0.02	0.79	0.55
Creatinine (mg/dL)	0.77	0.79	0.83	0.82	0.03	0.16	0.59
Total protein (g/dL)	6.78	6.50	6.57	6.37	0.14	0.07	0.80
Globulin (G; g/dL)	3.69	3.30	3.35	3.34	0.15	0.13	0.20
Albumin (A; g/dL)	3.09	3.22	3.20	3.03	0.55	0.41	0.009
A:G ratio	0.84	1.00	0.93	0.91	0.05	0.53	0.07
Cholesterol (mg/dL)	60.6	65.9	58.66	62.2	2.67	0.83	0.74
Bilirubin (mmol)	0.24	0.25	0.31	0.27	0.04	0.37	0.50
ALP (U/L)	103	86.2	72.33	83.30	10.34	0.11	0.18
LDH (U/L)	101.20	101.50	103.88	99.50	6.02	0.91	0.69
AST (U/L)	71.90	74.70	74.66	68.20	4.84	0.60	0.34
Calcium (%)	8.97	9.27	9.31	8.83	0.21	0.68	0.07
Phosphorus (%)	4.35	4.61	5.07	4.79	0.15	0.009	0.07

ALP - alkaline phosphatase; LDH - lactate dehydrogenase; AST - aspartate aminotransferase; SEM - standard error of the mean.

¹ Polyherbal additive based on *Emblica officinalis* and *Ocimum sanctum*.

Herbal C affected some cell counts (Table 5). Lymphocytes and basophiles were reduced linearly ($P < 0.01$), whereas monocytes ($P < 0.10$) and segmented neutrophils were augmented linearly ($P < 0.01$) by herbal C. Erythrocytes tended ($P = 0.12$) to increase linearly, and both mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCHC) tended to reduce linearly ($P < 0.10$).

Table 5 - Effects of polyherbal additive with vitamin C activity supplementation on lamb hemograms

	Polyherbal (g/kg DM) ¹				SEM	P-value	
	0	5	10	15		Linear	Quadratic
Hematocrit (%)	36.11	38.28	36.66	37.1	0.86	0.72	0.32
Hemoglobin (g/dL)	12.04	12.9	12.23	12.47	0.26	0.58	0.23
Erythrocytes (10^6 /mL)	5.07	5.54	5.2	5.49	0.13	0.12	0.51
MCV (fL)	71.18	69.01	70.67	67.42	1.25	0.08	0.66
MCH (pg)	23.75	23.22	23.56	22.67	0.40	0.1	0.64
MCHC (g/dL)	33.33	33.65	33.37	33.22	0.31	0.64	0.44
Platelets (10^3 /mL)	316.33	314.43	332	356.3	26.99	0.24	0.63
WSR (mL/h)	1.66	0.00	0.55	0.00	0.52	0.05	0.29
Leucocytes (10^3 /mL)	14.25	13.81	12.61	16.00	2.99	0.75	0.52
Lymphocytes (10^3 /mL)	37.44	32.71	27.77	24.70	3.84	0.01	0.83
Monocytes (10^3 /mL)	4.22	4.14	4.77	5.10	0.43	0.08	0.64
Neutrophils segmented (10^3 /mL)	49.22	55.42	60.00	62.60	4.11	0.01	0.66
Neutrophils in band (10^3 /mL)	5.00	3.57	4.33	4.10	0.50	0.37	0.24
Eosinophils (10^3 /mL)	3.22	3.00	3.11	3.2	0.39	0.97	0.69
Basophiles (10^3 /mL)	0.88	1.14	0.00	0.30	0.21	0.003	0.91
Plasma proteins (g/dL)	8.75	9.07	9.14	8.82	0.19	0.75	0.10

MCV - mean corpuscular volume; MCH - mean corpuscular hemoglobin; MCHC - mean corpuscular hemoglobin concentration; WSR - Wintrobe sedimentation rate; SEM - standard error of the mean.

¹ Polyherbal additive based on *Emblica officinalis* and *Ocimum sanctum*.

4. Discussion

4.1. Animal performance, carcass characteristics, and meat quality

Information concerning vitamin C in feedlot performance is scarce; however, there are some results that indicate that its dietary supplementation could improve meat quality. Pogge and Hansen (2013b) supplemented steers consuming a high-sulfur diet with 5 to 20 g/d vitamin C without affecting average daily gain but reported a linear reduction in intake with an improvement in feed conversion. However, in other experiments, those variables were not affected or reported (Oohashi et al., 2000; Mori et al., 2006; Pogge and Hansen, 2013b; Matsuda and Takahashi, 2014). In the experiment by Mori et al. (2006), no changes were observed in the *Longissimus dorsi* area as reported here. However, in other studies, this parameter was improved with rumen-protected vitamin C (Pogge and Hansen, 2013a; Matsuda and Takahashi, 2014) or with ascorbic acid (Oohashi et al., 2000). Mori et al. (2006) reported significant differences in firmness and texture and a tendency for improved marbling on feeding rumen-protected vitamin C to Japanese Black heifers, and Oohashi et al. (2000) reported a tendency to improve the same variables in Japanese Black steers.

The highest carcass dressing observed in this trial in lambs fed 15 g polyherbal indicates that more energy was retained in tissue, which can be explained by some of the functions of vitamin C in metabolism such as synthesis of carnitine and cholesterol, amino acids, and catecholamines (Akbari et al., 2016). Feedlot experiments involving supplementation with vitamin C where improvements in marbling score or rib eye area were observed (Oohashi et al., 2000; Mori et al., 2006; Pogge and Hansen, 2013b; Matsuda and Takahashi, 2014) suggest that vitamin C may modify the lipid content in carcass. Despite the fact that there is no clear evidence that vitamin C supplementation causes a shift in ascorbic

acid synthesis, leaving more glucose available for lipid deposition (Pogge and Hansen, 2013a), we could hypothesize that there may be differences in glucose turnover rate, a variable that represents a more dynamic view of carbohydrate metabolism (Reinauer et al., 1990).

The antioxidant potential of the polyherbal observed in this trial was manifested in the lipid oxidation of meat. Matsuda and Takahashi (2014) suggested that vitamin C supplementation during the late finishing period could be useful to improve meat quality, and Pogge and Hansen (2013b) recognized its potential to alleviate oxidative stress in steers consuming a high-sulfur diet.

Reduction in meat lipid oxidation is explained by vitamin C activity and other antioxidants present in the herbal mixture; other beneficial effects could be expected in meat parameters such as those observed with vitamin E in lamb diets (González-Calvo et al., 2015; Bellés et al., 2018; Martínez-Aispuro et al., 2019).

4.2. Blood biochemistry and biometry

In ruminants fed vitamin C, no changes have been reported in blood metabolites related to energy such as glucose, non-esterified fatty acids (Pogge and Hansen, 2013b), or cholesterol (Matsuda and Takahashi, 2014). The effects observed in serum Ca and P in this trial could be associated with functions of vitamin C in bone metabolism; ascorbic acid is required for the synthesis of collagen, an important component of the extracellular bone matrix (Akbari et al., 2016). Alkaline phosphatase (ALP) is used as an indicator of liver function (Dufour et al., 2000) and bone formation (Sousa et al., 2014). Values for ALP in this trial were within the normal range (Sousa et al., 2014), and the reduction of its levels suggests that herbal C promotes liver health and presumably better bone metabolism. Overall, the blood chemistry results indicate that the polyherbal additive has no negative effects on liver function (Dufour et al., 2000).

The polyherbal mixture has secondary metabolites that could be responsible for changes in hematological cell counts. Metabolites from plants may cause significant changes in those hematological parameters without being indicators of liver damage (Riaz et al., 2014). Large circulating erythrocytes are not always associated with a pathologic process (Aslinia et al., 2006). Neutrophils are not necessarily correlated with the presence of bacterial disease (Honda et al., 2016), and the Wintrobe sedimentation rate confirms that there was no inflammatory process in the lambs (Chirkena et al., 2016). The effects on cell counts were not related to any infections because carcass dressing was improved with the polyherbal, and daily gain tended to be higher. In addition, vitamin C also has effects on the immune system such as improved activity of antimicrobial and natural killer cells; enhanced neutrophil phagocytic capacity and protection from oxidative damage; support of lymphocyte proliferation and interferon production; and contribution to maintenance of the redox integrity of cells. Its deficiency reduces resistance against infections and inflammatory response (Ranjan et al., 2012; Akbari et al., 2016).

Herbal mixtures cannot be compared directly with synthetic vitamins since they may have nutrients, precursors, and secondary metabolites with nutraceutical effects (Mendoza et al., 2019). The polyherbal evaluated provides ascorbic acid, hydrolyzable gallo-tannoids, and bio-flavonoids in conjugated form that have vitamin C activity. A major constituent of the polyherbal is the herbal plant *Phyllanthus emblica* (also known as *Emblica officinalis*) with a superior antioxidant activity compared with its equivalent amount in pure isolated form (Khopde et al., 2001; Muruganandam et al., 2004; Pozharitskaya et al., 2007). Herbal mixtures can be incorporated into the feed while remaining stable. Changes observed in lambs confirmed that the product resisted ruminal degradation, presumably allowing the phyto-constituents of herbal C to be available in the small intestine, thus providing ellagic acid and gallic acid vitamin C analog (2-keto-gluconolactone) in addition to the antioxidant activity of vitamin C.

Considering all of the above, the polyherbal additive with vitamin C activity has potential in feedlots. Use of high grain levels in ruminant diets can cause subacute acidosis, an important metabolic disorder that disrupts acid-base balance and liver health associated with the toxic compounds from the rumen

(Humer et al., 2018a). These compounds can increase oxidative stress to the liver cells (Humer et al., 2019), maintaining chronic stress in feedlot lambs and preventing full expression of the weight gain expected by the net energy of the ration (Hernández et al., 2017). Subacute acidosis also reduces plasma aminoacids associated with protein catabolism by inflammatory responses, which result in significant production of free radicals (Humer et al., 2019). Under these conditions, vitamin C may have a beneficial role because of its antioxidant activity through supplementation; higher doses of ascorbic acid in the diet have been shown to cause an imbalance between pro-oxidative and antioxidative activities (Berzina et al., 2012). The polyherbal could have potential benefits in feedlot diets, helping to maintain cell integrity, preventing cellular damage and improving animal health, and the numeric reduction in intake variation among individuals suggests that herbal C promotes better welfare in lambs.

5. Conclusions

The inclusion of polyherbal with vitamin C activity does not affect lamb performance; however, it improves carcass dressing and the antioxidant capacity of meat.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

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