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Full Length Article

Characteristics of Canary Hair Sheep´s Breed Carcass Fed Banana (*Musa acuminate)* By-Products: Effects on Regional Tissue Composition, pH and Color

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Abstract

The contributions of replacing rye-grass (*Lolium spp*.) hay with banana (*Musa acuminata)* by-products on carcass and tissue characteristics, pH and color, in the Canary hair sheep breed were studied. Twenty-two lambs with an initial live weight of 14.8 ± 2.5 kg were individually housed and fed two different diets for 58 days: The first group (experimental diet) received as forage a mixture of fresh banana (*Musa acuminata*) by-products composed by leaves and pseudo-stem. The other one got commercial rye-grass (*Lolium* spp.) hay (conventional diet) as a fiber source. The two groups got an additional commercial concentrate food (CON). After the 58 days growing trial (24.3 kg ± 1.0 kg), seven lambs of each group (n=14) were slaughtered in the experimental slaughterhouse. The muscle, the pH, and the color were measured at the time immediately after slaughter and 24 h later, using the muscles *Longissimus thoracis et lumborum* and *semimembranosus*. At that time (after 24 h), the remaining semi-carcass was butchered and dissected for analysis of the carcass´s regional and tissue composition. Although there is no significant difference on the tissue composition, carcass regional and the muscle pH, there are significant differences in the color in the *Longisimus toracis et lumborum* between the two assessed diets. The incorporation of banana by-products in a diet to fatten lambs Canary hair sheep breed would not grossly alter the carcass quality, at least based on the assessed parameters. Banana by-products as a feeding resource can maintain animal productivity and meat quality.

Keywords: Banana by-products; Carcass traits; Hair sheep; Meat quality; Pelibuey sheep

Introduction

The potential use of non-conventional feeds (alternative feeds) in animal nutrition, in particular for the ruminant species, is being recommended by different international organizations in order to develop a more sustainable system of animal production (Ben Salem *et al.* 2008; Archimède *et al.* 2012). Conventional concentrate and forages are scarce, expensive, and irregular in arid and tropical areas. The cost of many traditional feeds is restricting their use in many countries, and producers are now turning to alternative feed sources (Blache *et al*. 2008).

A good approach to solve this problem is to find alternative feeds as local feeds and by-products, not used for the local human population, as a resource for animal nutrition (Ben Salem *et al.* 2008). However, animal health, animal production, and product quality should be preserved (Vasta *et al*. 2008).

Globally, 102 tonnes of banana was produced in 2010 to 116 million tons in 2019, at an approximate value of 31 billion USD. Worldwide, the banana is one of the main fruits, after grapes, tomatoes, and apples (FAO 2020). It is cropped in tropic areas for its important relevance in the food sector and the bulk of banana cultivation is conducted informally by smallholder farmers. Bananas are mainly produced between twentieth parallels North (20ºN) and South (20ºS), cultivated in different climatic areas of the world. This fruit is mainly cultivated for human food, although almost 50% of this is not suitable but adequate for animal feeding (Ecocrop 2010; Archimède *et al.* 2012). Different by-products banana crops as leaves (5 to 10 kg per plant), pseudostems (25 to 50 kg per plant) and raceme stems (2 to 3 kg per plant), with 5–10 t dry matter per Ha of by-products production, is determined by the intensification of crops (Pieltain *et al*. 1999). Different parts of the fruit (peels) and the plant (leaves, stems, and stalks or pseudostems) are used in animal feeding as fresh plantain, ensiled and can be dehydrated, chopped, milled or cooked, to fed to livestock (Ecocrop 2010; Heuzé and Tran 2016). Dried banana leaves and pseudo stems have been used to

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feed goats and sheep by (González–García *et al.* 2008; Marie-Magdeleine *et al*. 2009; Heuzé and Tran 2016; Barbera *et al.* 2018) achieving good results on intake and growth performance. Hence, the evidence of its nutritional value has been demonstrated in pigs and ruminants. However, little information is found regarding the effects of feeding with banana by-products (*Musa acuminate)* in characteristics and composition of sheep´s breed carcass.

This paper aimed to study the outcomes of feeding with banana by-products (*Musa acuminate)* on the characteristics and composition of Canary Hair Sheep´s breed carcass. The regional and tissue characteristics, the pH and the color of the carcass using Canary hair sheep breed lambs were analyzed. The Canary hair sheep breed is an original Canary meat sheep native of the Canary Islands (Spain), they are easily adaptable animals and are similar to other sheep breed spreading widely in tropical countries of America, Antilles and some African countries (called Pelibuey, Tabasco, West African sheep, Ovin Martinik sheep). This breed is directly associated with the intensive production of bananas and tomatoes being a basic element in the production cycle. The sheep consume the banana by-products, both leftovers from production and packaging and also produce the manure necessary to maintain the fertility of the farmland. It is a fundamental element in the recovery of certain agricultural residues (Spanish Ministry of Agriculture, Fisheries and Food 2020).

Materials and Methods

Animals and feeding supervision

A total of 22 Canary hair sheep breed were collected. After weaning (mean weight 14.8 ± 3.1 kg), they were reared in individual pens and classified into two groups of eleven animals each (equilibrated based on body weight (BW). Lambs were individually fed ad libitum. After adapting the animals (10 days), they were dewormed and housed in individual corrals and fed for 58 days; each group received different forages. The first group (experimental diet) got a fodder comprised of 50% leaves and 50% pseudo-stem of banana by-products. The second group got commercial rye-grass (*Lolium* spp.) hay (conventional diet) as a fiber source. The groups got a supplement commercial concentrate feed (CON). The chemical compositions and ingredients are shown in Table 1; mineral blocks and water were ad libitum for all the lambs. By-products of banana were collected daily, chopped, and mixed on the experimental farms. Fodders were offered ad libitum. Fodder offered and rebuffs were weighed and noted daily in the two groups. The animals were fed for 58 days to reach slaughter weight (approximately 24 kg BW). The live weight of lambs was noted initially and at five days' intervals until slaughtered. Feed intake, daily gain and feed conversion ratio were determined in a recent study (Barbera *et al.* 2018). Finally, fourteen animals (n=14) were randomly selected (seven lambs of each group) and slaughtered.

Analytical methods of feedstuffs

Analyses of the fodder provided (leaves and pseudostems of banana, commercial diets, and rye-grass) were calculated according to those described in AOAC (2003). *In vitro* digestibility of organic matter (IVOMD) was determined using the technique developed by Van Soest *et al.* (1966), following the modification by Ankom Technology Corporation, and digestible energy (DE) was estimated at 0.0185 x IVOMD (NRC 1988).

Slaughter and carcass evaluations

After 58 days growing trial, the slaughter weight was 24 kg ± 1.0 kg live body weight (LWT). The lambs were slaughtered in the experimental slaughterhouse available in the College of Veterinary Medicine of Las Palmas de Gran Canaria University.

Carcass characteristics

After the slaughter, bleeding, skinning, and evisceration of the carcasses were done and the carcass was located in a room at 5ºC, during 24 h.

After 24 h slaughter, the carcasses were sagittally cut with an electric saw. Then, the left semi-carcass was butchered and left back to be dissected for the estimation of the carcass regional and tissue composition, following the methodology described by Colomer-Rocher *et al*. (1987).

After that, these carcasses were divided into five parts: cervical area, shoulder area, ribs (section between the 1st and 12th thoracic vertebrae), loin (section between the 1st and 6th lumbar vertebra) and leg (section between the last lumbar and the first sacral vertebra). The five cuts were weighed and added to obtain the weight of the cold half-carcass.

For tissue assessment, subcutaneous fat and intermuscular fat, muscles, bones, and other structures, such as lymph nodes, tendons, vessels, and nerves, were pulled apart and weighed individually to be expressed as a percentage relative to each cut.

The experiments described in this study meet requirements of the European Union Council (2010/63/EU) for animal experimentation.

Meat quality: muscle pH and color parameters

The muscle pH and the color were measured immediately after slaughter (pH_0, L_0, $Chroma_0$, Hue_0) and 24 h later (pH_1, L_1, $Chroma_1$, Hue_1) using the muscles *Longissimus thoracis et lumborum* and *semimembranosus*. The pH was performed with an electronic pH-meter equipped with a combined pH surface electrode (Model MP 220, Mettler Toledo, USA), and the results were averaged and recorded. The meat color was measured in 5.0-cm-thick steaks between the 12th and 13th ribs using Minolta Model CR-300 chromameter.

Statistical study

The information obtained from the carcass and meat quality traits were subjected to analysis of variance. Statistical analysis was based on mean comparison using the LSD test, with a minimum of $P < 0.05$ for statistical significance (SAS 2000).

Results

Carcass characteristics

Parameters related to regional and tissue composition of the carcasses are summarized in Table 2. No statistical differences ($P < 0.05$) were observed on composition of the carcasses (shoulder, breast, leg, neck, ribs, and loin) and tissue composition (bone, muscle, and fat) between animals receiving banana by-products and conventional diets.

Total fat ranged from 10.2% on lambs fed banana by-products to 10.8% from conventional diet; the subcutaneous fat contents (6.8 and 7.0%) were similar in both groups, whereas the inter-muscle fat (3.1 and 3.9%) and total fat (10.2 and 10.8%) percentage was higher in the conventional diet but not significantly different ($P < 0.05$).

Meat quality: muscle pH and color parameters

Regarding the meat quality, the muscle pH (Table 3) showed similar levels independently of the diet received ($P < 0.05$); the muscle pH for the two groups analyzed was in the range of 5.5 (average initial pH_0) to 6.5 (average pH 24 h after slaughter pH_1) in the *Longissimus toracis et lumborum* muscle, and in the *semimembranosus* muscle as well.

The meat color results (Table 3) showed that lightness (L*) was between 33.8 and 41.4; Chroma between 15.8 and 26.0 and Hue between 11.5 and 28.0 being higher on *semimembranosus* muscle 24 h after slaughter (L_1; $Chroma_1$; Hue_1).

Nevertheless, the meat color (Table 3) was affected by the diet ingested but only showed a significant difference ($P < 0.05$) at the time of slaughter ($Chroma_0$; Hue_0) and 24 h after slaughter (lightness L_1; $Chroma_1$) in the *Longissimus toracis et lumborum* muscle, as *semimembranosus* muscle color did not show color differences Thus, luminosity coordinate ($Chroma_0$; lightness L_1; $Chroma_1$) was lower in the banana by-products group compare to a conventional diet.

Discussion

The nutritive value of the experimental diet used in this study seems to be promising as forage for the livestock, as values shown in Table 1 determined by (Barbera *et al.* 2018) in a previous study and values found by González-García *et al.* (2008) and Pieltain *et al.* (1999).

Table 1: Ingredients, chemical composition and nutritive characteristics of the ingredients of the diets*

	Banana diet	Conventional diet	
Ingredients (%)			
Rye-grass	0	35	
Banana pseudostems	18	0	
Banana leave	18	0	
Corn	35	35	
Barley	14	15	
Soybean meal	10	10	
Minerals premix	0.5	0.5	
	BBP	RGHAY	CON
Chemical composition			
Dry matter (DM, g/kg fresh weight)	138	914	898
Chemical composition of DM (g/kg DM)			
Crude Protein	99.5	100	140
Estimated digestible energy (MJ/kg DM)	10.8	11.1	13.5

BBP: by-products banana plant; RGHAY: Ray-Grass hay; CON: concentrate. * Barbera *et al.* (2018)

Table 2: Effect of the assessed diets on the carcass regional and tissue composition (% weight semi-carcass)

% Weight (semi-carcass)	Type of diet		
	Banana by-products	Conventional	*P*
Shoulder	16.9 ± 0.97	17.1 ± 1.14	NS
Breast	10.4 ± 1.20	10.7 ±1.16	NS
Leg (pelvic limb)	32.3 ± 2.17	32.9 ± 2.02	NS
Neck	8.4 ± 1.12	8.0 ± 1.35	NS
Anterior Ribs	7.5 ± 0.78	7.3 ± 1.13	NS
Ribs + Loin	19.0 ± 0.76	19.2 ± 1.18	NS
Bone	24.8± 3.45	23.5 ± 1.17	NS
Muscle	64.3 ± 3.44	65.2 ± 1.94	NS
Subcutaneous fat	7.0 ± 3.49	6.8 ± 1.74	NS
Inter-muscle fat	3.1 ± 4.59	3.9 ± 1.05	NS
Total fat	10.2 ± 3.80	10.8 ± 1.80	NS
Waste material	0.74 ± 0.38	0.69 ± 0.14	NS

NS: No statistical significance $P < 0.05$

Table 3: Effect of the assessed diets on the muscle pH and color

	Type of diet		
	Banana by-products	Conventional	*P*
Longissimus thoracis et lumborum			NS
pH_0	6.5 ± 0.12	6.4 ± 0.2	NS
pH_1	5.5 ± 0.07	5.5 ± 0.08	NS
L_0	33.8 ± 1.86	34.2 ± 0.84	NS
$Chroma_0$	15.8 ± 1.31	17.5 ± 2.14	0.081
Hue_0	13.4 ± 1.44	11.5 ± 0.95	0.047
L_1	36.6 ± 3.90	41.4 ± 2.94	0.021
$Chroma_1$	21.5 ± 1.10	26.0 ± 3.79	0.043
Hue_1	27.7 ± 2.91	28.4 ±2.60	NS
Semimembranosus			
pH_0	6.4 ± 0.27	6.4 ± 0.22	NS
pH_1	5.5 ± 0.05	5.6 ± 0.09	NS
L_0	36.0 ± 1.99	35.8 ± 1.74	NS
$Chroma_0$	17.6 ± 0.81	17.3 ± 0.83	NS
Hue_0	14.2 ± 1.47	12.8 ± 1.05	NS
L_1	38.33 ± 1.43	36.6 ± 1.91	NS
$Chroma_1$	21.7 ± 2.13	21.7 ± 3.47	NS
Hue_1	26.7 ± 9.45	28.9 ±7.49	NS

NS: Non statistical significant $P < 0.05$

pH_0: pH at the time of slaughter; pH_1: pH 24 h after slaughter; L_0: lightness at the time of slaughter; $Chroma_0$:at the time of slaughter; Hue_0:at the time of slaughter; L_1: lightness 24 h after slaughter; $Chroma_1$: after 24 of slaughter; Hue_1: after 24 h after slaughter

Means slaughter weight (24. 3 ± 1.0 kg) was gained in 58 days, reach in both cases in less time than the results described by Marie-Magdeleine *et al.* (2009) which Ovin Martinik sheep, where lambs spend 90 days to reach 22–24 kg feeding also with banana by-products.

Values of slaughter and carcass weights were similar to values reported for tropical-sheep fed low-energy diets (Mahgoub *et al.* 2000; Santana-Andrade *et al.* 2017). Shoulder, breast, leg, neck, anterior ribs, and ribs + loin were not significantly affected by banana by-product based diet as compared to a conventional diet, whereas the percentage of shoulder weight on the carcass was lower than that described by Marie-Magdeleine *et al.* (2009) using similar experimental diet. Additionally, (Santana-Andrade *et al*. 2017) reported, with the similar breed and breeding conditions, a low percentage of the neck weight, a highs percentage of the shoulder weight and a similar percentage of the legs weight on the regional composition of the carcasses of Santa Ines hair sheep breed.

On the other hand, the animals belonging to the banana by-product-based diet did not show variations concerning fat content or other tissue characteristics in the back muscles compared to the conventional-diet group. Total fat ranged from 10.2% on lambs-fed banana by-products to 10.8% from the conventional diet. Although animals feeding rye-grass hay on a conventional diet ingested a higher level of digestible energy (11.1 MJ/kg DE) compared with banana by-product groups (10.8 MJ/kg DE), the subcutaneous fat contents (6.8 and 7.0%) were similar in both groups whereas the inter-muscle fat (3.1 and 3.9%) and total fat (10.2 and 10.8%) percentage was higher in the conventional diet but not significantly different ($P < 0.05$). Despite all, it seems necessary to evaluate the fatty acid profiles in order to estimate the quality of the fat content in the carcass. Combellas (1982) studied the tissue composition for similar sheep breeds (West African) and similar slaughter weight (24 ± 1.0 kg.), reporting a lesser percentage of muscle tissue and bones but the higher fat content of the carcass. However, when the West African is raised in crossbreeding with more productive breeds like Dorset Horn, the tissue composition is similar to those observed by Combellas (1989).

Regarding the meat quality, the muscle pH (Table 3) showed similar levels independently of the diet received, not showing significant differences between different diets ($P < 0.05$); the muscle pH for the different groups was in the range of 5.5 (initial $pH_{0)}$ to 6.5 (24 h after slaughter pH_1) in the *Longissimus toracis et lumborum* muscle and in the *semimembranosus* muscle as well. These pH results were expected given the low difference in energy intake levels by both groups, as the lack of nourishment is the main reason for elevated pH in meats (Priolo *et al.* 2001).

Similar results were reported by (Al-Owaimer *et al*. 2008) that found that muscle pH was in the range of 5.6 to 5.7 of sheep fed *Atriplex*. Andrade *et al*. (2015) also reported an average of 6.24 initial pH (pH_0) and an average of 5.5, 24 h after slaughter (pH_1) of the meat from Santa Inês hair breed lambs. The values found are normal and are indicative of meat quality, higher values can affect other characteristics such as color.

Nevertheless, the color of the meat of the lambs from this study can be considered light, as their lightness (L*) was between 33.8 and 41.4 and lightness values for sheep are considered to vary from 30.0 to 49.5 (Leão *et al*. 2012). The meat color was affected by the diet ingested but only was significantly different ($P < 0.05$) in the *Longissimus toracis et lumborum* muscle, as *semimembranosus* did not show color differences. Otherwise, luminosity coordinate ($Chroma_0$; lightness L_1; $Chroma_1$) was lower in the banana by-products group, in agreement with other studies described by Morbidini *et al.* (2001) but opposite to results reported by Priolo *et al.* (2001), which found that meat from ruminants fed on pasture is darker than meat from animals fed concentrates. As an example, tannin-containing feeds produce opposite effects on meat, depending on the number of condensed tannins eaten by the sheep; meat color is paler when condensed tannins are showed in the diet (Vasta *et al.* 2008); further studies would be necessary to determine the condensed tannins contents on banana by–products.

Conclusion

The inclusion of banana by-products in a diet for growing Canary hair sheep breed lambs would not grossly alter the carcass quality, at least from the assessed parameters. Banana by-products as feed resources can preserve sheep productivity and meat quality. Nonetheless, diets supplemented with banana by-products should be carefully formulated, in order to guarantee to ruminants their nutritional requirements. Finally, it is important to emphasize that mixed-farming systems can improve the possibilities of better recycling of nutrients within systems, limiting expensive feeding inputs, and safeguarding the biodiversity of agricultural ecosystems by taking advantage of manure of the animals and by-products waste of crops.

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Author contributions

MRV designed the investigation, interpreted the results and wrote the manuscript. SA and VN carried out the growth trial and the analysis of the carcasses characteristics.SA, EP and ES performed the statistical analysis and analysed the data. JRJ helped performed analysis and co-wrote the paper.

Conflicts of Interest

All authors declare no conflicts of interest

Data Availability

The data generated during the current study are available from the corresponding author on reasonable request.

Ethics Approval

The experiments described in this study meet requirements of the European Union Council (2010/63/EU) for animal experimentation.

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