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Carcase and meat quality of Blanca Andaluza kids fed exclusively with milk from their dams under organic and conventional grazing-based management systems

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ABSTRACT

The number of organic farms is growing, but switching from conventional to organic production requires farms continue to produce high quality products. This study compares the carcass and meat quality of Blanca Andaluza goat suckling kids raised under organic and conventional grazing-based stock raising production systems. Twenty-four twin kids (12 males, 12 females) were selected from representative farms of each system. Body weight, dressing percentage, carcass linear measurements, non-carcass components, primary carcass and minor cuts, tissue composition, chemical composition and rheological variables, pH and colorimetric variables, were examined. No significant differences were seen between the production systems or sex with respect to most of the variables studied. However, some non-carcass components and colorimetric variables were affected, with the organic kids' meat returning lower values for lightness, yellow index, chroma and Hue angle. Indeed, some of the meat colour variables examined easily discriminated between the animals raised under the different production systems. These results show that conventional grazing-based farms raising these goats could easily turn to organic production without carcass or meat quality being affected.

HIGHLIGHTS

- Organic farms are growing in number.
- The transformation to organic kid-raising is easy, with meat quality unaffected.
- These results are of interest with respect to the viability of conventional goat farms.

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Introduction

Organic production systems should contribute towards a balance being struck between agriculture and the natural environment, seek sustainable agricultural development, minimise pollution, show respect for animal well-being, avoid the systematic use of chemicals and make no use of genetically modified organisms. Organic production has grown rapidly in the European Union over recent years, with Spain in first place in terms of the amount of land devoted to organic cultivation. Interest in the preservation of native breeds, raised under extensive or semi-extensive grazing regimens, is also becoming of increasing

interest to Spanish farmers. Many of these breeds, such as the Blanca Andaluza goat (a meat breed), are considered endangered according to the Official Catalogue of Spanish Livestock Breeds (BOE 2008). Farms that raise Blanca Andaluza goats generally aim to send kids for slaughter when they reach a body-weight of 7–9 kg.

Converting conventionally managed Blanca Andaluza farms to organic production should be straightforward given these animals' resistance to disease and their ability to adapt to the rustic environment and nutritional resources available in the mountainous areas of Andalusia (southern Spain) from

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where the breed comes. Indeed, other authors concur that the management of mountain goat systems, which are largely grazing-based (Ruiz et al. 2008), ought to be easily transformable to organic production (Mena et al. 2009). The possibility of such a transformation, however, requires that a farm's technical and economic viability as an organic operation be assessed. The quality of its products must also be examined to be sure that quality is maintained. Thus, the aim of the present work was to compare the carcass and meat quality of Blanca Andaluza goat suckling kids (both sexes) raised under conventional and organic and grazing-based production systems.

Materials and methods

Study area, experimental farms and kids

This work was performed in the Sierra de Huelva (Hinojales, Andalusia, Spain). All the goats studied were of the Blanca Andaluza breed. Currently, there are 20 organic and 21 conventional farms raising this breed (Blanca Andaluza Breeders' Association, unpublished data). One representative farm operating under each of these management systems was selected (the organic farm was certified as such under Regulation (EC) No 834/2007 of 28 June 2007). Twenty-four October-born twin goat kids (12 males and 12 females) were selected from each farm; all were fed entirely on their mothers' milk. The dams were raised similarly under semi-extensive conditions based on the grazing of natural pasture (pasture is available year-round), but while lactating were provided a supplementary feed concentrate (for details see De la Vega et al. 2013).

Slaughter and post-slaughter manipulation

All goat kids were slaughtered at a body weight of 7.75 ± 0.11 kg [and a farm live weight (FLM) of

8.26 ± 0.11 kg] at the San Juan del Puerto (Huelva, Spain) slaughterhouse, according to current EU regulations (Council Regulation (EC) N° 1099/2009). The carcasses were kept in a chilling room at 4 °C for 24 h and then split down the dorsal midline. The left half of each carcass was removed according to the procedure of Colomer-Rocher et al. (1987) and sent under refrigeration to a receiving laboratory.

Carcass quality

Farm live weight was recorded on the farms. Slaughter live weight (SLW) was recorded immediately prior to slaughter. Hot carcass weight (HCW) and the weight of the non-carcass components (Table 1) were recorded after slaughter. The gastrointestinal content was determined as the difference between the full and empty gastrointestinal tract. The tail, kidneys, pelvic fat and testes were retained in-carcass. After chilling (24 h at 4 °C), the cold carcass weight (CCW) was recorded and the empty body weight (EBW) calculated by subtracting the weight of the gastrointestinal contents from the SLW. The slaughter dressing percentage (SDP) was calculated as $100 \times (\text{HCW}/\text{SLW})$.

Carcass linear measurements were taken based on standard protocols (Palsson and Verges 1952; Boccad et al. 1958); these included internal carcass length (L), external carcass length (K), leg length (F), buttock width (G), buttock perimeter (BG), chest depth (Th), thorax width (Wr) and thoracic perimeter (PT).

After chilling, the left half of the carcass was weighed and dissected into five prime cuts (shoulder, flank, neck, ribs and long leg) according to Colomer-Rocher et al. (1987). Minor cuts (tail, kidney, kidney fat and pelvic fat) were removed before jointing and weighed. All cuts were vacuum packed and frozen at -20 °C until analysis, except for the ribs which were chilled before further processing. The shoulder, after

Table 1. Contribution of the weight of the kids' non-carcass components (means, expressed as a percentage of empty body weight) according to production system.

Item	Production system		SEM ^a	Significance ^b
	Conventional (n = 24)	Organic (n = 24)		
Blood	5.35	5.02	0.08	**
Skin	10.48	10.51	0.12	ns
Head	6.87	7.53	0.13	*
Feet	5.02	4.62	0.06	*
Heart	0.63	0.53	0.01	***
Lungs + trachea	1.74	1.78	0.04	ns
Liver	2.45	2.17	0.04	**
Spleen	0.27	0.24	0.01	*
Thymus	0.14	0.20	0.01	ns
Gastro intestinal tract	10.56	10.30	0.31	ns

^aStandard error of mean.

^bns = not significant ($p > .05$).

* $p < .05$; ** $p < .01$; *** $p < .001$.

thawing under chilled conditions (4 °C) for 24 h, was weighed and separated into dissectible intermuscular fat, subcutaneous fat, muscle, bone and other tissues.

Meat sampling and analysis

Twenty-four hours after slaughter, muscle colour was measured in the *longissimus* muscle (4/5th lumbar vertebra) directly on the muscle surface after removing any other connective tissue with a scalpel. All meat colour variables, i.e. lightness (L^*), red index (a^*), yellow index (b^*), saturation chroma (C) and the tone Hue (H°), were recorded according to the CIELAB colour system (CIE 1986) using a Minolta CM-2002 portable chromometer (results are the mean of three measurements). The pH was measured at the same time and place as the colour readings were taken, using a penetrating combined glass electrode attached to a Crison 25 pH metre.

After removing the rib cut and maintaining it chilled for 24 h, the *longissimus* muscle was dissected out. A sample from this muscle was taken and used to determine the water holding capacity (two repetitions for each sample) according to Alcalde et al. (2017), which was expressed as percentage expelled juice. The rest of the muscle was vacuum packed and frozen at -20°C until further analysis. After thawing under chilled conditions (4 °C) for 24 h, samples of this muscle were then used to determine their objective tenderness (performed in duplicate). Meat samples of similar shape (individually vacuum-packed in plastic bags) were submerged in a water bath at 75°C for 30 min. These cooked samples were then cooled to room temperature, removed from the bags and dried with filter paper. The Warner–Bratzler shear force (WBSF) was measured in at least three subsamples of 1 cm^2 cross sectional area, using a Stevens QTS 25 apparatus. Results were expressed in kg/cm^2 . The haem pigment content was measured according to Hornsey (1956) and expressed as mg myoglobin/g fresh muscle.

Once thawed, the shoulder was dissected to obtain the *triceps brachii* muscle. The chemical composition of this muscle was determined according to standard AOAC (1984) procedures (the moisture content by procedure 24003, the fat content by procedure 13032, the nitrogen content by procedure 2057, and the ash content by procedure 14066).

Statistical analysis

Differences in the values of the studied variables were assessed by ANOVA using the general linear model

(GLM) of the IBM SPSS Statistical Package for Windows v.22, taking into account production system and sex as fixed effects. Pairwise comparisons were performed using Tukey's honest significant difference test. Significance was set at $p < .05$. Finally, stepwise discriminant analysis involving all the analysed variables was used to discriminate between kids raised under the different systems.

Results and discussion

No significant differences were seen between the two production systems with respect to live animal and carcass weights, SDP ($49.47 \pm 0.66\%$) or carcass linear measurements (L, 38.91 ± 0.43 ; F, 23.89 ± 0.15 ; G, 8.71 ± 0.11 ; BG, 28.97 ± 0.48 ; Th, 17.05 ± 0.10 ; Wr, 9.83 ± 0.12 and PT, $42.75 \pm 0.22\text{ cm}$). The interaction *production system* \times *sex* had no significant effect on these variables either. The literature contains few comparisons between these two production systems with respect to carcass and kid meat quality. In one study with wider differences between the examined management systems, Cutrignelli et al. (2007) compared kids of the Cilentana breed that were housed in a stall and led to pasture. Following a different EU Regulation 1804/99 on organic farming to that of this work, and for a higher slaughter weight (12 kg), they no found effect of the production system on HCW, dressing percentages, linear carcass measurements or the tissue composition of the right hind leg. In contrast, Morbidini et al. (2001), who worked with the Italian Merino sheep breed (slaughtering at 75 days), observed differences between organically and conventionally raised animals' meat, with the former returning higher dressing percentages, better carcass quality, greater cooked meat tenderness and smaller drip losses. These authors attributed the lower warm dressing percentages of the conventionally produced carcasses to early weaning and transportation stress.

In this work, sex had no influence on the different weights recorded, or on the dressing percentages or carcass linear measurements. Peña et al. (2007) reported similar results when comparing Florida breed goat kids at a similar slaughter weight (7–8 kg).

Significant differences were seen between the production systems in terms of some of the non-carcass components examined (Table 1). Compared to the organic kids, the conventional kids showed a significantly higher percentage contribution to the EBW for the feet and spleen ($p < .05$), blood and liver ($p < .01$) and heart ($p < .001$), while the percentage contribution of the head was significantly lower ($p < .05$). No

significant differences were seen between the sexes with respect to these variables; neither did the interaction *production system* \times *sex* have any significant effect on them. The weight of the non-carcase components (liver, digestive tract and skin) is of interest given the large maintenance energy requirements of (at least) growing sheep (>50% of all requirements) (Ortigue 1991). The lighter weights recorded for the organically raised kids are consistent with a decreasing plan of protein or energy provision leading to a reduced metabolic rate and mass of metabolically active tissue (Wester et al. 1995). In this work, the supplementary feed provided to the dams on the organic farm was less copious than that provided on the conventional farm (see also De la Vega et al. 2013). However, the kids were fed exclusively on their mothers' milk; this is, therefore, the only factor that could have influenced the values recorded for the non-carcase components. The composition of the milk was not examined in this work: this should be taken into account in future studies. Interestingly, Cutrignelli et al. (2007) found no effect of production system on the weight of some of organs (skin, liver + spleen, kidney + bladder and empty digestive tract), even when the groups compared had very similar levels of nutrition. Finally, although sex is reported to be one of the main factors influencing the weight of non-carcase components (Warmington and Kirton 1990), it had no significant effect in this study. Similarly, Peña et al. (2007) reported no effect of sex on the weight of the blood, skin, head, feet or lung + trachea, heart, liver, spleen or thymus in kids of the Florida breed slaughtered at 7–8 kg and that were raised on milk replacer and housed indoors in group boxes at 20–25 °C with automatic feeders.

No significant differences were seen between the production systems or sex in terms of the percentage contribution of the prime (shoulder, 22.01 \pm 0.22; flank, 9.64 \pm 0.20; neck, 9.42 \pm 0.19; ribs, 21.36 \pm 0.34 and long leg, 32.24 \pm 0.20%) and minor cuts (tail, 0.54 \pm 0.02; kidney, 1.05 \pm 0.02; kidney fat, 1.74 \pm 0.20 and pelvic fat, 0.30 \pm 0.04%) to the weight of the left half-carcase.

The tissue composition of the shoulder (intermuscular fat, 8.17 \pm 0.63; subcutaneous fat, 3.65 \pm 0.33; muscle, 57.62 \pm 0.59; bone, 25.74 \pm 0.42; and the other tissues, 4.81 \pm 0.22%) was affected by neither management system nor sex.

Neither the production system nor sex affected the chemical composition of the *triceps brachii* muscle (moisture, 73.05 \pm 0.35%; ashes, 4.90 \pm 0.08; fat, 7.90 \pm 0.35; protein, 87.34 \pm 0.56% DM), nor the values

for WBSF (5.59 \pm 0.27 kg/cm²), WHC (17.49 \pm 0.46%) nor the myoglobin content (0.63 \pm 0.14 mg/g) of the *longissimus* muscle. The interaction *production system* \times *sex* had no significant effect either.

The pH (6.3 \pm 0.05) was unaffected by production system or sex, or their interaction. In agreement with Zurita Herrera et al. (2012), who studied Murciano-Granadina kids, the pH was not affected by either the production system or sex. Similar results have been reported by other authors who examined kids of a similar slaughter weight (Caputi Jambrenghi et al. 2007; Bonvillani et al. 2010).

The lack of differences between the production systems with respect to the variables mentioned in the preceding four paragraphs is probably explained by the fact that, in both systems, the dams were raised under similar semi-extensive conditions based on the grazing of natural pasture. As a consequence, the provision of concentrate was insufficient to modify the carcase and meat quality.

Neither sex nor the interaction *production system* \times *sex* had any influence on muscle colour. The lack of effect of sex in this work might be explained by the fact that the kids were slaughtered at a mean body-weight of just 7.75 kg, when any possible sexual dimorphism might not yet have appeared. Nevertheless, Bonvillani et al. (2010), who worked with older and heavier kids (60–90 days old and 10.5–12 kg at slaughter), reported meat from males to return higher L* values and lower a* values than that of females. These differences could be partly due to female carcasses being cooled more slowly than those of the males.

Muscle colour (Table 2) was significantly affected by the production system ($p < .05$), with the conventionally raised kid meat returning higher L*, b*, chroma and Hue values than the organic meat; the a* value, however, was higher for the organic kid meat. In the discriminant analysis, the canonical discriminant functions correctly assigned 100% of the animals to the management system under which they were raised. More specifically, function 1 explained 100% of the total variance (Table 3), and according to the canonical structure matrix (data not shown) the variables showing the strongest correlation with this function were meat colour L* and b*, and percentage contribution of the heart to EBW. Meat colour is well known to influence consumer choice (Zervas and Tsiplakou 2011), and an animal's diet can strongly affect this variable (Priolo et al. 2001). L* and b* are closely related to the quantity and quality of intramuscular fat (Mancini and Hunt 2005; De Palo et al. 2012); fats of

Table 2. Meat colour at 24 h post-slaughter according to production system.

Variable ^a	Production system		SEM ^b	Significance
	Conventional (n = 24)	Organic (n = 24)		
L*	45.97	39.94	0.83	***
a*	7.62	8.83	0.27	*
b*	10.28	6.95	0.51	**
Chroma	13.02	11.63	0.35	*
Hue (°)	52.84	35.03	2.38	***

^aL*: luminosity; a*: red index; b*: yellowness index; chroma = $(a^{*2} + b^{*2})^{0.5}$; Hue (°) = $\tan^{-1}(b^*/a^*)$ expressed in degrees (CIE 1986).

^bStandard error of mean.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 3. Discriminant functions and classification matrix resulting from discriminant analysis.

Evaluating discriminant function							
Function	Eigenvalue	% Explained variance	Canonical correlation	Wilks' lambda	Chi-square	df ^a	Significance
1	12.97	100.00	0.96	0.07	109.40	9.00	***

Classification matrix: assignment (columns) against real data (rows)

Group	Predicted group (%)	
	Conventional	Organic
Conventional	100.00	0.00
Organic	0.00	100.00

^aDegrees of freedom.

*** $p < .001$.

different quality have different fatty acid compositions, which oxidise differently, and this has a strong influence on muscle colour (Emami et al. 2015). Differences detected in earlier work (De la Vega et al. 2013) with respect to the fatty acid composition of the *longissimus thoracis* muscle in the same kids as used in the present work (the percentages of C17:0, C17:1, C20:1, ARA, C22:2, DPA and DHA were higher in the organic kid meat than in the conventionally reared kid meat), might therefore explain the differences in the colour of the conventionally and organically produced kid meat. However, Emami et al. (2015) affirm that, as a function of a* and b*, the Hue value might provide more realistic information regarding meat browning than single colour values. In this work, the conventional meat had higher Hue values, and was therefore lighter.

Conclusions

These results reveal there to be few differences between the meat of the kids raised under the examined systems. However, the values of L* and b* easily discriminated between the animals raised under the different production systems. Goat farms that raise kids under conventional grazing-based management might easily switch to organic production with no lack of carcase or meat quality.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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