Straw for bedding and forage in fattening lambs: effects on fatty acid composition and sensory characteristics of the longissimus muscle

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A b s t r a c t

The effect of straw on the fatty acid composition and sensory aspects of the longissimus muscle was analysed in 24 entire Rasa Aragonesa male lambs (weaned at 45 days) housed for 28 days in two pens (0.90 m^2 per lamb, initial weight 17.7 ± 0.70 kg) until reaching 88 days of age. One group received wheat straw for bedding and forage, whilst the other group had none. Instrumental meat quality variables were similar in both treatments ($P > 0.05$). Lambs with straw bedding presented a higher proportion of C18:0, whereas lambs without straw presented a higher proportion of C15:0 and C17:1 ($P \leq 0.05$), which might indicate a ruminal change. Of the 11 sensory attributes evaluated, none were significantly affected by treatment ($P > 0.05$). However, overall liking tended to be higher for meat from the lambs with straw than without straw ($P = 0.09$). The results from this study suggest that the deprivation of wheat straw during the fattening period has a slight effect on the variables analysed and that the lack of straw does not negatively affect the meat quality.

Keywords: Rasa aragonesa; Bedding; Welfare; Meat quality

1. Introduction

In the Mediterranean region, the old traditional sheep produc-tion in pastoral systems has given way to more intensive schemes, which nowadays could be considered the conventional system. In Spain, most lambs are fattened within large flocks indoors called cooperative classification centres (CCs). In the most intensive sys-tem, lambs are fed indoors with ewe milk and a concentrate-based diet until weaning (45–50 days old) and then receive concentrate and straw at the CC until slaughter. One of the main outputs is the highly appreciated meat from light lambs, which are slaughtered at an age younger than 90 days old and 8.0–12.5 kg of carcass weight (Sa ñudo et al., 1996). This intensive scheme simplifies the process and reduces farm labour requirements whilst producing a more homogeneous product with reduced production costs. However, CCs have been reducing the use of straw, mainly due to its growing cost.

There are some practical disadvantages associated with the use of straw, as incompatibility with manure drainage systems (Tuyttens, 2005), require a high storage capacity and both bedding and lambs are dirt at the end of the fattening period (Teixeira et al., 2014b). On the other hand, besides providing fibre, straw promotes chewing activity and saliva flow, thus preventing the ruminal pH drop and some digestive disorders that normally occur when con-centrate diets are used (Faleiro et al., 2010). To solve some of these problems, Blanco et al. (2014) showed that straw can be included in a pellet. However, the provision of straw as bedding and for-age in animal production systems is also widely presumed to be beneficial for the welfare of the animals (Tuyttens, 2005; Teixeira et al., 2012) and thus could be reflected in the quality of the meat (Ferguson and Warner, 2008). Finishing animals in stressful inten-sive environments may experience excessive glycogenolysis in the muscle, resulting in impaired energy metabolism that may affect different meat quality indicators (Warriss et al., 1994). Straw can provide comfort and is a practical way to stimulate stabled animals (Fraser et al., 1991). Lambs without straw perform more stereotypi-cal behaviours, concentrating more on social relationships because of their barren physical environment (Teixeira et al., 2014a).

Even in ruminants, where a biohydrogenation of dietary fatty acids takes place and the dietary lipid content is lower than in monogastrics, nutritional factors can still affect the fatty acid com-position of the intramuscular fat (De Smet et al., 2004). Concentrate

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diets for ruminants can increase available soluble carbohydrates, resulting in lower ruminoreticular pH, which decreases hydro-genase activity, thus affecting fatty acid composition (Tove and Matrone, 1962). A review has shown that concentrate-only diets with no reported supply of straw presented the highest C18:1 per-centage and the lowest percentage of total saturated fatty acids (SFAs) in fat deposits of lambs compared to other diets richer in roughage (Bas and Morand-Fehr, 2000).

Few studies related to lamb production have evaluated the effect of straw as bedding and forage on meat quality. Teixeira et al. (2012) reported that the lack of straw does not increase stress levels to the point that it jeopardises productive performance and instru-mental meat quality variables, including pH, colour, texture, and cooking losses. Recently, Aguayo-Ulloa et al. (2014) investigated how environmental enrichment affects the fatty acid composition and sensory aspects of light lambs; however, feeder ramps with cereal straw were included in the enriched pens. The aim of our study was to evaluate the effect of wheat straw as bedding and forage on the fatty acid composition and sensory aspects of the M. longissimus of finishing light lambs.

2. Materials and methods

The study was carried out at the experimental farm of the Uni-versity of Zaragoza, Spain (latitude 41◦41 N), during the autumn of 2012. The area is located in the Ebro River depression, characterised by a dry Mediterranean climate with an average annual temper-ature of 15 ◦C and 317 mm average annual rainfall. The Animal Experimentation Ethics Committee of the University of Zaragoza approved the experimental protocol.

2.1. Study description

Twenty-four healthy Rasa Aragonesa single male lambs (weaned at 45 days) with an average live weight of 17.75 (±0.7) kg that were 60 days old at the start of the experiment were used to analyse the effect of wheat straw on instrumental meat quality variables, which are described in detail by Teixeira et al. (2012), and on the fatty acid composition and sensory aspects of the longissimus muscle. Two groups of 12 lambs were housed in 2.9 × 3.7 m pens (stock-ing density 0.90 m2 per lamb) and fattened for 28 days, with one group receiving wheat straw for bedding and forage and the other group receiving none (maintained in barrier pen). The pen with straw was 10 cm deep at the beginning of the trial and straw was added once a week during the trail. Straw as forage was provided ad libitum. Both groups were fed ad libitum with pellet concentrate in a feeder, and were also provided fresh water. The commercial con-centrate (Ovirum High Energy(r)) contained barley, corn, wheat, vegetable fat, soya tort, sugar cane molasses, calcium carbonate, sodium chloride, and a vitamin mineral corrector (18% crude pro-tein and 3.5 Mcal metabolisable energy/kg dry matter). The wheat straw contained 91.33% dry matter, 93.93% organic matter, and 34% crude protein. All lambs were transported and slaughtered the same day, and pre-slaughter conditions were standardised.

The animals were slaughtered within the weight range of the Ternasco-type category (Sa ˜nudo et al., 1996) at a European Union licensed abattoir located in the city of Zaragoza. After overnight lairage in pens with cemented walls and non-skid floors (water available but no food), the lambs were electrically stunned and dressed using standard commercial procedures. After slaughter, the carcasses were stored in cold rooms at 2 ◦C for 24 h. Then, the left rack from T1 to L6 vertebrae (normalised cut for lambs by Colomer-Rocher et al., 1988) was removed and trans-ferred to the meat laboratory at the Faculty of Veterinary Medicine of the University of Zaragoza, without disrupting the cold chain. The M. longissimus was excised and sampled. The methodology used to analyse carcass traits and instrumental meat quality variables is described in detail by Teixeira et al. (2012). The section from T6 to T10 was vacuum-packed, frozen, and stored at −20 ◦C to assess fatty acid composition, and the section from T13 to L6 was used for sensory evaluation.

2.2. Fatty acid composition

To determine the intramuscular fatty acid composition, the fat was extracted using the technique described by Bligh and Dyer (1959), based on chloroform-methanol extraction with BHT as an antioxidant and methylation using KOH in methanol. The methyl esters of fatty acids were analysed by gas chromatography using an HP 6890 gas chromatograph with a capillary column SP 2380 (100 m× 0.25 × 0.20 mm). Identification was performed according to SIGMA(r) standards (Carrilho et al., 2009).

2.3. Sensory evaluation

The section of M. longissimus was vacuum-packaged, aged for 72 h at 4 °C, and then frozen and stored at −20 °C until analysis. Sensory analyses were performed in a tasting room with individual booths following the normative ISO 8586-1:1993. Two tasting ses-sions were held with a trained eight-member sensory panel, with two samples per plate. To avoid the possible effects of the order of presentation and first-order carry-over effects, the samples were presented to panellists in different orders (MacFie et al., 1989). Samples were thawed in tap water at 15–17 °C for 2 h. Then, the meat was wrapped in aluminium foil and cooked in a double plate grill (SAMMIC P8D-2, Azkoitia, Gipuzkoa, Spain) at 200 °C until the internal temperature reached 70 °C, monitored by an internal thermocouple (JENWAY 2000 Stone, Staffordshire, UK). External connective tissue and fat were trimmed, and each sample was cut into eight portions. Each portion was wrapped in aluminium foil, identified, and stored in a warm cabinet at 50 °C until it was served to the sensory panel. The time between cooking and serving was approximately 10 min. To avoid differences in meat colour, sam-ples were served under red light. Each treatment was analysed and compared 11 times for each panel member (88 taster-samples per treatment). The sensory profile and specific training were devel-oped in an additional previous session using samples from animals on each treatment. The analysis was based on 10 sensory descrip-tors (Table 1) that used a 10 semi-structured point scale (0 = low, 10 = high), which was transformed into a numerical scale (0–10) for the statistical analysis. Additionally, overall acceptability was assessed.

2.4. Statistical analysis

Data were tested for normality before analysis using the Shapiro–Wilk test and examination of the normal plot. The effect of straw on the fatty acid composition and sensory analysis was assessed by the GLM procedure of SAS (SAS Institute Inc., 1988). For the fatty acid composition, treatment was included as the fixed effect, fatty acid traits as the dependent variables, and cold car-cass weight as the co-variable. For the sensory data, treatment was included as the fixed effect and sensory attributes as the dependent variable. Finally, we also tested the multiple regressions between overall liking and the other sensorial parameters using a stepwise methodology from SAS, considering the overall data and each treat-ment. A probability of $P \leq 0.05$ values was considered statistically significant, and a P value between 0.05 and 0.10 was considered as a trend toward significance. The results are reported as least square means (±SEM).

3. Results

Productive performance and instrumental meat quality mea-surements were not affected by treatment (Table 2), as described in detail by Teixeira et al. (2012). There were only slight differ-ences in fatty acid composition and a tendency for a statistical difference in sensory evaluation between treatments. Both groups demonstrated acceptable technical performance.

3.1. Fatty acid composition

The percentage of intramuscular fatty acid compositions (±SEM) is shown in Table 3. Intramuscular fatness was similar between treatments. The major SFAs were C16:0 (palmitic acid) and C18:0 (stearic acid) in both treatments. Lambs with straw tended to have more SFAs than the lambs without straw ($P = 0.09$). The per-centage of palmitic acid was similar in both treatments; however, lambs in straw bedding presented a higher percentage of the C18:0 (stearic acid) than lambs without straw ($P \leq 0.05$). In the opposite way, lambs without straw presented a higher percentage of C15:0 than lambs with straw ($P \leq 0.05$).

The most important monounsaturated fatty acid (MUFA) was C18:1 n-9 (oleic acid) with a mean of 34.83% of the total fatty acids for both treatments. Lambs without straw tended to have more MUFAs than lambs with straw ($P = 0.06$). Although the percentage of C17:1 was small, this value was significantly lower in lambs with straw than in the other group ($P \leq 0.05$).

The highest percentages of polyunsaturated fatty acids (PUFAs) were C18:2 n-6 (linolenic acid) and C20:4 n-6 (arachidonic acid) with a mean of 4.44% and 1.08% of total fatty acids in both

treatments. There were no significant differences in PUFA, PUFA:SFA ratio, or the n6:n3 PUFA ratio between treatments ($P \geq 0.05$).

3.2. Sensory evaluation

The least square means (±SE) of the sensory meat quality variables are presented in Table 4. Of the 11 sensory attributes evaluated, none were significantly affected by treatment ($P \leq 0.05$). However, the overall liking tended to be higher for meat from the lambs with straw than without straw ($P = 0.09$).

A stepwise multiple regression analysis of the relationship between the overall liking of the meat and other sensory parame-ters is presented in Table 5. Overall liking was significantly related to several sensory parameters ($P \leq 0.05$), but with a different order between treatments in the set of associated variables. In general, juiciness and rancid flavour were the most powerful parameters related to overall liking ($P \leq 0.05$), and lamb odour tended to be associated with the overall liking ($P = 0.07$). Other variables were significantly related to overall liking, but not in the same order for each treatment. Tenderness was the most powerful parameter related to overall liking for the straw treatments ($P \leq 0.05$). Lamb odour and fat flavour were ranked the second and third in impor-tance for the straw treatment ($P \leq 0.05$); however, they were not important for the group without straw ($P > 0.05$). Metallic flavour (MF) was ranked first in importance for the group without straw ($P \leq 0.05$), while lamb flavour, oiliness, juiciness, and tenderness were moderately related to the overall liking for this treatment ($P \leq 0.05$). Oiliness and acid flavour tended to be associated with the overall liking for the straw and no-straw treatments, respectively ($P = 0.07$).

4. Discussion

The findings from this study show that the provision of straw as bedding and forage for fattening lambs has slight effects on the fatty acid composition and sensory aspects of the M. longis-simus. The lack of straw during the fattening period of lambs has a negative effect on animal welfare but does not affect productive performance, carcass traits, or instrumental meat quality variables (Teixeira et al., 2012). Aguayo-Ulloa et al. (2014) found that the provision of straw in combination with ramps during 35 days for lambs in similar conditions helped the lambs to adapt to the new environment during the fattening period, and the M. longissimus of those animals showed slight differences in the fatty acid profile and organoleptic perception but greater effects on performance, car-cass traits and instrumental meat quality variables. However, the authors designed their study to test the effects of a fully enriched environment, which included the combination of ramps and cereal straw, and, unfortunately, they did not individually evaluate the two elements. The ramps per se could stimulate the animals to per-form more exercise and, consequently, affect their physiological adaptation response compared to lambs in a barren environment.

In general, both treatments showed similar profiles of the most important SFAs and MUFAs to those found by Aguayo-Ulloa et al.(2014) and Sa ˜nudo et al. (2000), who used a similar type of lamb and production system. However, PUFAs in our study were lower than in these previous studies. It is difficult to explain the reason for such a reduction, as the three studies reared the lambs in simi-lar conditions and slaughtered them at similar ages. Moreover, the concentrate diets were the same in the present study and in the study of Aguayo-Ulloa et al. (2014). A lack of difference between treatments was expected since the percentage of intramuscular fat and carcass fattening score were similar in both conditions.

Although both treatments had similar percentages, total intra-muscular fat, and PUFAs, the lambs with straw tended to have more SFAs and less MUFAs than the lambs without straw. The ratio of polyunsaturated/saturated fatty acid (ratio PUFA:SFA) was similar in both treatments. The finding of a ratio near to 0.15 in both treat-ments is lower in comparison to the minimum ratio of 0.23 reported by Aguayo-Ulloa et al. (2014) and far from the recommendation for healthy meat, which is a ratio of 0.4 or more. Ruminant meats have a low ratio PUFA:SFA because of the hydrogenating action of the rumen microorganisms on dietary fatty acids (Enser et al., 1996).

Similarly to Aguayo-Ulloa et al. (2014), we found lower levels of C17:1 and higher levels of C18:0 in the lambs with straw, which could indicate some ruminal change. Furthermore, we also found a lower level of C15:0 in lambs with straw. The higher percentage of the odd fatty acids C15:0 and C17:1 found in our study in the no-straw diet could indicate an increased relative importance of amylolytic with respect to cellulolytic bacteria, as occurs in diets richer in concentrates compared to forage (Vlaeminck et al., 2006). Increasing crude fibre content in diets is also associated with an increase in C18:0 percentage and a decrease in C18:2 percentage (Enser et al., 1998; Bas and Morand-Fehr, 2000).

Within PUFAs, there were no differences between the two treat-ments. The percentages of the n-6 and n-3 PUFA were similar to those reported by Aguayo-Ulloa et al. (2014), and the ratio n-6:n-3 PUFA was much higher than that reported by Sa ñudo et al. (2000). Unfortunately, this ratio was much higher than those preferred on health grounds, which means a value of 4.0 or less (Department of Health, 1994).

There is a great interest in conjugated linoleic acids (CLAs), because they could be beneficial to health (Wood et al., 2004). CLAs are formed by the partial biohydrogenation of conjugated fatty acids, which are mainly affected by ruminal pH, the ratio for-age:concentrate feed, and the type and level of fatty acid intake (Ramírez-Retamal and Morales, 2014). The levels of CLAs were sim-ilar in both treatments in our study and higher than those reported by Aguayo-Ulloa et al. (2014).

The fatty acid composition of meat affects organoleptic attributes, especially flavour (Wood et al., 2004). Therefore, the lack of differences between treatments for the sensory variables was not a surprise, since there were few differences in fatty acid com-position and an absence of differences in the instrumental meat quality variables (Teixeira et al., 2012). On the other hand, the over-all liking was higher in lambs with straw than without straw. In the study performed by Aguayo-Ulloa et al. (2014), the lamb odour and grass odour intensities of the lambs in the full enriched pens (with straw and ramps) were higher than the controls. Similar to the findings of these authors, the lamb odour intensity was mod-erate in both treatments in our study, approaching the middle of the evaluation scale. Resconi et al. (2009) found that lamb flavour intensity was significantly correlated with the proportion of intra-muscular fat and subcutaneous fat. However, the intramuscular fat was not affected by treatment in our study (Teixeira et al., 2012) or Aguayo-Ulloa et al. (2014) study.

We did not find differences in tenderness between the treat-ments, but in studies of sensory quality, meat palatability is positively related to increased tenderness, juiciness, and flavour (Wood, 1990). The stepwise correlation analysis of the sensory meat quality variables showed that straw treatment was sig-nificantly related to tenderness, which could explain the slight preference of the panel for the meat from the straw treatment (e.g., higher overall liking, $P = 0.09$).

5. Conclusions

The results from this study suggest that the deprivation of wheat straw during the fattening period has a slight effect on the fatty acid profiles and sensory evaluation of the meat from light lambs. In fact, it is possible to confirm that the lack of straw does not negatively affect the meat quality, even though the welfare of the animals without straw can be compromised.

Conflict of interest

None.

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References

Aguayo-Ulloa, L., Pascual-Alonso, M., Campo, M., Olleta, J., Villarroel, M., Pizarro, D.,.Miranda-de la Lama, G., María, G., 2014. Effects of an enriched housing environment on sensory aspects and fatty-acid composition of the longissimus muscle of light-weight finished lambs. Meat Sci. 97, 490–496.

Bas, P., Morand-Fehr, P., 2000. Effect of nutritional factors on fatty acid composition of lamb fat deposits. Livest. Prod. Sci. 64, 61–79.

Blanco, C., Bodas, R., Prieto, N., Andres, S., Lopez, S., Giraldez, F.J., 2014. Concentrate plus ground barley straw pellets can replace conventional feeding systems for light fattening lambs. Small Rumin. Res. 116, 137–143.

Bligh, E.G., Dyer, W.J., 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Phys. 37, 911–917.

Carrilho, M.C., López, M., Campo, M.M., 2009. Effect of the fattening diet on the development of the fatty acid profile in rabbits from weaning. Meat Sci. 83, 88–95.

Colomer-Rocher, F., Delfa, R., Sierra, I., 1988. Método Normalizado Para El Estudio. De Los Caracteres Cuantitativos Y Cualitativos De Las Canales Ovinas Producidas En El Área Mediterránea Según Los Sistemas De Producción. Cuadernos INIA, Madrid, Espa ˜na, pp. 19–41.

De Smet, S., Raes, K., Demeyer, D., 2004. Meat fatty acid composition as affected by fatness and genetic factors: a review. Anim. Res. 53, 81–98.

Department of Health, Report on health and social subjects No. 46. Nutritional aspects of cardiovascular diseases. Her Majesty's Stationery Office London.1994.

Enser, M., Hallett, K., Hewitt, B., Fursey, G., Wood, J., 1996. Fatty acid content and composition of English beef, lamb and pork at retail. Meat Sci. 42, 443–456.

Enser, M., Hallett, K., Hewett, B., Fursey, G., Wood, J., 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 Sci. 49, 329–341.

Faleiro, A.G., Gonzalez, L.A., Blanch, M., Cavini, S., Castells, L., Ruiz de la Torre, J.L., Manteca, X., Calsamiglia, S., Ferret, A., 2010. Performance, ruminal changes, behaviour and welfare of growing heifers fed a concentrate diet with or without barley straw. Animal 5, 294–303.

Ferguson, D.M., Warner, R.D., 2008. Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants? Meat Sci. 80, 12–19.

Fraser, D., Phillips, P.A., Thompson, B.K., Tennessen, T., 1991. Effect of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 30, 307–318.

MacFie, H.J., Bratchell, N., Greenhoff, K., Vallis, L.V., 1989. Designs to balance the effect of order of presentation and first order carry over effects in hall tests. J. Sens. Stud. 4, 129–148.

Ramírez-Retamal, J., Morales, R., 2014. Influence of breed and feeding on the main quality characteristics of sheep carcass and meat: a review. Chil. J. Agric. Res. 74, 225–233.

Resconi, V., Campo, M., Furnols, M., Montossi, F., Sa ˜nudo, C., 2009. Sensory evaluation of castrated lambs finished on different proportions of pasture and concentrate feeding systems. Meat Sci. 83, 31–37.

Sa ˜nudo, C., Enser, M., Campo, M., Nute, G., Marıa, G., Sierra, I., Wood, J., 2000. Fatty acid composition and sensory characteristics of lamb carcasses from Britain and Spain. Meat Sci. 54, 339–346.carcass weight on instrumental and sensory lamb meat quality in intensive production systems. Meat Sci. 42, 195–202.

SAS Institute Inc., 1988. SAS/SAT User's guide: Statistics Analysis Institute, Cary, N.C., U.S.A.

Teixeira, D.L., Miranda-de la Lama, G.C., Villarroel, M., Escós, J., María, G.A., 2014a. Lack of straw during finishing affects individual and social lamb behavior. J.Vet. Behav. 9, 177–183.

Teixeira, D.L., Miranda-de la Lama, G.C., Villarroel, M., Garcia-Belenguer, S., Sa ˜nudo, ., Maria, G.A., 2012. Effect of straw on lamb welfare, production performance and meat quality during the finishing phase of fattening. Meat Sci. 92, 829–836.

Teixeira, D.L., Villarroel, M., María, G., 2014b. Assessment of different organicbeddings materials for fattening lamb. Small Ruminant Res. 119, 22–27.

Tove, S., Matrone, G., 1962. Effect of purified diets on the fatty acid composition of sheep tallow. J. Nutr. 76, 271–277.

Tuyttens, F.A.M., 2005. The importance of straw for pig and cattle welfare: a review. Appl. Anim. Behav. Sci. 92, 261–282.

Vlaeminck, B., Fievez, V., Demeyer, D., Dewhurst, R., 2006. Effect of forage: concentrate ratio on fatty acid composition of rumen bacteria isolated fromruminal and duodenal digesta. J. Dairy Sci. 89, 2668–2678.

Wood, J., 1990. Consequences for meat quality of reducing carcass fatness. In:

Wood, J., Fisher, A. (Eds.), Reducing Fat in Meat Animals. Elsevier Science Publishers Limited, London, pp. 344–397.
Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R., Enser, M., 2004. Effects of fatty acids on meat quality: a review. Meat Sci. 66, 21–32.