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Effect of weaning status on animal performance and meat quality of Rubia Gallega calves

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ABSTRACT

The effect of weaning calves at different ages (NW = not weaned, W5 = 5.5 months old and W2 = weaned after being born and then fed with natural Holstein Friesian milk until 2 months old), on animal performance and carcass and *Longissimus thoracis* muscle quality, was studied in 36 eight month-old Rubia Gallega calves. Feed ingestions, weight gains, slaughter (SW) and carcass weights (CW), carcass conformation and fat scores, and meat characteristics (24 hours *postmortem*): colour, pH, water holding capacity, chemical composition and texture (Warner Bratzler (WB) test, sensory panel), were studied. NW calves showed the highest SW and CW ($P<0.001$). Yellowness (b^*), redness (a^*) and chroma (C^*) were higher in NW than W2 calves ($P<0.05$). Shear firmness was higher in W2 than in NW and W5 veal. W2 veal was less elastic ($P<0.05$), tender ($P<0.05$) and juicy ($P<0.01$) than NW and W5 veal.

1. Introduction

Beef production in Galicia (Northwest of Spain), has been based on small family herds of the Rubia Gallega (RG) breed, the most important local beef breed in Spain with more than 50,000 animals registered in the herd book (ACRUGA, 2009). Recognition of the unique quality of Galician beef prompted the European Union (EU) to accept, in 1996, the Protected Geographical Indication (PGI) of Galician Veal "Ternera Gallega", which comprises pure RG and its crosses (CEE, 1996). The PGI "Ternera Gallega" classifies the animals as calves (98%) and yearling bulls (2%) depending on whether slaughter was earlier or later than ten months of age, respectively. Two classes of veal are commercialized, the "Normal" class calves (40%) suckle their mothers for at least two months and are weaned before being slaughtered, and the "Suprema" class calves (60%) suckle their mothers throughout their life (Ternera, Gallega, 2008).

Traditional production of not weaned young calves involves indoor management, maternal suckling and complementary concentrate-based diet (Monserrat, 1990). Due to the way of rearing, the higher polyunsaturated fatty acids/saturated fatty acids (P/S) ratio (Moreno et al., 2006) and the higher sensorial quality of meat from milk-fed animals (Sañudo et al., 1998), means veal from not weaned animals, "Suprema" class is more desirable than veal from weaned calves ("Normal" class) and fetches higher prices. However, the indoor finishing period makes maternal suckling difficult, consequently many farmers choose to wean calves before slaughter.

Within "Normal" class, the provision of artificial milk replacement and early weaning could show economic advantages, such as, calving interval shortening due to the elimination of a suckling-induced anoestrus (Wettemann, Lents, Ciccioli, White, & Rubio, 2003) and the use of RG milk to produce high quality cheeses due to its higher fat content and more suitable k-casein genotype than found in dairy cows milk (Viana, Fernandez, Iglesias, Sanchez, & Becerra, 2001).

Previous studies have reported that late- or not-weaning, results in significantly higher growth rates (Bispo et al., 2010) and fatter carcasses (Moreno et al., 2006; Vieira, García, Cerdeño, & Mantecón, 2005) in ruminants. Meat quality is also affected by the weaning management (Blanco, Villalba, Ripoll, Sauerwein, & Casasús, 2009; Oliete et al., 2006).

Organoleptic attributes of meat are important as indicators of quality; moreover, perceived eating quality and appearance determine consumers purchasing decisions, together with health related characteristics and branding (Banović, Grunert, Madalena Barreira, & Aguiar Fontes, 2009; Grunert, Bredahl, & Brunsø, 2004; Resurreccion, 2003). For instance, (1) meat and subcutaneous fat colour affects consumer acceptance and satisfaction (Dunne, Monahan, O'Mara, & Moloney, 2009; Grunert, 1997; Kramer, 1994; Robbins et al., 2003; Shackelford et al., 1992); (2) tenderness is appreciated by consumers (Dransfield, 1994; Koohmaraie, 1996; Robbins et al., 2003), a minimum is required to perceive the flavour adequately; (3) consumers prefer lean meat (Banović et al., 2009; Resurreccion, 2003; Robbins et al., 2003) and (4) water holding capacity (WHC) affects juiciness.

Since feeding affects parameters, such as ultimate pH, colour, cooking losses and tenderness (Andersen, Oksbjerg, Yung, & Therkildsen, 2005), growth patterns and carcass and meat quality of RG calves might respond differently to various weaning managements. Moreover, the PGI "Ternera

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Gallega" is of major importance in Spain regarding the commercialization of high quality meat, 48% is marketed in Galicia, 50% in other areas of Spain and 2% exported (Ternera, Gallega, 2008). Owing to the importance of "Ternera Gallega", the objectives of this study were to determine the effect of weaning status on animal performance, carcass quality and physical characteristics of the *Longissimus thoracis* (LT) from RG calves and establish that meat from non-weaned compared to weaned calves, justifies the higher prices of "Suprema" class meat. Variations of "Normal" class veal, induced by the artificial lactation system with early weaning were also studied.

2. Material and methods

2.1. Animals

Thirty six RG breed male calves from Mabegondo Research Centre herd were used. Calves were born in the autumn and were randomly assigned to three different weaning treatments (Fig. 1): 12 calves suckled their mothers until slaughter, they were not weaned (NW), 13 calves were weaned when they were 5.5 months old (W5) and 11 calves were weaned when they were two days old and then fed with natural Holstein Friesian milk until they were two months old (W2).

NW and W5 calves were reared with their mothers on pasture and were allowed to suck freely. They were housed indoors when they were 90 days old (Table 1). Animals were arranged in groups of five animals per pen, with concrete floor, straw bedding, good aeration, one drinking trough and one feeding trough. Calves were fed with a concentrate and hay *ad libitum* ration and suckled their mothers twice daily. Dams grazed on a rotational grazing system and were taken to the feed-lots for suckling.

W2 calves were separated from their mothers two days after birth, assuring a sufficient colostrums intake. They were arranged in the same conditions as described for NW and W5 groups. W2 animals were fed Holstein Friesian (HF) milk from Mabegondo Research Centre dairy farm, which was provided twice a day with buckets fitted with soft rubber nipples; they also received starter concentrate and hay *ad libitum*. When they were two months old, they were weaned and received the same concentrate and hay *ad libitum* as NW and W5 calves.

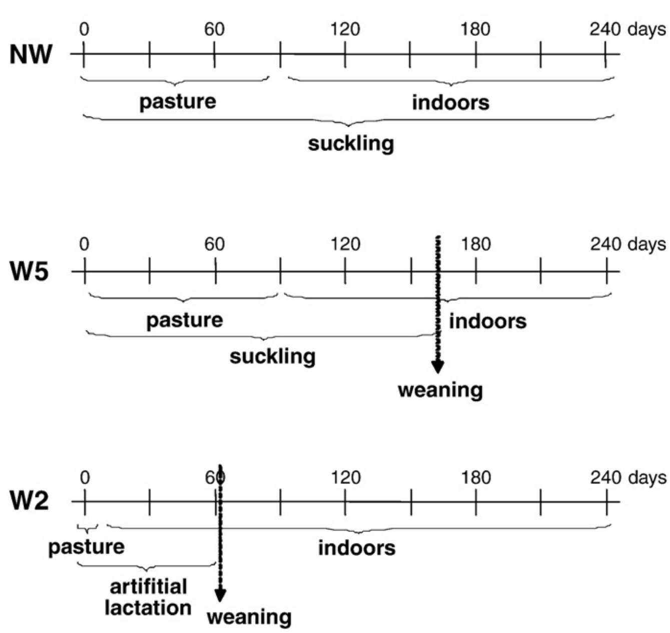

Fig. 1. Diagram of the three treatments studied in the experiment with Rubia Gallega calves: NW (not weaned), W5 (weaned when 5.5 months old) and W2 (weaned when they were two days old, and then fed natural Holstein Friesian milk for two months).

Table 1
Mean time (days) on pasture (PD) and indoors (ID); intakes of concentrate (CI), hay (HI) and milk (MI); average daily gain (ADG) during the finishing period and total daily gain (TADG) during the entire life of Rubia Gallega (RG) calves.

	NW	W5	W2	SEM	Sig
PD (d)	88.7^{a}	89.6^{a}	2^{b}		
ID (d)	151.1^{a}	147.3^{a}	235^{b}		
CI (kg DM/day)	3.03	3.95	5.21		
HI (kg DM/day)	1.1	1.2	0.9		
MI (kg/day)	6.32	6.14‡	0		
ADG (g/day)	1960^{a}	1703^{b}	2014^{a}	45.95	**
TADG (g/d)	1432^{a}	1269^{b}	1218^{b}	23.62	***

NW = not weaned; W5 = weaning at 5.5 months old; W2 = weaned when they were two days old, and then fed natural Holstein Friesian milk for two months; DM = dry matter.
a, b Treatments means in the same column bearing different letters are significantly different ($P<0.05$) under Duncan test.
NS, *, **, *** refer to the level of significance at $P>0.05$ (non-significance), $P<0.05$, $P<0.01$ and $P<0.001$, respectively.
‡ Before being weaned.

2.2. Pasture

Fourteen hectares of perennial ryegrass (*Lolium perenne*, 20 kg/ha) and white clover (*Trifolium repens*, 6 kg/ha) were offered to animals for grazing. In spring, animals grazed 50% of the total area, whilst the remaining 50% was kept for silage and hay production for complementary requirements in winter time. The sward was sown in the autumn and the fertilisation rate was 84, 84 and 44 kg/ha of P_2O_5, K_2O and N, respectively. Annual maintenance fertilisation was 80, 80 and 152 kg/ha of P_2O_5, K_2O and N, respectively, for the silage and hay area.

Animals were grazed on a rotational system, moving into a plot when the grass height was 15 cm; it was measured at 40 to 50 random points on each plot by a sward stick. Calves were rotated using an advanced grazing system, which allowed them to select the first grass.

Hay samples (0.5 kg) from each bale used to feed the calves, were taken to the dry matter (DM) laboratory (Mabegondo Research Centre) for analysis. Hay DM was determined in a drying oven at 80 °C for 17 h. Hay chemical composition (Table 2) was determined by infrared reflectance spectroscopy (NIRS), (Bran Luebe, Infra Analyzer 500, Germany).

Table 2
Mean chemical composition of hay and concentrate consumed by Rubia Gallega calves.

	Hay	Concentrate
DM (g/kg fresh matter)	853.8	874.8
OM (g/kg DM)	927.5	945.2
Ashes (g/kg DM)	72.5	54.8
CP (g/kg DM)	683.3	159.0
EE (g/kg DM)	nd	48.8
CF (g/kg DM)	322.7	46.3
NDF (g/kg DM)	647.3	nd
ADF (g/kg DM)	382.0	nd
ADL (g/kg DM)	nd	13.1
Ca (g/kg DM)	nd	7.6
TP (g/kg DM)	nd	4.9
UFL (/kg DM)	0.79	1.14
UFV (/kg DM)	0.72	1.12

DM = dry matter; OM = organic matter; CP = crude protein; EE = ether extract; CF = crude fibre; NDF = neutral-detergent fibre; ADF = acid-detergent fibre; ADL = acid-detergent lignin; Ca = Calcium; TP = total phosphorus.
UFL = net energy value expressed as "Unité Fourragère Lait"; UFV = net energy value expressed as "Unité Fourragère Viande" (Vermorel, 1978).
nd = not determined.

2.3. Management during the indoor period

The duration of the indoor period (ID) is shown in Table 1. Concentrate and hay intakes (Table 1) were estimated as the difference between the daily amounts offered and rejected by the animals in each pen. Milk intake during the finishing period (Table 1) was assumed to be the cow milk yield, which was estimated using the oxytocin and machine milking method (Le Du, Macdonald, & Peart, 1979) during the indoor period. The W2 group received 3 L and 1.5 L of HF milk in the morning and afternoon, respectively, for two months (before starting the finishing diet). At the same time, they were offered starter concentrate *ad libitum*, which was composed of a mixture of corn (34.9%), soybean flour (18.3%), residues from corn distillery (10.8%), barley (9.6%), wheat (7.3%), wheat bran (6.3%), soybean husk (4.4%), sugar cane molasses (3%), lucerne flour (2.7%), calcium carbonate (1.59%), palm tree oil (0.7%), sodium bicarbonate (0.52%), sodium chloride (0.34%) and monocalcium phosphate (0.25%). The finishing concentrate used in all experimental groups was composed of corn flour (38%), corn gluten (17%), soybean flour 44% (10.5%), wheat bran (10%), wheat flour (8%), dried residues from wheat distillery (5.5%), barley flour (5%), calcium soaps of palm oil (2%), sugar cane molasses (1%), calcium carbonate (0.9%), sodium bicarbonate (0.7%), palm oil (>90% hydrogenated) (0.5%), sodium chloride (0.5%) and calcium phosphate (0.07%). This ration was supplemented with vitamin A (8000 IU/kg), vitamin D3 (2500 IU/kg), vitamin E (20 mg/kg), copper (15 mg/kg) and butyl-hydroxytoluene (0.3 mg/kg). Hay offered to calves was composed of 77% perennial ryegrass and 23% white clover.

Chemical composition of the concentrate (Table 2) was determined by NIRS. RG and Holstein Friesian milk composition, determined by infrared scan (Milkoscan, FT6000, FOSS ELECTRIC, Denmark), and on the basis of 100 mL contained 3.8 g and 3.6 g of crude fat, 4.0 g and 2.9 g of crude protein and 4.8 g and 4.7 g of lactose, respectively.

2.4. Veterinary treatments

Calves were not subjected to any veterinary treatment. Dams were vaccinated three weeks before calving, against rotavirus, coronavirus and enteropathogenic *E. Coli*, to prevent diarrhoeas in their calves. At the beginning of winter, dams were also wormed with ivermectin 1%, for protection against gastrointestinal round worms, lung worms, *Hypoderma* spp., mites and lice.

2.5. Carcass recordings and sampling procedures

Animals were weighed before being transported to a commercial abattoir sited 4 km away from the Research Centre. They were slaughtered within two hours of arrival. CW was recorded immediately after slaughter (Table 3). A licensed technician graded carcasses for fat and conformation scores according to the European beef grading system (CEE, 1991). Carcasses were classified using the SEUROP classification scales for CS (P poor, O fair, R good, U very good, E excellent, and S superior) and for the fat cover classification (1 low; 2 slight; 3 average; 4 high; and 5 very high). Numbers from 1 to 18 and from 1 to 15 were given to the different levels of CS and FS, respectively, in order to perform the statistical analysis (Table 3). After slaughtering, carcasses were hung by the Achilles tendon and were chilled at 2 °C for 24 h until sampling. Loin was removed from the left half carcass between the 5th and the 10th ribs. Loin pieces were boned in the abattoir and taken to the laboratory where the *Longissimus thoracis* (LT) muscle was isolated, this muscle being the reference for most studies. LT was cut into steaks of different thicknesses depending on the analyses they were going to be used for. Two 1.5 cm thick steaks for press loss and drip loss (WHC) analyses, several 2.5 cm thick steaks to measure pH, colour, chemical composition, cooking loss (WHC), Warner Bratzler (WB) test and one 2 cm thick steak for sensory analysis. The sensory analysis steaks were vacuum-sealed (97%) (TECNOTRIP model EV-15-1-D) and frozen at −18 °C. A sample of subcutaneous fat, from the loin area, was also collected.

Table 3
Least-square means of slaughter age (SA), slaughter weight (SW), carcass weight (CW), carcass yield (CY), carcass fat score (FS) and carcass conformation score (CS) of Rubia Gallega calves weaned at three different ages (at slaughter, 5.5 months and 2 months).

	NW	W5	W2	SEM	Sig
SA (d)	239.67	236.92	237.55	0.79	NS
SW (kg)	387.75[a]	344.77[b]	331.36[b]	6.23	***
CW (kg)	204.67[a]	173.39[b]	166.09[b]	4.05	***
CY (%)	52.8[a]	50.3[b]	50.1[b]	0.46	*
FS	4.45	4.1	3.54	0.27	NS
CS	8.76	8.55	8.1	0.08	NS

NW = not weaned; W5 = weaning at 5.5 months old; W2 = weaned when they were two days old, and then fed natural Holstein Friesian milk for two months.
Fatness score (FS): 1–15; 4 = 2-; 5 = 2.
Carcass conformation score (CS): 1 –18; 5 = O; 8 = R; 11 = U.
[a,b] Treatments means in the same column bearing different letters are significantly different ($P<0.05$) under Duncan test.
NS, *, **, *** refer to the level of significance at $P>0.05$ (non-significance), $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

2.6. Analytical methods

2.6.1. pH, colour and myoglobin content

The pH and the colour were measured in LT muscle and subcutaneous fat 24 h postmortem. The pH was measured using a pH-meter (Hanna Instrument HI-9024, Portugal) equipped with a penetration electrode. A portable colorimeter (Minolta CR-300 Osaka, Japan; machine settings from CR-300 measuring head are: pulsed xenon arc lamp, 0° viewing angle geometry and aperture size 8 mm) was used to measure meat colour in the CIELAB space (lightness, L^*; redness, a^*; and yellowness, b^*) (CIE, 1978). Chroma (C^*) and hue (h^*) were calculated from the a^* and b^* values as:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \text{ and } h^* = \arctan\frac{b^*}{a^*}.$$

Samples were allowed to bloom for 1 h in air before measuring (Insausti et al., 1999). All measurements were made in triplicate. Haeminic pigments (expressed as myoglobin and haematin) were measured in duplicate, according to Hornsey (1956).

2.6.2. Chemical composition

A near infrared spectrophotometer (Foss Tecator NIRS 6500, Denmark) was used to determine chemical composition, in duplicate, as proposed by Moreno et al. (2007). Moisture, ash, crude protein and ether extract contents were measured.

2.6.3. Water holding capacity

Water holding capacity (WHC) was determined, 24 h *postmortem*, using the method of Grau, and Hamm (1953) modified by Sierra (1973), it was measured in three ways: press loss (PL), drip loss (DL) and cooking loss (CL).

To determine PL, a 5 g sample of minced meat was placed between two disks of Whatman No. 1 filter paper (Filter Lab, Spain). After weighing the meat, a mass of 2.5 kg was applied for 5 min. The percentage of released water was calculated as:

$$\textit{Initial weight} - \textit{Pressed weight} \times 100 \,/\, \textit{Initial weight}.$$

To determine DL, a sample of intact meat (80–100 g and 1.5 cm thick) was weighed and placed on the top of a net, inside a closed container, in order to avoid evaporation into the environment. This container was placed in a chamber at 4 °C for 48 h and reweighed. The percentage drip loss was calculated as:

$$DL(\%) = \frac{(initial\ fresh\ meat\ weight - meat\ after\ 48\ hours\ weight)}{(initial\ fresh\ meat\ weight}) \times 100.$$

To evaluate CL, two 2.5 cm thick steaks were packed individually under vacuum (97%) (TECNOTRIP model EV-15-1-D) and cooked in a water bath at 75 °C for 1 h (Selecta Tectron Bio, Barcelona, Spain). Samples were cooled at room temperature and CL was calculated as follows:

$$\mathrm{CL}(\%) = \frac{(\mathrm{weightloss})}{(\mathrm{initialfreshmeatweight})} \times 100.$$

2.6.4. Texture analysis

2.6.4.1. Warner Bratzler (WB) test. To measure texture at 24 h *postmortem*, two steaks were cooked as indicated for CL. Steaks were cut into pieces (1 × 1 × 2.5 cm; height × width × length), parallel to the muscle fibre direction. They were completely sheared using a WB shear blade (3 mm thick) with a triangular cutting edge and three parameters were measured. The maximum shear force (Møller, 1980); represented by the highest peak of the force–time curve, the shear firmness (Brady, & Hunecke, 1985), represented by the slope from the beginning of the cut to the highest point of the force–time curve and the total work required to cut the sample, represented by the area under the curve. A texture analyser (Stable Micro Systems TA-XT2, UK) was used and all samples were cut perpendicular to the muscle fibre direction at a crosshead speed of 2.5 mm/s. The average value for each sample was recorded from six to eight measurements.

2.6.4.2. Sensory analysis. The vacuum-sealed (97%) samples were thawed at 4 °C for 24 and cooked in an oven at 200 °C (Teka, HA 890 vr02 E00, Spain), inside aluminium foil, to an internal temperature of 70 °C, monitored by thermocouples type K (Comark, PK23M, UK), connected to a data logger (Comark Dilligence EVG, N3014, UK). Every steak was then trimmed of external connective tissue, cut into 2 cm^3 samples, wrapped in codified aluminium paper and stored warm until analysis. To avoid the effect of order presentation and first-order and carryover effects, the samples were presented to panellists in different orders (Macfie, Bratchell, Greenhoff, & Vallis, 1989). The sensory analysis was performed in individual cabins fitted with red light (ISO 8589, 1988). The panel included eight selected and trained panellists (ISO 8586-1, 1993). The test used a quantitative descriptive method within a complete and balanced design that included 12 plates containing three samples, one of each treatment on each plate. Testing was in four sessions with three plates per session.

On a ten point scale, panellists assessed four attributes of the texture profile: tenderness (defined as the opposite of the force required to bite through the sample with the molars), juiciness (amount of moisture released by the sample after the first two chews), chewiness (number of chews needed to swallow the sample) and elasticity (capacity of recuperation of the sample initial shape after being deformed between the molars without being broken). A score of 1 stood for tough, dry, not chewy and firm and 10 stood for tender, juicy, chewy and elastic.

2.7. Statistical analysis

Data were analysed by analysis of variance for a completely randomised design using the General Linear Model (GLM) procedure of SAS (Statistical Analysis Systems Institute, 2000). The model used was:

$$Y_{ij} = \mu + W_i + \varepsilon_{ij},$$

Where Y_{ij} is the observation of weaning status i and animal j, for any of the dependent variables such as animal live weight and age, carcass weight and classification, pH, colour, myoglobin content, chemical composition, texture, and water holding capacity; μ is the overall mean; W_i is the effect of the weaning status i ($i = 1,2,3$) and ε_{ij} is the residual random error associated with the observation ij. When differences between weaning status appeared ($P < 0.01$) a Duncan test was done. Least-square means are presented and weaning status differences were considered significant at $P < 0.05$.

3. Results and discussion

3.1. Animal and carcass performance

The average daily gain during the life of the calves (TADG) (Table 1) was significantly ($P < 0.001$) higher in the NW group, these calves gained 214 g and 163 g more per day than the W2 and W5, respectively.

In spite of the TADG values (Table 1), the daily gain during the finishing period (ADG) (Table 1) was significantly higher ($P < 0.01$) in W2 and NW calves than in W5. Artificial lactation calves, weaned when they were two months old (W2), showed the highest daily gain during the finishing period. These results could be due to compensatory growth (O'Donovan, 1984; Ryan, Williams, & Moir, 1993) after an under nutrition period because of the adaptation of the W2 calves to suckle from a bucket instead of their mothers. Moreover, since W2 calves started having solid food earlier, their rumen development could have happened sooner (Baldwin, McLeod, Klotz, & Heitmann, 2004; Tamate, McGilliard, Jacobson, & Getty, 1962) than in NW and W5 calves, which favours a higher intake capacity. W5 calves showed the lowest ADG values (Table 1); however, after being weaned, these animals ingested higher amounts of feed (CI) than the NW group. The extra concentrate ingested by W5 calves was not enough to compensate the energy supplied by dam's milk in the NW group over the same period.

NW animals showed higher SW ($P < 0.001$), CW ($P < 0.001$) and CY ($P < 0.05$) than W5 and W2 calves (Table 3). It is difficult to compare these results with others where weaning status was studied (Blanco et al., 2009; Moreno et al., 2006; Vieira et al., 2005), since most of them fixed the slaughter date by weight and not age.

3.2. Meat quality attributes

3.2.1. pH

LT pH measured 24 hours *postmortem* (Table 4) was significantly higher ($P < 0.05$) in calves weaned when they were two months old (W2) than in W5 and NW calves. Many studies consider that nutrition has no major influence on meat ultimate pH (Crouse, Cross, & Seideman, 1984; Dufrasne, Hornick, Gauthier, Korsak, & Istasse, 1995; Hornick, Clinquart, Gauthier, van Eenaeme, & Istasse, 1995; Hornick et al., 1998), however other authors (Albertí, & Sañudo, 1987; Albertí, Sañudo, Lahoz, Jaime, & Tena, 1988; Sierra, Sañudo, Olleta, & Forcada, 1988) found higher pH values in meat from animals finished on concentrate for long periods. In NW and W5 animals, the finishing period with concentrate was three months shorter than in W2 group (Table 1), this could account for the higher LT pH in W2 meat. It is important to note that the pH values were below 5.8, in the normal range for beef (Garrido, & Bañón, 2001; Renerre, 1996). When the pH is over this value the meat is unattractive (Monserrat, Sánchez, Fernández, Viana, & De La Calle, 1997), termed DFD (dry, firm and dark) (Garrido, & Bañón, 2001) and is less acceptable to consumers than normal pH meat (Viljoen, Kock, & Webb, 2002). Other authors

Table 4
pH and colour parameters of *Longissimus thoracis* muscle and subcutaneous fat of Rubia Gallega calves weaned at three different ages (at slaughter, 5.5 months old and 2 months old).

	NW	W5	W2	SEM	Sig
24 hours postmortem					
pH	5.44[b]	5.45[b]	5.59[a]	0.03	*
Colour *Longissimus thoracis*					
L*	42.07	40.82	40.16	0.80	NS
a*	15.81[a]	14.80[a,b]	13.25[b]	0.41	*
b*	6.74[a]	6.25[a,b]	5.55[b]	0.19	*
Chroma (C*)	17.20[a]	16.08[a,b]	14.38[b]	0.44	*
Hue (h_{ab})	23.17	22.98	22.66	0.43	NS
Myoglobine (mg/g muscle)	3.01	2.88	2.71	0.11	NS
Hematine (µg/g muscle)	116.92	111.69	105.05	4.11	NS
Colour subcutaneous fat					
L*	68.83	69.82	69.22	1.03	NS
a*	6.42	7.53	8.26	0.42	NS
b*	8.00	8.61	8.85	0.33	NS
Chroma (C*)	10.31	11.49	12.22	0.51	NS
Hue (h_{ab})	51.41	49.93	47.14	0.99	NS

NW = not weaned; W5 = weaning at 5.5 months old; W2 = weaned when they were two days old, and then fed natural Holstein Friesian milk for two months.
[a,b] Treatments means in the same column bearing different letters are significantly different ($P<0.05$) under Duncan test.
NS, *, **, *** refer to the level of significance at $P>0.05$ (non-significance), $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

Table 5
Water holding capacity (WHC), tenderness and chemical composition of *Longissimus thoracis* muscle of Rubia Gallega calves weaned at three different ages (at slaughter, 5.5 months old and 2 months old).

	NW	W5	W2	SEM	Sig
Chemical composition					
Moisture (%)	77.21	77.43	77.52	0.15	NS
Ashes (%)	1.17	1.18	1.18	0.00	NS
Crude protein (%)	21.26	21.51	21.62	0.12	NS
Ether extract (%)	1.62	1.11	1.17	0.12	NS
Water holding capacity					
Pressing looses (%)	25.48	25.43	24.65	0.42	NS
Drip loss (%)	3.69	3.17	3.23	0.14	NS
Cooking looses (%)	31.46	30.64	31.28	0.73	NS
Texture					
WB test					
Maximum shear force (kg/cm^2)	9.57	9.83	10.39	0.37	NS
Shear firmness (kg/seg)	2.79[b]	2.71[b]	3.45[a]	0.11	**
Total cut work (kg×seg)	32.19	32.78	30.60	1.65	NS
Sensory analysis					
Elasticity	4.84[a]	4.65[a]	3.64[b]	0.33	*
Tenderness	6.16[a]	6.55[a]	5.11[b]	0.36	*
Juiciness	6.02[a]	5.77[a]	4.53[b]	0.35	**
Chewiness	6.06	6.27	5.41	0.37	NS

NW = not weaned; W5 = weaning 5.5 months; W2 = weaned when they were two days old, and then fed natural Holstein Friesian milk for two months.
[a,b] Treatments means in the same column bearing different letters are significantly different ($P<0.05$) under Duncan test.
NS, *, **, *** refer to the level of significance at $P>0.05$ (non-significance), $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

have reported that weaning status had no influence on the pH of ruminants' muscles (Blanco et al., 2009; Oliete et al., 2006; Velasco, Cañeque, Lauzurica, Pérez, & Huidobro, 2004).

3.2.2. Colour

LT luminosity (L^*) at 24 h *postmortem* did not differ significantly among the three weaning treatments (Table 4). Similar results were found in other Spanish local breeds (Blanco et al., 2009) when two different ages (3 and 5 months) at weaning were compared. Other studies dealing with milk ingestion in calves (Hornick, Clinquart, Van Eanaeme, Diez, & Istasse, 1996; Vieira et al., 2005) are also in accord with these results.

Yellowness (b*) (Table 4) was significantly higher ($P<0.05$) in NW than in W2 calves. This could be related to a higher content of intramuscular fat (Table 5). Similar results were reported by Oliete et al. (2006) when weaned and non-weaned calves were compared.

Redness (a*) (Table 4) was also significantly higher ($P<0.05$) in NW than in W2 calves. Moreno (2004) also found that the weaning status had a significant effect on redness.

Chroma (C*) was significantly higher ($P<0.05$) in NW than in W2 calves; since C* is related with *ante-mortem* factors such as age, nutrition and management (Albertí, 2001), these results were expected. However, when the weaning status was studied in lambs fed concentrate or barley (Velasco et al., 2004), C* was not affected. Significant differences were not found in RG calves when the influence of weaning status and vacuum storage time were studied (Oliete et al., 2006).

Hue (h^*) was not affected by the weaning status, as expected, since this parameter is mainly affected by *postmortem* factors (Albertí, 2001) that were not studied in the present experiment. When two different ages at weaning were compared (Blanco et al., 2009) h^* did not vary.

The myoglobin and haematin values were not affected by weaning status. When *ad libitum vs.* restricted milk ingestion (Vieira et al., 2005) was compared the haem pigment contents were not affected.

In agreement with other studies (Blanco et al., 2009; Vieira et al., 2005), colour in the subcutaneous fat 24 h *postmortem* (Table 4) was not affected by weaning status. However, the values in the present study were not the same as reported in other studies with calves, probably due to intrinsic factors such as breed, age or growth rate (Dunne et al., 2009). Since the calves ingested little or no green forage, the subcutaneous fat was white (low b*, 8.00 *vs.* 8.61 *vs.* 8.85), (Crouse et al., 1984; Kerth, Branden, Cox, Kerth, & Rankins, 2007); this fits well with the taste of Mediterranean consumers who prefer beef with pale adipose tissue (Dunne et al., 2009).

3.2.3. Chemical composition

The moisture, ash and crude protein contents of LT muscle were very similar for all groups (Table 5). Although the ether extract percentage was not significantly different among treatments, it was 30% higher in LT from NW than in W5 and W2 calves. Another study with the RG breed (Moreno et al., 2006) also found 23% higher levels of intramuscular fat in non-weaned compared to weaned calves (1.15% *vs.* 0.89%, $p<0.05$). Similar results were found in calves of the Spanish Brown Swiss breed when milk-fed and grain fed calves were compared (Vieira et al., 2005). In agreement, Moreno et al. (2006) and Xiccato, Trocino, Queaque, Sartori, and Carazzolo (2002) found an increase in overall milk consumption increased the percentage of ether extract in LT.

3.2.4. Water holding capacity

The water holding capacity (WHC), expressed as percentages of initial weight and measured by three different methods, was similar for all groups (Table 5). In accordance with these results, Velasco et al. (2004) found weaning status had no effect on WHC. When cooking and press losses were studied in RG veal Oliete et al. (2006) also found no significant differences in WHC. Further milk supplementation in a concentrate diet had no effect on the water holding capacity of beef from Belgian Blue bulls (Hornick et al., 1996); however, the drip losses were higher and cooking loss lower than in the present study, probably due to a longer ageing period.

3.2.5. Texture

3.2.5.1. WB test. WB maximum shear force (Table 5) was not significantly affected by weaning status, as found in other studies where the effect of weaning was studied (Blanco et al., 2009; Hornick et al., 1996; Oliete et al., 2006; Vieira et al., 2005); however, the values obtained in the present study were higher than those obtained by other authors. This could be due to differences in ageing time as texture was measured 24 h postmortem in the present study while Hornick et al. (1996), Vieira et al. (2005) and Blanco et al. (2009) aged samples for 7 days.

The WB shear firmness (Table 5) showed significant differences ($P<0.01$) among treatments, being higher in W2 than in NW and W5 veal. This was the only WB parameter significantly affected. The present results cannot be compared with other studies dealing with veal and weaning status (Oliete et al., 2006; Vieira et al., 2005; Xiccato et al., 2002) since only the maximum shear force was measured.

3.2.5.2. Sensory analysis. The sensory quality of veal from W2 calves appeared to be worse than that of calves suckled for a longer period (NW and W5), W2 veal was less elastic ($P<0.05$), tender ($P<0.05$) and juicy ($P<0.01$) than NW and W5 veal (Table 5). The differences between NW and W5 veal were not significant, however those calves that were not weaned (NW) produced juicier, more elastic meat (Fig. 2). In agreement with the present results Notter, Kelly, and Berry (1991) and Sañudo et al. (1998) found tendencies towards higher scores in lambs suckled for longer periods.

Although the results for veal from NW and W5 calves were not significantly different, the higher prices achieved in the market of NW veal could be justified because of its more favourable fatty acid profile (Bispo et al., 2010).

Veal obtained from later weaned (W5) or not weaned (NW) calves was more desirable than W2 veal, since their elasticity, tenderness and juiciness were higher. Thus there are differences between and early (W2) or late (W5) weaning and this should be taken into account since currently veal from RG calves weaned before slaughter is all marketed with the same label and price.

4. Conclusions

The length of the suckling period of RG calves had a marked effect on animal performance and meat quality attributes of PGI "Ternera Gallega" veal.

Calves that suckled their mothers during their entire life had the highest TADG.

Veal from later weaned calves was tastier and more appealing than that from calves finished for longer on concentrate because of its higher elasticity, tenderness and juiciness and also because of its better colour (a^*, b^* and C^*).

Differences between early and later weaning, which affected several meat quality attributes, should be considered to distinguish such veal by label and price.

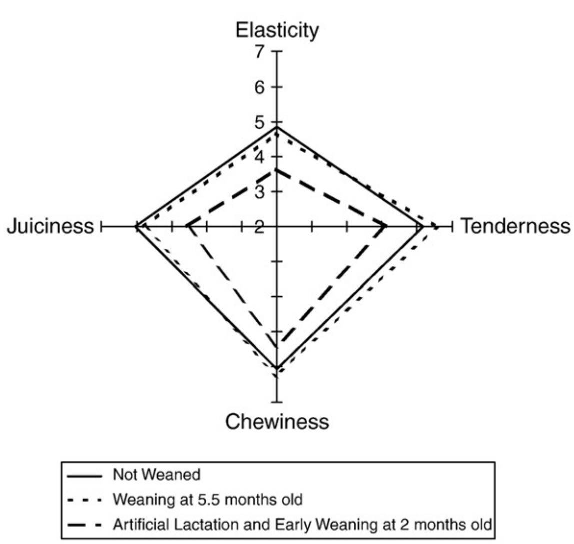

Fig. 2. Texture analysis by a trained panel of meat from Rubia Gallega calves weaned at different ages (not weaned, weaned at 5.5 months old and weaned at 2 months old).

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