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SHORT COMMUNICATION

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Effect of concentrate supplementation and prolificacy on the productive and economic performance of autochthonous sheep breeds fed forage-based diets

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Abstract

Sheep farming systems in Spain are experiencing an intensification process, characterised by a general selection criteria of enhancing prolificacy in ewes, and by increasing indoor feeding with concentrates to the detriment of grazing. This study evaluated the effects of concentrate supplementation and prolificacy on productive and economic performance of a local sheep breed in different price scenarios. Ewes were fed forage hay *ad libitum,* without (in pre-partum period, PRE-HAY; and in post-partum period, POST-HAY) or with concentrates (300 g d^{-1} in pre-partum period, PRE-CON; and 750 g d^{-1} in post-partum period, POST-CON). The inclusion of concentrate during the pre-partum period (last 10 weeks of pregnancy) had no effect on the productive performance of the ewes. In contrast, the inclusion of concentrate in the post-partum period (6 weeks), resulted in greater milk yield (1009 *vs*. 1275 ± 89 g d^{-1}), lamb average daily gain (151 ± 12 *vs*. 225 ± 19 g d^{-1}) and lamb output (kg of lamb LW weaned). However, the greater productivity thanks to the use of concentrates did not always turn into greatest profitability, since the economic margin was highly influenced by the cost of the diet and extremely subjected to variability in price of concentrates. Hence, the inclusion of concentrates in sheep meat production was not always justified in economic terms. In conclusion, the use of concentrates should only be considered as long as prices of commodities remain low, and inadvisable when prices reach a certain threshold or are subject to certain volatility in markets.

Additional key words: feedstuffs; physiological status; body fat reserves; lamb growth; economic evaluation; partial budgeting.

Non-improved autochthonous sheep breeds for lamb-meat production are well-adapted to produce in harsh environments and are closely linked with the use of semi-natural and natural areas in less favoured areas. However, these sheep breeds and the traditional farming systems in these regions are experiencing an intensification process characterised, on the one hand, by a general selection criteria of increasing prolificacy and, on the other hand, by a significant reduction of grazing and augmentation of indoor feeding with external inputs, such as concentrates (Bernués *et al.*, 2011). This is the case of the Spanish autochthonous sheep breed 'Ojinegra de Teruel' (43-50 kg live weight, LW), where the use of concentrates to feed ewes has increased significantly, especially during the lactation period (Ripoll-Bosch *et al.*, 2012). However, the current volatility and spikes in prices of commodities and inputs (Naylor & Falcon, 2010) further threaten the battered economic situation of many sheep-meat farms (Pardos & Fantova, 2009). In that sense, some authors

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Abbreviations used: ADG (average daily gain); BCS (body condition score); LFT (lumbar fat thickness); LW (live weight); SCC (somatic cell count).

state that local sheep breeds may not be used under intensive conditions, because this does not always yield higher economic performance and efficiency (Ripoll-Bosch *et al.*, 2014) and raising more than one lamb may result challenging when feed availability and/or quality are scarce (Bernes & Stengärde, 2012).

The aim of this experiment was to evaluate the effects of different levels of concentrate inclusion in forage hay diets and prolificacy on the productive and economic performance of the 'Ojinegra de Teruel' sheep breed in three scenarios differing in the price of commodities.

Twenty-one 'Ojinegra de Teruel' ewes (aged 4.3 ± 2.4 years) from a commercial flock were diagnosed pregnant and then enrolled in the trial. The trial comprised the last 10 weeks of pregnancy (pre-partum period) and the first 6 weeks of lactation (post-partum period). During the pre-partum period, 10 ewes were fed sanfoin (*Onobrychis viciifolia*) hay *ad libitum* (PRE-HAY) and 11 ewes were fed the same plus 300 g of concentrate daily (PRE-CON). Pre-partum feeding treatments were balanced by the diagnosed number of carried foetus (twin, n = 12 *vs*. single, n = 9). After lambing (occurred on January 12th ± 3.5 days, in 2010) half of the ewes (45.9 ± 1.7 kg LW and body condition score, BCS, 2.44 ± 0.05) were exchanged from their pre-partum treatment and the rest remained in the same treatment during the first 6 weeks of lactation. Hence, during the post-partum period, 11 ewes were fed pasture hay *ad libitum* (POST-HAY) and 10 ewes were fed the same plus 750 g of concentrate (POST-CON). Post-partum feeding treatments were balanced by the number of raised foetus (twin, n = 6 *vs*. single, n = 15) and lamb sex (females, n = 13 *vs*. males, n = 14). Lambs did not receive any concentrate supplement during the experimental period. Further information regarding the trial design, chemical composition of diets, as well as results concerning voluntary feed intake, metabolic profile and milk fatty acid composition, can be found in Joy *et al.* (2014). Herein, measurements of ewe body reserves, milk production, lamb performance and the economic assessment of these feeding strategies are described.

The LW and BCS of ewes were recorded at fortnightly intervals from week –10 to week –1 before lambing and at weekly intervals after lambing until week 6 of lactation. Lumbar fat thickness (LFT) was measured at weeks –10 and –2 before lambing and at week 6 of lactation by ultrasound scanner, between the 3rd and 4th lumbar vertebrae. Lambs were weighed within 24 h after lambing and then, at weekly intervals until weaning at 6 weeks of age. The average daily gain (ADG) of lambs was estimated by linear regression of LW against time. Milk yield was estimated at weekly intervals during the 6 weeks of lactation by the oxytocin technique proposed by Doney *et al.* (1979). Briefly, ewes were injected 5 IU oxytocin in the jugular vein prior to bucket machine milking at 08:00 and 12:00 h (with hand finishing up). Absence of clinical mastitis, mammary indurations, or atrophic half-udders was checked in all ewes involved in the study. The milk obtained in the second milking was weighed, and yield was extrapolated to the daily period. In addition, milk samples (2 × 50 mL) were taken at that moment for chemical and somatic cell count (SCC) analyses. Milk yield was standardized on the basis of a standard caloric value of 5.0 MJ L^{-1} using the equation suggested by Bocquier *et al.* (1993).

The economic analysis was performed under partial budgeting principles, which only concern those financial items that change as an outcome of a particular decision (Warren, 1998). In this case, the feeding costs and lamb outputs associated to the four different diets when accounting for the overall pre- and post-partum period (*i.e.* PRE-HAY + POST-HAY; PRE-HAY + POST-CON; PRE-CON + POST-HAY; PRE-CON + POST-CON). Feeding costs were assessed according to market price in 2009 (*i.e.* 0.26 € kg^{-1} of concentrate and 0.11 € kg^{-1} of hay) and in 2012 (*i.e.* 0.37 € kg^{-1} of concentrate and 0.11 € kg^{-1} of hay) and adjusted for dry matter content. According to the trend observed in prices between years 2009 and 2012, a potential future scenario named "+50%" was assessed, considering a further increase in price of concentrates by 50% and no changes in price of forages (*i.e.* 0.51 € kg^{-1} of concentrate and 0.11 € kg^{-1} of hay). Labour and facility requirements were assumed equal and differences in ewe LW and BCS during lactation were not computed as there were no significant differences between treatments. Price of suckling lambs at weaning was considered steady across scenarios (Ripoll-Bosch *et al.*, 2012) and computed in two ways: those lambs reaching specific quality label of suckling lambs 'Lechal' (minimum LW at weaning of 10 kg) had the market price of 3.54 € kg^{-1} of lamb live-weight, and those lambs that did not reach the minimum LW at weaning were sold for feed-lot fattening as standard quality product at the price of 3.00 € kg^{-1} of lamb live-weight (–15% price devaluation). The economic margin was calculated as the income achieved minus the above mentioned costs.

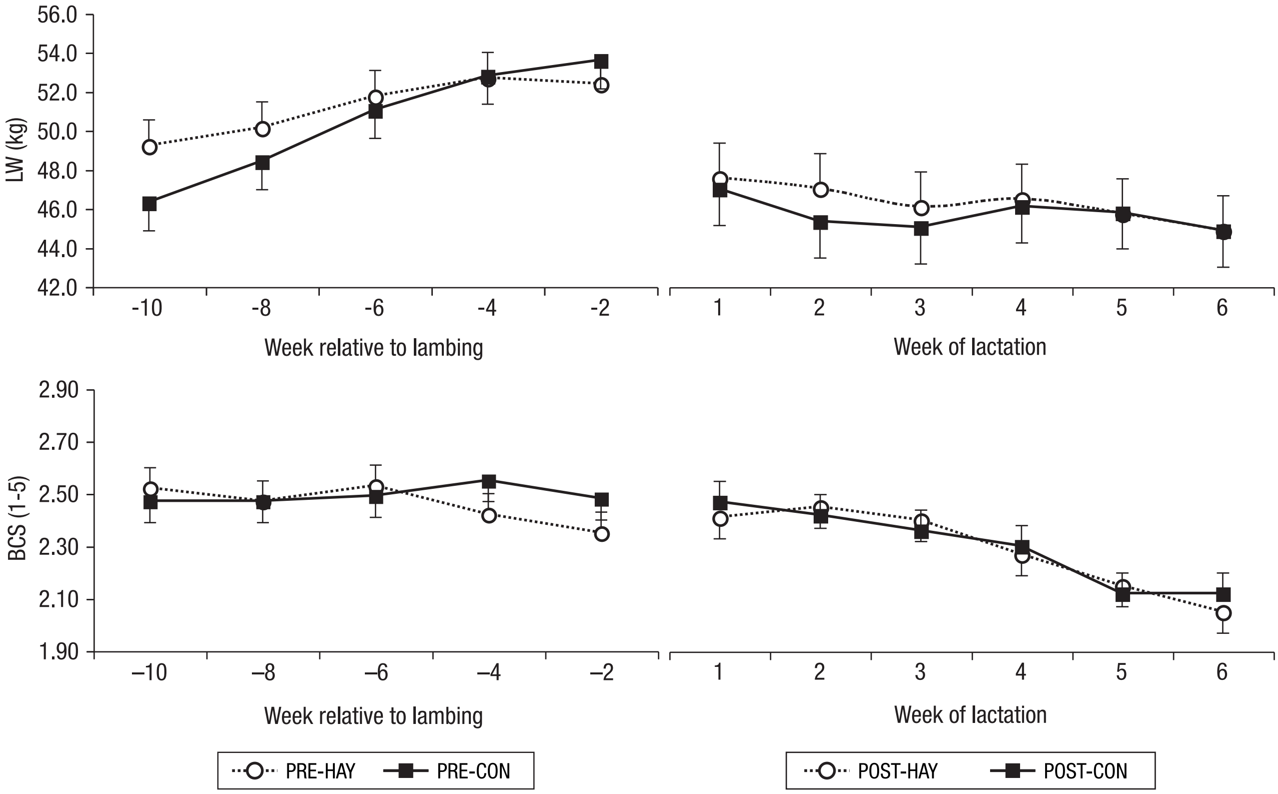

Figure 1. Ewes' live-weight [LW] (a) and body condition score [BCS] (b) according to the diet in pre- and post-partum periods. Diets: PRE-HAY, ewes fed sainfoin hay *ad libitum*; PRE-CON, ewes fed sinfoin hay *ad libitum* and 300 g d^{-1} of concentrate; POST-HAY, ewes fed pasture hay *ad libitum*; POST-CON, ewes fed pasture hay *ad libitum* and 750g d^{-1} of concentrate.

Data were analysed using the SAS statistical software (SAS Institute Inc., Cary, NC, USA). Ewes LW and body reserves, milk yield, and lamb LW were tested with repeated measures analysis of variance (Proc Mixed), by means of the following model:

$$Y_{ijkm} = \mu + D_i + A_j + W_k + F_m + (D_i \cdot W_k) + (F_m \cdot W_k) + (D_i \cdot F_m) + E_{ijkm}$$

where: Y_{ijkm} = dependent variable, μ = overall mean, D_i = diet effect (with or without concentrate), A_j = animal or pen random effect, W_k = week of pregnancy or lactation effect (pre-partum: from –9 to –1, post-partum: from 1 to 6), F_m = carried foetuses or raised lambs effect (single *vs*. twin) and E_{ijkm} = residual error. In post-partum ewe mixed models, pre-partum dietary treatment was also accounted as a fixed effect. Lambs' LW at birth and their ADG were analysed through analysis of variance (proc GLM) by including also in the model the gender effect and its second-degree interactions with the rest of fixed effects.

Regarding ewes performance, during the pre-partum period, LW increased alike in PRE-HAY and PRE-CON treatments ($p < 0.05$), whereas BCS remained constant throughout all weeks studied ($p > 0.05$). LFT decreased from week –10 to week –2 before lambing (8.9 ± 0.47 *vs*. 7.5 ± 0.62 mm, $p < 0.01$), regardless of the treatment. The number of foetuses did not affect LW evolution ($p > 0.05$), but ewes carrying twins showed lower BCS at weeks –4 and –2 before lambing than single-bearing ewes (averaging 2.33 ± 0.07 *vs*. 2.58 ± 0.08, for twin and single bearing, respectively; $p < 0.05$). The pre-partum feeding treatment did not affect LW, BCS or LFT on the following lactation period ($p > 0.05$), which allowed presenting results for the pre- and post-partum periods separately. Regarding the post-partum period, there were no effects of feeding treatment (POST-HAY and POST-CON) or the number of raised lambs on LW, BCS or LFT during the post-partum period ($p > 0.05$). However, there was a significant effect of week of lactation on LW and BCS, which decreased steadily from lambing until drying-off (Fig. 1; $p < 0.05$). The LFT decreased from late pregnancy until the end of lactation, with the lowest thickness at week 6 post-partum (4.0 ± 0.82 mm; $p < 0.05$), regardless of concentrate inclusion or prolificacy ($p > 0.05$).

Milk yield was affected by concentrate inclusion during post-partum period and also by the week of lactation ($p < 0.05$), but not by the concentrate inclusion during pre-partum period, by the number of raised lambs or any interaction between these parameters ($p > 0.05$). Ewes supplemented with concentrate during lactation (POST-CON) showed greater gross (1009 *vs*. 1275 ± 89 g d^{-1}) and standard (859 *vs*. 1108 ± 67 ml d^{-1}) milk production than ewes fed hay (POST-HAY). Maximum values for milk yield occurred in weeks 1 to 3 of lactation (1252 *vs*. 1031 ± 89 g d^{-1}, at first to third week *vs*. the rest of lactation; $p < 0.05$), whereas maximum values for standard milk yield were at week 1 of lactation (1314 *vs*. 918 ± 67 ml d^{-1}, first week *vs*. the rest of lactation; $p < 0.05$). Milk fat and protein contents were not affected by diet, but their contents were greater at the first week (74 ± 4.1 and 51 ± 1.0 g kg^{-1}, for fat and protein respectively) than in the rest of lactation (57 ± 4.1 and 46 ± 1.0 g kg^{-1}, in the same order, $p < 0.05$). Mammary health status in the ewes was monitored through SCC in milk, whose mean values were 504 × 10^3 cells mL^{-1} ($\log_{10}$ SCC = 2.70) at first week of lactation and 227 × 10^3 cells mL^{-1} ($\log_{10}$ SCC = 2.35) subsequently.

Lamb LW at birth was not affected by dam prepartum feeding treatment (3.3 *vs*. 3.4 ± 0.3 kg, in PRE-HAY and PRE-CON, respectively; $p>0.05$) or lamb gender (3.5 *vs*. 3.1 ± 0.3 kg, in males and females, respectively; $p > 0.05$). However, LW at birth was greater in single than in twin lambs (4.0 *vs*. 2.6 ± 0.3 kg; $p < 0.01$). Lamb ADG during lactation and LW at weaning were not affected by pre-partum diet or gender ($p > 0.05$). However, lambs raised by POST-CON ewes showed greater ADG (225 ± 19 *vs*. 151 ± 12 g d^{-1}) and consequently were heavier at weaning than those raised by POST-HAY-fed ewes (12.4 ± 0.8 *vs*. 9.0 ± 0.5 kg; $p < 0.001$). Likewise, single lambs grew faster (226 ± 11 *vs*. 150 ± 11 g d^{-1}) and attained heavier LW at weaning than twin lambs (12.9 ± 0.9 *vs*. 8.4 ± 0.5 kg; $p < 0.001$).

Despite some studies reported greater milk production and lamb performance due to higher feed supplementation in late pregnancy (López-Gallego *et al.*, 1998), in this study supplementation with concentrate during pregnancy (300 g d^{-1} per ewe) did not improve animal performance. However, feeding concentrate during lactation (750 g d^{-1}) allowed increasing the milk production and hence, greater ADG of lambs. Notwithstanding, the milk production level of ewes raising two lambs could not offset their greater energy demands for lamb growth, thereby reducing the ADG of twin compared to single lambs. The absence of a clear peak of lactation has been also described in other local sheep-meat breeds fed with similar diets (Alvarez-Rodriguez *et al.*, 2012). Contrary to dairy sheep, concentrate supplementation did not depress milk fat content. The negative association between milk yield and milk fat content may be either weak or not significant in low milk production (Pulina *et al.*, 2006). In any case, compared to Ripoll-Bosch *et al.* (2012), it can be observed that ewes fed a nearly pure concentrate-based diet yielded lower milk (814 g d^{-1}) and fat (47 g d^{-1}) than the ewes fed forage-base diets in this experiment.

The economic evaluation was performed accounting for the overall pre- and post-partum period, which means that four different diets were considered (Table 1). The greater lamb output was obtained in those diets using the higher amount of concentrates (PRE-CON + POST-CON and PRE-HAY+POST-CON). The cost of the diet was highly influenced by the use of concentrates (*i.e.* the higher the use of concentrates, the higher the cost the diet) and its price. The maximum difference in cost between diets in 2009 was of 1.5 times (PRE-HAY + POST-HAY *vs*. PRE-CON + POST-CON), but such difference scaled up to 2.3 times for the "+50%" scenario. Therefore, the economic margin was influenced by lamb output but particularly by the cost of the diet, which was extremely subjected to variability in price of concentrates. In that sense, the economic margin of PRE-CON+POST-CON diet diminished by –28.2% and –63.3% for the 2012 and the "+50%" scenarios, respectively. In contrast, economic margin of forage-based diet (PRE-HAY+POST-HAY) remained steady across scenarios, and should it be considered as moderate in 2009 situation, became the greater in the "+50%" scenario.

Feeding represents the largest single cost in animal production and hence, impacts significantly on the profitability and sustainability of the production systems (Finneran *et al.*, 2010). In this sense, Pardos & Fantova (2009), when analysing the economic profitability of sheep farms between years 2002-2007, reported a diminution in economic margins per ewe of about –32.9%, mainly triggered by increase in feeding costs. As observed in this study, under the current uncertainty in markets, characterised by a generalised increase and rapid fluctuation in prices of major inputs (concentrates, cereals and energy), the economic advantage is greater for feed self-sufficient farms (Benoit *et al.*, 2009; Bernués *et al.*, 2011). According to Ripoll-Bosch *et al.* (2014), high feed self-sufficiency and low depen-

Table 1. Lamb output (kg of lamb meat sold ewe^{-1}), income (€ ewe^{-1}) and diets cost (€ ewe^{-1}) under different scenarios (year 2009, year 2012 and possible future situation "+50%")

	PRE-CON		PRE-HAY		SE[d]
	POST-CON	POST-HAY	POST-CON	POST-HAY	
Concentrate use (kg)	48.15	18.06	30.09	0.00	±4.00
Hay use (kg)	124.47	133.81	125.99	144.81	±2.56
Lamb output (weaned) (kg ewe^{-1})	14.30	9.30	13.50	10.50	±0.90
Income (€ ewe^{-1})[a]	48.79	29.25	45.74	33.80	±3.19
Diet cost 2009 (€ ewe^{-1})[b]	28.43	21.56	23.77	18.10	±0.88
Diet cost 2012 (€ ewe^{-1})	34.17	23.71	27.36	18.10	±1.34
Diet cost "+50%" (€ ewe^{-1})	41.30	26.39	31.82	18.10	±1.93
Economic margin 2009 (€ ewe^{-1})[c]	20.36	7.69	21.97	15.69	±2.88
Economic margin 2012 (€ ewe^{-1})	14.62	5.54	18.38	15.69	±2.82
Economic margin "+50%" (€ ewe^{-1})	7.48	2.86	13.92	15.69	±2.86

[a] Income: kg of lamb meat sold per ewe, considering 3.54 € kg^{-1} of lamb live-weight for those lambs reaching a minimum live weight of 10 kg at weaning and 3.00 € kg^{-1} of lamb live-weight for those at lower live weight at weaning. [b] Diet cost: In 2009 and 2012, diets were assessed according to market prices, resulting in nearly 50% increase in price of concentrates and no modification in price of forages; for "+50%" situation, a further increase by 50% in price of concentrates and no modification in price of forages was considered. [c] Economic margins: calculated as income minus the diet costs. [d] SE: standard error.

dency on off-farm input (variable costs) in sheep-meat farming systems enhance the economic performance per labour unit and guarantees farm stability, which is particularly the case of the forage-based diet (PRE-HAY + POST-HAY). Increasing numeric productivity of ewes may increase farm income, but does not necessarily imply better overall economic performance, especially when the increased productivity relay on the augmented use of inputs. Most intensive production systems (based on high inputs requirements) may be suitable for prolific or selected breeds with high productive potential, but might not be balanced for local sheep breeds with lower productive potential.

For this local sheep breed, and for many low-input low-output sheep breeds, supplementing forage-based diets with concentrates during lactation can improve animal performances. However, the use of concentrates should only be considered as long as prices of commodities remain low, and inadvisable when prices reach a certain threshold or prices are subject to certain volatility in markets.

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