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EFFECT OF BENTONITE-GINGER COMBINATION ON OULED DJELLAL EWES' PRODUCTIVITY IN PERIPARTURIENT PHYSIOLOGICAL STAGE

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ABSTRACT: This study evaluated the effects of dietary supplementation with a combination of 5% bentonite (clay) and 2% ginger on the productive performance of Ouled Djellal ewes during the periparturient period, from eight weeks before lambing to twelve weeks after lambing. Twelve clinically healthy Ouled Djellal ewes, with a mean age of 3.75±1.22 years, an average body weight of 67.50±8.63 kg, and a mean body conditions score (BCS) of 2.54±0.54 were randomly allocated to two groups (n = 6 per group). Both groups received a basal diet consisting of alfalfa hay and wheat straw *ad libitum* supplemented with concentrate. The control group received the basal concentrate without additives, whereas the experimental group received concentrates supplemented with 5% bentonite and 2% ginger. The experiment was conducted at the demonstration station of the Technical Institute of Livestock Breeding, Ain M'lila, Algeria. The results showed that no statistical significant differences were observed in body condition score between the two groups throughout the experimental period. However, milk production was significantly higher in the supplemented group during the first and fifth weeks of lactation (P = 0.02), increasing by 30.10% and 14.10%, respectively, compared with the control group. This effect was no longer significant during the eighth week of lactation (P > 0.05). Regarding milk composition, total protein and total solids did not differ significantly between treatments. In contrast, milk fat content was significantly higher (+36.91%; P = 0.01) and lactose concentration was significantly lower (−22.38%; P = 0.03) in the supplemented group during the first week of lactation. During the fourth week, lactose was the only milk component that differed significantly between treatments, showing a 14.44% increase (P = 0.04). No significant differences in milk composition were observed during the second and twelfth weeks of lactation. Dietary supplementation with the bentonite–ginger combination had no significant effect on lamb birth weight or average daily gain throughout the suckling period. The absence of significant effects on lamb growth may be related to the inclusion levels of the additives used in the present study.

Keywords: Feed efficiency; Gestation; Lactation; Natural additives; Prebiotic; Sheep.

INTRODUCTION

In Algeria, meat production relies mainly on sheep farming, which represents 81% of the total livestock population (M.A.D.R, 2020), but this sheep population faces chronic feed shortages (Slimani et al., 2021). Natural rangelands have deteriorated due to recurrent droughts and now provide only limited forage resources for livestock, dominated by poorly digestible woody shrubs with low nutritional value. This problem has prompted many researchers (Ouachem and Soltane, 2009; Kaboul and Ouachem 2012) to seek solutions based on the incorporation of natural products to improve nutrient digestibility and utilization in lignified forages (Ouachem et al., 2008). Among natural additives, we can include the use of clay (Duval, 1993; Kahouli et al., 2020), as well as phytobiotics (Alloui, 2011; Kahouli et al., 2023) and, particularly, ginger as a medicinal plant (Gupta et al., 2025; Paudel et al., 2025).

In this context, the present study focuses on the use of clay and the medicinal plant ginger as phytobiotic included at dietary levels of 2% and 5%, respectively. The objective is to evaluate the impact of incorporating these two products on the performance of ewes at the end of gestation and during lactation, and on their offspring. It should be noted that to the best of our knowledge similar studies are not reported on combined supplementation with clay and ginger in ewes from late gestation to the end of lactation.

MATERIALS AND METHODS

Location, period of the experiment and ethical consideration

The experiment was conducted at the T.I. Bre Ain M'lila Demonstration Station in Oum El Bouaghi province, Algeria, located in the semi-arid region of eastern Algeria, over a period of six months from February to July 2019. All procedures involving the ewes, including diet modification with natural additives, housing, and handling, were performed in strict compliance with Algerian national regulations on animal health and welfare. The trial relied exclusively on non-invasive zootechnical measurements and was supervised by certified zootechnicians and veterinary staff.

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Animal material, feed and additives

Twelve clinically healthy Ouled Djellal ewes in late gestation were selected for the experiment The average age of the ewes was 3.75 ± 1.22 years, with an average live weight of 67.50 ± 8.63 kg and a body condition score (BCS) of 2.54 ± 0.54. The control ration (C) consisted mainly of roughage (alfalfa hay supplemented with wheat straw ad libitum) and 500 g/head/day of concentrate feed, composed of corn, bran, soybean meal, vitamins, minerals, phosphate and limestone. Water was provided ad libitum. Powdered ginger and bentonite (clay) were purchased commercially.

Experimental protocol

The 12 ewes were randomly allocated to two experimental groups (n = 6 per group):

- One control group (C) receiving the basal ration without additives.
- One experimental group (E) receiving the basal ration supplemented with 5% bentonite (clay) and 2% ginger.

Both groups underwent a 15-day adaptation period before the start of the experiment to adapt to their respective diets.

Feed analyses

Chemical analyses of the feed and supplemented diets focused on the determination of their chemical composition and nutritive value, in accordance with the guidelines of the French Standardization Association (AFNOR, 1982) and the Association of Official Analytical Chemists (AOAC, 1990). The analyses included determination of dry matter (DM), organic matter (OM), mineral matter (MM), total nitrogen (TN), crude fiber (CF), calcium (Ca) and phosphorus (P). The energy value of the diet, expressed in French INRA units as UFL (Milk Feed Unit) was calculated using the equations proposed by Soltner (1986). The protein value, expressed as Protéines Digestibles dans l'Intestin (PDI) or metabolizable protein (PDI), was calculated according to the equations proposed by INRA (2010).

Table 1 - Nutritional value of feed served to sheep.

Feed	DM (%FM)	OM (%DM)	F (%DM)	MM (%DM)	CP (%DM)	CF (%DM)	Ca (%DM)	P (%DM)
Alfalfa hay	89.48	89.87	0.45	10.13	20.85	23.91	0.16	0.31
Wheat straw	93.33	90.46	3.11	09.54	03.59	29.74	0.12	0.29
Concentrate	86.20	89.65	0.60	10.35	16.39	01.44	0.05	0.49

DM: dry matter; FM: fresh matter; OM: organic matter; F: fat; MM: mineral matter; CP: crude protein; CF: crude fiber; Ca: calcium; P: phosphorus.

Body condition score and body weight

The body condition score (BCS) and body weight of the ewes were recorded in the morning during the eighth and third weeks before lambing and during the second, fourth, eighth and twelfth weeks after lambing. BCS was assessed using the 0-5 scale developed by Russel et al. (1969), based on palpation of the lumbar region. Each ewe was weighed using appropriate livestock scale (Marechalle-pesage, PM 150, France) with a maximum capacity of 200 kg and an accuracy of ± 500 g. The lambs were also monitored for growth performance. They were weighed at birth, week during the first month of life, and subsequently at 8 and 12 weeks of age using a precision scale (Dahongying, China) with a maximum capacity of 30 kg and an accuracy of ± 5 g. Average daily gain (ADG) was calculated as follows:

$$\text{ADG (g)} = \frac{\text{weight (g)at (n)days}}{\text{(n)days}}$$

Milk yield

The milk yield of each ewe during the first, fifth and eighth weeks of lactation was estimated using the equations developed by Torres-Hernandez and Hohenboken (1980), which predict milk production based on the weight gain of suckling lambs and litter size.

Table 2 - Regression equations to predict milk production per day relative to ADG and correlation coefficient (r) according to Torres-Hernandez and Hohenboken (1980)

N° of week	Single lambing		Double lambing	
	Equation	r^2	Equation	r^2
1	MY= 0.17+5.06×ADG**	0.65	MY= 0.03+4.98×ADG**	0.69
5	MY= 0.92+3.03×ADG*	0.30	MY= 1.65+0.61×ADG	0.01
8	MY= 0.42+3.45×ADG*	0.33	MY= 0.63+1.89×ADG*	0.20

MY: Milk Yield; ADG: Average Daily Gain; (** P < 0.01); (* P < 0.05).

Milk analyses

Milk samples were collected by manual milking in the morning after temporary separation of the ewes from their lambs. Samples were collected during the first, second, fourth, and twelfth weeks of lactation into labelled glass tubes and transported to the laboratory in a cooled container to preserve milk quality and prevent acidification. Milk composition, including fat (FM%), total protein (TP%), lactose (L%) and total solids (TS%), was determined using an ultrasonic milk analyser (BQC®, Ultrasonic Milk Analyzer), which automatically aspirates the milk sample through a probe and displays the analytical results digitally.

Statistical analyses

Statistical analyses were performed using STATISTICA version 10 (StatSoft Inc., USA). Differences between the control and experimental groups were evaluated using Student's *t*-test. Statistical significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

To ensure that the experiment was not influenced by pre-existing differences between the treatment groups, the body weight and body condition score the ewes were evaluated before the start of the experiment. As shown in Table 3, no significant differences were observed between the control and experimental groups in either ewe body weight (EW) or body condition score (BCS) before lambing.

Table 3 - Ewes Weight (EW) and Body Condition Score (BCS) of ewes before and after lambing.

Treatments		Control	Experimental	P-value
Before lambing	EW -8 week	65.83±9.60	60.67±10.67	0.44
	BCS -8 week	2.58±0.66	2.50±0.45	0.84
	EW -3 week	69.17±8.06	65.00±10.02	0.47
	BCS -3 week	2.17±0.60	2.25±0.61	0.84
After lambing	EW +2 week	58.00±8.69	56.42±9.30	0.78
	BCS +2 week	1.67±0.41	1.83±0.52	0.61
	EW +4 week	53.33±7.47	50.83±9.56	0.56
	BCS +4 week	1.67±0.26	1.50±0.45	0.47
	EW +8 week	52.42±6.57	52.08±7.30	0.93
	BCS +8 week	1.67±0.26	1.58±0.38	0.70

EW: Ewes Weight (Kg); BCS: Body Condition Score; P > 0.05: insignificant difference.

Although no statistically significant differences were detected throughout the experimental period, the BCS results revealed interesting trends. Eight weeks before lambing, the control group exhibited a 3.2% higher BCS than the Clay–Ginger group. However, by three weeks before lambing, the supplemented group had surpassed the control group by 3.7%, maintaining this advantage until the second week postpartum, when the difference reached 8.7%. During the fourth and eighth weeks of lactation, BCS values were again slightly higher in the control group by 11.3% and 5.7%, respectively.

Although supplementation with the Clay-Ginger combination did not significantly increase BCS, it appeared to reduce the mobilization of body fat reserves due to transition period. This effect may reflect an improved energy status during the physiologically demanding period extending from three weeks before lambing to two weeks after lambing. Similar observations were reported by Kahouli et al. (2020), who evaluated 5% clay supplementation under comparable experimental conditions using Ouled Djellal ewes from late gestation to weaning. Likewise, Chemmam et al. (2009) reported that nutritional supplementation during late gestation and early lactation significantly reduced body weight and BCS loses in Ouled Djellal ewes grazing natural pastures.

Although no significant differences were observed, Abo Bakr (2019) reported lower body weight loss during early lactation in ewes supplemented with different forms and doses of ginger (3 or 6 g/head/day of ginger powder or 2 ml/head/day of ginger oil). Similar findings were reported by Shams Al-Dain and Jarjeis (2015) in dairy cows receiving 75 or 150 g/head/day of ginger powder.

According to available literature and the researchers knowledge no available studies prior to present study have evaluated the combined supplementation of clay and ginger in ewes from late gestation through the end of lactation. However, studies conducted in dairy cattle have demonstrated beneficial effects of lay supplementation. Karatzia et al. (2013) reported significantly higher BCS ($P < 0.05$) in dairy cows supplemented with 200 g/day of zeolite compared with controls. Likewise, Garzón et al. (2017) observed highly significant improvements ($P < 0.01$) in BCS in cows receiving 2% zeolite before and after calving.

Overall, clay supplementation may improve body condition indirectly by modifying ruminal fermentation patterns, altering volatile fatty acid production, and increasing starch flow to the intestine, thereby improving the animal's energy balance (Katsoulos et al., 2006; Karatzia et al., 2013).

Milk production

The clay-ginger supplementation significantly increased milk yield during the first (P = 0.02) and fifth (P = 0.02) weeks of lactation by 30.1% and 14.1%, respectively, compared with the control group. During the eighth week, milk yield remained higher in the supplemented group, although the difference was not sufficiently significant (P = 0.06) (Table 4).

Table 4 - Estimated milk production for the 1st, 5th and 8th weeks, according to the Torres-Hernandez and Hohenboken (1980).

Milk Yield	Control	Experimental	P-value
1^{st} week (kg/d)	$1.13^{b} \pm 0.10$	$1.47^{a} \pm 0.18$	0.02
5^{th} week (kg/d)	$1.49^{b} \pm 0.06$	$1.70^{a} \pm 0.04$	0.02
8^{th} week (kg/d)	0.94 ± 0.05	1.08 ± 0.04	0.06

a, b: In the same row, means with different subscripts are significantly different (P < 0.05); (P > 0.05): insignificant difference.

These results are partially consistent with those reported by Abo Bakr (2019), who observed significant increases (P < 0.05) in milk yield at four weeks of lactation in ewes supplemented with different forms and doses of ginger. The greatest increase was obtained with 3 g/day of ginger powder, followed by 2 ml/day of ginger oil and 6 g/day of ginger powder. At eight weeks, however, the increase was no longer significant, whereas total milk production over the three-month lactation period remained significantly higher than that of the control group. Similarly, Al-Musodi and Jaafar (2019) reported that supplementation of Iraqi goats with 60 g of ginger powder per kilogram of concentrate significantly increased milk production during the fourth, fifth, and sixth weeks after kidding. Kholif et al. (2012) also demonstrated that supplementation with 2 ml/day of ginger oil significantly increased milk production (P < 0.05) throughout the first 90 days of lactation in Damascus goats, beginning on the seventh day after kidding, resulting in an 18.9% increase compared with the control group.

In contrast to the present findings, Kahouli et al. (2020) reported a significant increase in milk production during the eighth week of lactation (+ 29.40%; P < 0.05) in ewes receiving kaolinite, whereas significant effect was observed during the first week. Helal and Abdel-Rahman (2010) found that supplementation with 4% bentonite significantly increased milk yield by 7.7% and fat-corrected milk (4% fat) by 10.7%, possibly due to increased retention time of feed in the rumen. Similarly, Abdel Mawla et al. (1998) reported that sodium bentonite supplementation (6 or 12 g/head/day) had no significant effect during the second week of lactation but significantly increased milk production during the fourth (P < 0.05) and sixth (P < 0.01) weeks. Tayeb (2017) also reported significant improvements in daily milk yield following supplementation with 2% bentonite combined with either 2% or 2.5% urea. Likewise, Ammar and Al-Hafz (2019) observed significant increases (P ≤ 0.05) in weekly and monthly milk production in Awassi ewes receiving 20 or 30 g/head/day of ginger. In dairy cows, Shams Al-Dain and Jarjeis (2015) reported significant increases (P ≤ 0.05) in milk yield of 30.9% and 58.2% following supplementation with 75 and 150 g/head/day of ginger powder, respectively. The increase in milk production reported in these studies has been attributed to several mechanisms:

1. Reduced methane production, decreased acetate concentration, increased propionate production, and higher total volatile fatty acid concentrations, resulting in improved energy efficiency (Patra and Saxena, 2010; Kholif et al., 2012).
2. Improved digestibility of fiber and dry matter (Nanon et al., 2014; Abo Bakr, 2019).
3. Enhanced nitrogen and energy utilization, leading to improved feed efficiency and animal health (Giannenas et al., 2013).
4. Stimulation of bile acid synthesis and pancreatic enzyme activity, thereby improving lipid digestion and nutrient absorption (Kumar et al., 2014).
5. Increased retention time of feed within the rumen (Helal and Abdel-Rahman, 2010).
6. The duration of dietary supplementation (Katsoulos et al., 2006).

Milk quality

The effects of the combined natural additives (Clay-Ginger) on milk composition are presented in Table 5.

During the first week of lactation, milk fat (MF) content was significantly higher in the experimental group than in the control group (12.24 ± 0.74% vs. 8.94 ± 0.78%; +36.91%; *P* = 0.01).In contrast, the control group exhibited a significantly higher lactose concentration than the supplemented group (5.14 ± 0.40% vs. 4.20 ± 0.10%; +22.38%; *P* = 0.03). No significant differences were observed between the groups in total protein or total solids. During the fourth week of lactation, lactose was the only milk component that differed significantly between treatments, showing a 14.44% increase compared with the control group (*P* = 0.04).

Overall, no significant differences in milk composition were observed between the two groups during the second and twelfth weeks of lactation (Table 5).

Table 5 - Milk quality (Milk Fat, Total Protein, Lactose and Total Solid) during the 1st, 2nd, 4th and 12th weeks.

Treatments	Milk components	Milk Fat (%)	Total Protein (%)	Lactose (%)	Total Solid (%)
1st week	Control	08.94 [b] ± 0.78	4.14 ± 0.13	5.14 [a] ± 0.40	10.96 ± 0.11
	Experimental	12.24 [a] ± 0.74	4.12 ± 0.09	4.20 [b] ± 0.10	10.77 ± 0.19
	P-value	0.01	0.64	0.03	0.06
2nd week	Control	6.54 ± 2.30	3.77 ± 0.15	6.08 ± 1.25	10.21 ± 0.40
	Experimental	7.24 ± 2.12	3.91 ± 0.20	4.48 ± 0.42	10.56 ± 0.53
	P-value	0.64	0.40	0.10	0.41
4th week	Control	6.12 ± 1.64	3.67 ± 0.31	4.71 [b] ± 0.24	09.96 ± 0.88
	Experimental	7.28 ± 0.90	3.75 ± 0.14	5.39 [a] ± 0.66	10.15 ± 0.43
	P-value	0.23	0.53	0.04	0.59
12th week	Control	3.98 ± 2.16	3.91 ± 0.21	5.47 ± 0.35	10.63 ± 0.60
	Experimental	2.96 ± 0.65	3.90 ± 0.12	5.59 ± 0.51	10.64 ± 0.34
	P-value	0.33	0.98	0.35	0.97

a, b: In the same column, means with different subscripts are significantly different ($P < 0.05$); ($P > 0.05$): insignificant difference.

Unlike the present findings for the first week of lactation, Al-Musodi and Jaafar (2019) reported no significant effects ($P > 0.01$) of supplementing Iraqi dairy goats with ginger powder (60 g/kg concentrate) on milk fat, protein, or lactose during the same period. However, they observed highly significant increases ($P < 0.01$) in milk fat during the third and fourth weeks, milk protein during the fourth and fifth weeks, and lactose during the fourth, fifth, and sixth weeks, all in favour of the ginger-supplemented diet. Similarly, Abo Bakr (2019) reported that supplementation with different forms and doses of ginger (3 or 6 g/day of ginger powder and 2 ml/day of ginger oil) had no significant effect on the percentages of total protein, total solids, or lactose during the first four weeks of lactation. However, supplementation with 6 g/day of ginger powder significantly increased ($P < 0.05$) milk fat content, whereas 3 g/day of ginger powder and 2 ml/day of ginger oil had no positive effect compared with the control group. During the second month of lactation, no significant differences were observed. Nevertheless, supplementation with 2 ml/day of ginger oil resulted in significant decreases ($P < 0.05$) in milk fat and total solids during the final four weeks and over the entire 12-week lactation period. Likewise, Kholif et al. (2012) reported a significant reduction ($P < 0.05$) in milk fat content in goats receiving ginger oil supplementation compared with the control group, whereas milk protein concentration was significantly higher in the supplemented animals.

No significant differences were observed in lactose concentration. Hendawy et al. (2019) reported significant improvements ($P < 0.05$) in milk fat and total solids in ewes supplemented with ginger powder, whereas milk protein and lactose concentrations remained unaffected. Similarly, Ammar and Al-Hafz (2019) found no significant effects of ginger powder supplementation on milk fat, protein, or lactose content in ewe milk. The findings of Kahouli et al. (2020) who evaluated 5% kaolinite supplementation in Ouled Djellal ewes, differ from those of the present study. They reported no significant differences between the supplemented and control groups in milk fat, lactose, or protein concentrations during the first week of lactation. Likewise, Ouachem et al. (2012) reported that supplementation with 5% marl significantly increased ($P < 0.05$) milk protein concentration by 15% in Arbia goats but had no effect on milk fat or lactose.

Salem and El-Shewy (2001) reported that supplementing goat diets with 3% bentonite from parturition until the sixth week of lactation significantly increased ($P < 0.05$) milk fat and protein percentages. In sheep, however, Tayeb (2017) observed that supplementation with 2% bentonite significantly affected only milk fat content ($P < 0.05$). Other studies have reported highly significant effects ($P < 0.01$) of bentonite supplementation on milk fat and lactose concentrations in goats (Abdel Mawla et al., 1998) and on milk fat and total solids in ewes (Helal and Abdel-Rahman, 2010). Suggested that the improvement in milk fat content may result from increased acetate production associated with enhanced ruminal microbial activity following an improved immune response.

Kholif et al. (2012) also attributed changes in milk fat concentration to increased milk yield and to the effects of ginger essential oil supplementation, although these effects were not always statistically significant. Similar conclusions were reported by Abo Bakr (2019). Helal and Abdel-Rahman (2010) proposed that improvements in milk protein content result from enhanced microbial protein synthesis in the rumen. A similar explanation was provided by Ouachem et al. (2012), who attributed the increase in milk protein concentration to the stimulatory effect of marl on ruminal microbial activity. According to Ahmide and Abouzogaya (2009) cited by Shams Al-dain and Jarjeis (2015) the higher lactose concentration observed in cows supplemented with ginger root may be associated with reduced blood glucose concentrations.

Newborn weight and average daily gain

No significant effect (P > 0.05) of Clay–Ginger supplementation was observed on lamb birth weight compared with the control group. Similarly, no significant differences in average daily gain (ADG) was detected throughout the suckling period between lambs born to supplemented and control ewes. Despite the absence of statistically significant differences, lambs born to supplemented ewes exhibited a clear numerical improvement in growth during the first four weeks of life. Growth rates were approximately 18%, 22%, 29%, and 36% higher than those of the control group during the first, second, third, and fourth weeks, respectively. However, this trend was reversed during the later stages of the suckling period. At the eighth and twelfth weeks, growth performance of lambs from the supplemented group was approximately 27% and 19.5% lower, respectively, than that of the control group (Table 6).

CONCLUSION AND RECOMMENDATION

This study demonstrated the following fundamental findings:

- Although the combined supplementation with clay (5%) and ginger (2%) did not significantly affect the body condition score (BCS) of the ewes, it appeared to reduce the mobilization of body fat reserves during the last three weeks of gestation and the first two weeks of lactation.
- Combined supplementation significantly increased milk production during the first and fifth weeks of lactation, whereas no significant effect was observed during the eighth week.
- Milk fat content was significantly higher in the supplemented group during the first week of lactation; however, no significant differences were detected during the subsequent weeks.
- Total solids differed significantly between the groups during the first week of lactation, with higher values in the control group, whereas no significant differences were observed during the remaining weeks.
- Lactose concentration differed significantly during the first and fourth weeks of lactation, with higher values in the control group; no significant differences were detected at the other sampling times.
- No significant effects of Clay–Ginger supplementation were observed on lamb birth weight or average daily gain (ADG), although lambs from supplemented ewes exhibited higher numerical growth rates during the first four weeks of life.

The results suggest that dietary supplementation with a combination of clay and ginger may provide beneficial effects on the productive performance of ewes during the transition period, particularly with respect to milk production and the conservation of body reserves. However, further studies involving larger sample sizes and detailed investigations of nutrient digestibility, ruminal fermentation characteristics, and rumen microbial populations are required to clarify the mechanisms underlying these effects.

DECLARATIONS

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Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Authors' contribution

A. Smaili: Conceptualization, methodology, data collection, manuscript drafting, data analysis, interpretation. N. Kaboul: Conceptualization, methodology, literature review, data analysis. M. Yousfi: Methodology, Statistical analysis, supervision, manuscript drafting, interpretation. F. Rekik: Conceptualization, methodology, critical revisions. All authors read and approved the final manuscript.

Ethical consideration

All animal care and experimental procedures, including dietary modifications, housing, and handling, strictly complied with the Algerian national regulations on animal health and welfare (Law No. 88-08 of January 26, 1988, amended and supplemented by Law No. 19-03 of July 17, 2019). All experimental phases were conducted under the direct supervision of certified zootechnicians and local veterinary services.

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Competing interests

The authors have not declared any competing interests.

Abbreviations

M.A.D.R: Ministry of Agriculture and Rural Development; T.I.Bre: Technical Institute of Breedings; BCS: Body Condition Score; AFNOR: French standardisation association; AOAC: Association of Official Analytical Chemists; INRA: National Institute for Agricultural Research; UFL: Milk Forage Unit; PDI: Proteins that can be Digested in the Intestine; ADG: Average Daily Gain.

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