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JOURNAL OF APPLIED ANIMAL RESEARCH
2018, VOL. 46, NO. 1, 1344–1351
https://doi.org/10.1080/09712119.2018.1505623

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High feeding level after early weaning had no impact on subsequent milk production in Alpine goats

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ABSTRACT

The objectives of this study were to explore the effects of feeding level after early weaning on growth, reproduction performances and milk production in early weaned kids. Ninety Alpine goats were weaned at 9.7 ± 0.14 kg (30 days of age) and given different levels of concentrate: Control (C, 730 g DM/d, $n = 30$), Low (L, 365 g DM/d, $n = 30$) or High (H, 1090 g DM/d, $n = 30$) until 235 days of age. Goats were weighed twice a month until 11 months of age and once a month during lactation. Morphometric and reproduction parameters, as well as milk production during the first 100 days of the first lactation, were recorded. The ADG of the L group from birth to 230 days of age was decreased by 23% compared to the C group and by 33% compared to the H group ($P < .001$). The prolificacy was 30% higher in the C and H groups compared to the L group and was around 1.6 kids per goat in those two groups ($P < .05$). Milk yield for the first 100 days of lactation was not impacted by the feeding level ($P > .1$). To conclude, after early weaning, feeding level impacted growth but without detrimental effect on milk yield.

ARTICLE HISTORY
Received 26 April 2018
Accepted 13 July 2018

KEYWORDS
Rearing; feeding level; lactation; body weight; Alpine goats

Introduction

In dairy goat farms, replacement kids need to be productive at one year of age and achieve their optimal milk production in first lactation. However, management and feeding of replacement females is expensive and requires extensive labour (Lohakare et al. 2012). In France, changes in rearing practices have been recently observed in dairy goat farms, for many reasons including the reduction of costs (mainly milk replacer cost) and management flexibility. Indeed, the weight of female kids at weaning decreased and some farmers weaned their goat kids at a body weight under 14 kg (PEP Caprin 2011a). In dairy goat farms, early weaning is interesting because of the milk price, and thereby increases farm profitability (Delgado-Pertíñez et al. 2009). However, early weaning can induce a weaning shock resulting in a reduction in growth rate (Morand-Fehr et al. 1982). *Ad libitum* feeding post-weaning is often used after an early weaning to provide enough Dry Matter (DM) and to achieve a compensatory growth (Ferreira and Thornton 2004). In a recent study, we showed that early weaning (12 vs. 18 kg) in Alpine goats did not reduce growth and milk yield in first lactation (Panzuti et al. 2018). Moreover, we showed that *ad libitum* feeding after weaning either until 4 months of age or until 7 months of age did not affect milk production in first lactation (Panzuti et al. 2018). Furthermore, mammary growth is a major determinant of milk yield. Between weaning to 7 months of age (puberty), an allometric growth of the mammary gland seems to occurs in kids (Dessauge et al. 2009; Yart et al. 2012). This is, therefore, a critical period in relation to milk production. Consequently, the nutritional status between birth and puberty needs to be investigated and optimized.

Nutrition plays a major role in controlling many reproduction aspects, including hormone production, gametogenesis, fertilization and early embryonic development in farm animals. Like sheep, but in contrast to cattle, goats have the ability for multiple ovulations, but this may be impaired by inadequate feeding strategies. The onset and continuation of oestrus activity in goats are less dependent on feeding strategies than ovulation rate. In British Saanen, severe energy deprivation during the 19 days before a synchronized oestrus did not affect the proportion of goats coming into oestrus but did decrease the ovulation rate, and increased the length of time between prostaglandin injection and observation of oestrus (Mani et al. 1992). When concentrate offer was increased from 150 to 700 g from the first oestrus, ovulation rate at the sixth oestrus increased from 1.7 to 2.7 in Indonesian goats (Henniawati and Fletcher 1986). Vinõles et al. (2005) suggested that such an effect could be mediated through an increase in blood glucose, insulin and leptin, leading to increased folliculogenesis and ovulation rate. Hence, nutritional strategy during the rearing period is of utmost importance to insure adequate reproductive performances and needs to be optimized.

In goats, the literature on the effect of feeding management during the rearing period on further milk production is scarce. Studies on optimal rearing management after weaning are needed to produce kids with adequate body development to insure optimal milk production. This study was conducted to determine the effects of the level of concentrate offered after

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early weaning on growth, reproduction parameters and milk yield in first lactation in Alpine goats.

Material and methods

All of the animal procedures were approved by the CNREEA No. 07 (Local Ethics Committee in Animal Experiment of Rennes) in compliance with European Union guideline (Directive 2010/63/UE) and French regulations (Decree No. 2013-118, February 7, 2013) (n° APAFIS#3869-20 160 11317178853 vl).

Animals and treatments

Ninety female French Alpine goat kids born between 31 January and 19 February were used during 1.5 years. Immediately after birth, kids were separated from their dam and received 100 ml/kg of Body Weight (BW) of good quality colostrum (Arguello et al. 2004). Goat kids were selected based on their birth weight (over 2.8 kg). Until weaning, kids were housed in the same straw bedded pen and fed *ad libitum* with milk replacer by an automatic feeder. Concentrate, hay and water were available *ad libitum* at 2 weeks of age. Kids were early weaned at 9.7 ± 0.14 kg on average (32 ± 0.5 days of age). After early weaning, kids were randomly assigned to control, low or high feeding management ($n = 30$ per group) balancing the groups according to birth weight, Average Daily Gain (ADG) between birth and 30 days of age, and weaning weight. More precisely, they were 4.1 (± 0.12) kg, 210.6 (± 6.30) g/day and 9.8 (± 0.22) kg for L group; 4.1 (± 0.14) kg, 207.9 (± 5.50) g/day and 9.8 (±0.29) kg for C group; and 4.1 (± 0.12) kg, 203.1 (± 4.83) g/day and 9.8 (± 0.23) kg for H group.

From weaning to 235 days of age, the three groups were fed the same commercial concentrate (Sanders, Montauban-de-Bretagne, France; 19.4% Crude Protein and 11.3 MJ/kg of DM of Metabolizable Energy) according to three different levels. The Control (C) group received 730 g DM/day/kid, the Low (L) group received 365 g DM/day/kid and the High (H) group received 1090 g DM/day/kid. From 235 days of age to mid-gestation, the C and H groups received 730 g DM/day per kid and the L group received 455 g DM/day per kid of the commercial concentrate. 235 days of age are considered as the end of feeding treatments. From mid-gestation to 100 days of lactation, all the goats received the same diets formulated following INRA recommendation (INRA 2010). During the whole experiment, the animals were housed on straw bedding in three pens (one pen per group). Hay was provided *ad libitum*.

Three kids were excluded from the experiment before reproduction; two died for an unknown reason and a third one died of acute diarrhoea. Four goats were excluded from lactation measurements, two because of a back problem at parturition (Control group), one because of a lack of development (Low group) and one because of acute diarrhoea during lactation (Control group).

Measurement of feed consumption, growth, progesterone level, reproduction and milk production

Feed consumption and blood samples: Concentrate offered and refused was weighed daily. Concentrate was distributed homogeneously throughout the feeding trough and consumed quickly by the kids. Quantities of supplied hay were weighed twice a month. Hay refusals were weighed once a month. Dry mater intake of forage, and concentrate and feed conversion ratio, which is the amount of feed required to allow 1 kg of BW gain, were estimated.

From 110 (± 0.5) days of age to 240 (± 0.6) days of age, blood samples were taken every 10 days to estimate the age at first oestrus by the determination of plasma progesterone level. Blood was sampled from the jugular vein. Sampling was performed using Monovette syringes coated with lithium heparin (Sarstedt, Nümbrecht, Germany). The plasma was immediately separated by centrifugation at 3000 ×*g* for 15 min at 4°C and was stored at −20°C until assay. Plasma progesterone (AIA-PACK PROGII (0025239), Kitvia, Labarthe-Inard, France) concentrations were measured with the AIA 1800 ST robot (Tosoh Bioscience, Lyon, France). The intra- and interassay CV were 2.3% and 2.9%, respectively. A kid was considered in first oestrus once the plasmatic concentration of progesterone was over 1 ng/ml on 2 consecutive blood samples (Amoah and Bryant 1984; Waldron et al. 1999).

Growth, morphometric parameters: Goat kids were weighed every week until 30 days of age and every other week between 30 and 355 days of age. During lactation, goats were weighed once a month. In this study, goat kids referred to young animals until the reproduction period (215 days of age). ADG was calculated according to six periods:

- P1 is between birth and weaning (30 ± 0.6 days of age).
- P2 is between weaning and 60 (± 0.6) days of age.
- P3 is between 60 (± 0.6) and 120 (± 0.6) days of age.
- P4 is between 120 (± 0.6) and 230 (± 0.6) days of age which correspond to the closest weighing to the end of the three levels of feeding.
- P5 is between birth and the end of the three levels of feeding.
- P6 is between the weighing closer to fertilization and the weighing closer to 75 days before parturition. The fertilization date was estimated with the progesterone level. A goat was considered as being pregnant when the progesterone level was over 2 ng/ml on four consecutive blood samples and the first date at which the plasma concentration was over 2 ng/ml was considered as the date of fertilization.
- P7 is between the weighing closer to 75 days before parturition and parturition.
- Crown-rump length (distance between the crown and saccrococcygeal joint), wither height and heart girth were measured once a month from 2 months of age to 100 days of milking. Body Mass Index (BMI) was estimated by dividing weight by crown-rump length squared (Laporte-Broux et al. 2011).

Body Composition: At 210 (± 0.6) days of age (before mating) and at mid-gestation (70 ± 1.2 days of gestation), five goats of each treatment were slaughtered for mammary gland sampling. Results of mammary gland analysis will be presented elsewhere. At mid-gestation, the entire carcass was frozen at −20°C (except the mammary gland and the foetus) and ground. Homogeneous samples were taken from each goat and stored at −20°C. Samples were analysed for protein, mineral and lipid content. Protein content was determinated by the Dumas method on a MicroEA (Elementar, Langenselbold, Germany). The lipid content was quantified by methanol and chloroform extraction.

Mating: Reproduction management was flock mating for 6 weeks from 215 (± 0.6) to 257 (± 0.6) days of age. The heats were not synchronized and two billy goats were used for each group. On 30 November (57 ± 1.15 days of gestation), ultrasound scans were performed on all the goats to determine the physiological status (pregnant or not), the gestation stage and the number of fetuses. Goats delivered naturally and birth weight of the offspring, sex and litter size were recorded. In this study, the pregnancy rate referred to the number of pregnant goats at the time of ultrasound scans.

Milk production: Goats were milked twice a day from parturition to 100 days of milking. Milk yield (MY) was recorded at each milking during this period. Milk samples were collected twice a month for milk composition analysis (fat and protein contents). Milk composition was determined by an independent laboratory using an infrared method (MyLab, Chateaugiron, France).

Statistical analysis

Prolificacy was analysed by logistic regression using the multinom procedure of the nnet package of R software (R Core Team 2016). An Exact Fischer's test was performed as a comparison between treatments for the number of kids born. Weights, ADG, morphometric parameters, carcass composition, total litter weight and milk production on the first 100 days of milking were analysed with Type 3 ANOVA using Anova procedure of library car of R software (R Core Team 2016). Bonferroni test was performed as *post hoc* suitable for unbalanced data. Age at the days of measurement was used as a covariable for analysis of weight and morphometric parameters. The duration between parturition and first weighing after parturition was used as a covariable for analysis of weight at parturition. Litter size was used as a covariable for the analysis of total litter weight, ADG between reproduction and md-gestation and ADG between mid-gestation and parturition. Milk yield and composition were analysed as repeated measurements with the GLIMMIX procedure of the Statistical Analysis Systems Institute software (SAS Institute Inc. 2013). In the result section, means of the group and the Standard Error of the Mean (SEM) are presented.

Results

Growth, morphometric parameters and body composition were greatly impacted by feeding levels

The day of weaning, the concentrate consumption was of 33 g of DM/kid for the L group, 39.4 g of DM/kid for the C group and 112.9 g of DM/ kid for the H group (Figure 1). The L group reached its target concentrate level at 40 days of age, the C group at 70 days of age and the H group at 110 days of age. The three groups consumed the same quantity of concentrate per day per kid between weaning to 40 days of age and the C and H groups consumed the same quantity of concentrate

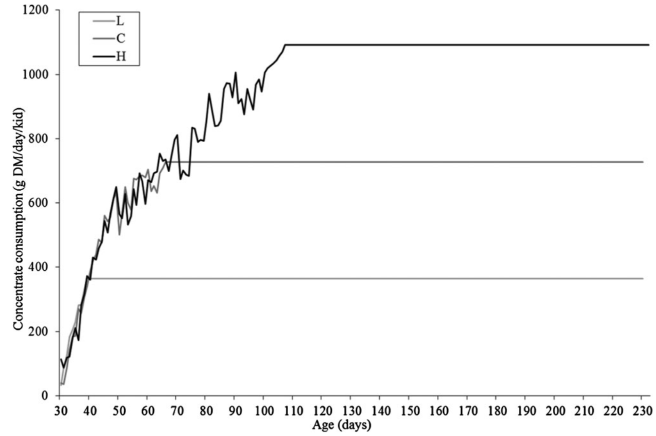

Figure 1. Concentrate consumption of kids fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age.

per kid between 40 and 70 days of age (Figure 1). The L group ate 24% more hay and the H group 40% less than the C group (Table 1). The H group had the highest feed conversion ratio (Table 1). From 60 to 120 days of age (P3), group L

Table 1. Body weight, average daily gain (ADG; g/d), feed consumption per group, age at first estrus and age at first parturition of kids fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age.

					$P > F$	
	L	C	H	SEM	Feeding	Age
Number of goat kids[1]	30/25/20	30/25/20	27/23/17			
Feed consumption per group between 30 and 210 days of age						
Concentrate consumption (g of DM/day/goat kid)	356	679	925	–	–	–
Hay (g of DM/day/goat kid)	579	468	282	–	–	–
Average feed conversion ratio (kg of DM/kg weight gain)	8.0	7.3	6.6	–	–	–
Body weight (kg)						
At birth	4.1	4.1	4.0	0.13	ns	-
At weaning (30 days of age)	9.8	9.8	9.6	0.27	ns	***
At 230 days of age (end of feeding treatment)	31.9^{c}	40.1^{b}	44.9^{a}	0.92	***	**
At parturition	43.3^{b}	49.4^{a}	48.2^{a}	1.17	***	–
ADG (g/d)						
ADG birth – 30 days of age (P1)	210.6^{a}	207.9^{a}	202.8^{a}	6.01	ns	–
ADG 30–60 days of age (P2)	171.5^{a}	188.0^{a}	177.6^{a}	6.12	ns	–
ADG 60–120 days of age (P3)	104.2^{c}	181.1^{b}	205.6^{a}	5.07	***	–
ADG 120–230 days of age	80.4^{c}	107.7^{b}	139.9^{a}	4.05	***	–
ADG birth – 230 days of age	113.2^{c}	147.0^{b}	168.3^{a}	3.57	***	–
ADG fertilization – mid-gestation (P6)	119.1^{b}	142.8^{a}	117.4^{b}	7.19	*	
ADG mid-gestation – parturition (P7)	32.5^{a}	4.4^{b}	-28.5^{b}	10.24	***	–
Age at first estrus	231	232	227	1.6	0.065	–
Age at parturition	382	380	375	2.6	ns	–

Notes: *P*-value: $P > .1$; ns, non-significant; t: $P < .1$; *$P < .05$; **$P < .01$; ***$P < .001$. Means within a row with different superscripts differ ($P < .05$).
[1]number of goat kids before 210 days of age/number of kids at mating/number of kids at first parturition

presented a growth rate 43% lower than group C ($P < .001$; Table 1) whereas the growth rate of group H was 14% higher ($P < .001$, Table 1). From 120 to 215 days of age (P4), the ADG of group H was 31% higher than that of group C (Table 1) whereas the ADG of group L was 22% lower. From birth to 230 days of age (P5), the ADG of group L was 23% lower than group C with a decrease of 47% of concentrate consumption ($P < .001$; Table 1) and the ADG of group H was 14% higher than that of group C with a raise of 36% of concentrate consumption ($P < .001$; Table 1). At 230 days of age, group L weighed 20% and 29% less than groups C and H, respectively (Table 1). The lightest kids weighed 25.0, 31.0 and 34.4 kg for L, C and H groups, respectively. For the L group, 48% of the kids weighed over 30 kg, 36% weighed between 27 and 30 kg and 16% weighed less than 27 kg (data not shown) (Figure 2). At parturition, groups C and H had similar body weight and group L was 12% lighter than the two other groups ($P < .001$; Table 1).

During the whole experiment, the morphometric parameters of groups C and H were not different for wither height (Table 2). However, the wither height of group L was 7% lower during the whole rearing period and 2% lower at the beginning of lactation compared to group C (Table 2). The heart girth of group L was 10% lower during rearing period and gestation and 5% lower during lactation, respectively, compared to group H (Table 2). Group L was on average 8% shorter than group H and was around 7% shorter during the rearing period compared to group C (Table 2). At the end of feeding treatment, group H had a heart girth 6% higher and was 3% longer than group C (Table 2). At 80 days of milking, the three groups had a similar crown-rump length (Table 2). During the whole experiment, BMI of C and H groups was similar (Table 2). BMI of L group was around 15% lower at the end of feeding level and 12% during gestation compared to the two others groups (Table 2).

The L group had more carcass mineral content than the C group (Figure 3(a)). On the contrary, the H group had the lowest carcass mineral content (Figure 3(a)). The H group had lower protein and higher lipid proportion in the carcass than the L group (Figure 3(b,c)). The proportion of lipid and protein was similar between C and H groups (Figure 3(b,c)).

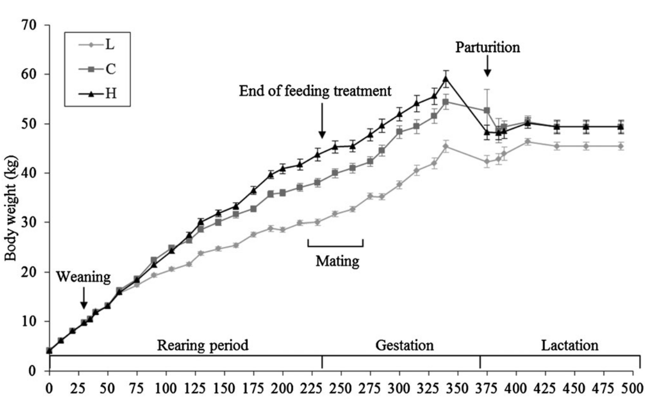

Figure 2. Body weight of kids fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age.

Reproduction performance was not modified by the level of concentrate

The age at first oestrus tended to be advanced in the H group compared to the two other groups ($P < .10$; Table 1). However, the age at first parturition was similar between groups. The duration between the beginning of mating and parturition was reduced in group H ($P < .05$; Table 3). Nevertheless, the pregnancy rate was not affected by the diets. The prolificacy was 30% higher in groups C and H compared to group L ($P < .05$; Table 3). The total litter weight was similar between the three groups ($P > .10$; Table 3).

The level of concentrate after early weaning did not affect milk production and milk composition

The lactation curve is presented in Figure 4 and average milk production is presented in Table 4. On average, during the second week of lactation, group C produced 22% more milk per day compared to group H (Figure 4). After the second week of milking, milk production was similar between groups (Figure 4). During the first 100 days of milking, the goats produced the same quantity of milk per day and of cumulated milk ($P > .05$; Table 4). Fat content, protein content, fat yield and protein yield were similar between groups (Table 4).

Table 2. Morphometric parameters over rearing period and first lactation in kids fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age

					P > F	
	L	C	H	SEM	Feeding	Age
Number of goat kids[1]	30/25/19	30/25/17	27/23/17			
Wither height (cm)						
At 4 months of age	58.2^{b}	61.8^{a}	62.3^{a}	0.48	***	*
At the end of feeding treatment	64.0^{b}	69.9^{a}	69.5^{a}	0.51	***	t
At mid-gestation	67.8^{b}	71.6^{a}	72.1^{a}	0.51	***	*
At 50 days of lactation	71.7^{b}	73.5^{a}	73.8^{a}	0.53	*	*
At 80 days of lactation	72.7^{b}	74.2^{ab}	74.6^{a}	0.52	*	ns
Heart girth (cm)						
At 4 months of age	65.5^{b}	69.7^{a}	71.3^{a}	0.54	***	**
At the end of feeding treatment	74.0^{c}	79.5^{b}	84.0^{a}	0.72	***	*
At mid-gestation	79.4^{c}	85.9^{b}	88.5^{a}	0.76	***	*
At 50 days of lactation	83.3^{b}	86.2^{a}	87.4^{a}	0.67	***	ns
At 80 days of lactation	83.3^{b}	85.2^{ab}	86.6^{a}	0.66	**	ns
Crown-rump length (cm)						
At 4 months of age	88.3^{b}	96.6^{a}	99.2^{a}	0.86	***	**
At the end of feeding treatment	95.1^{c}	100.0^{b}	103.2^{a}	0.88	***	ns
At mid-gestation	97.8^{b}	104.8^{a}	105.8^{a}	0.85	***	***
At 50 days of lactation	109.3^{b}	112.5^{ab}	114.1^{a}	1.09	**	ns
At 80 days of lactation	106.2	108.7	109.1	1.03	t	ns
BMI (kg/m^2)[2]						
At 4 months of age	30.7	30.8	30.7	0.52	ns	ns
At the end of feeding treatment	35.2^{b}	40.0^{a}	42.5^{a}	0.80	***	ns
At mid-gestation	39.5^{b}	44.0^{a}	46.0^{a}	0.84	***	ns
At 50 days of lactation	38.1	39.0	38.0	0.72	ns	t
At 80 days of lactation	41.2	42.4	41.5	0.73	ns	ns

Notes: *P*-value: $P > .1$; ns: non-significant; t: $P < .1$; *$P < .05$; **$P < .01$; ***$P < .001$. Means within a row with different superscripts differ ($P < .05$).
[1]number of goat kids before 210 days of age/number of kids at mating/number of kids at lactation.
[2]Body Mass Index (kg/m^2) = BW (kg)/(Crown-rump length (m))^2.

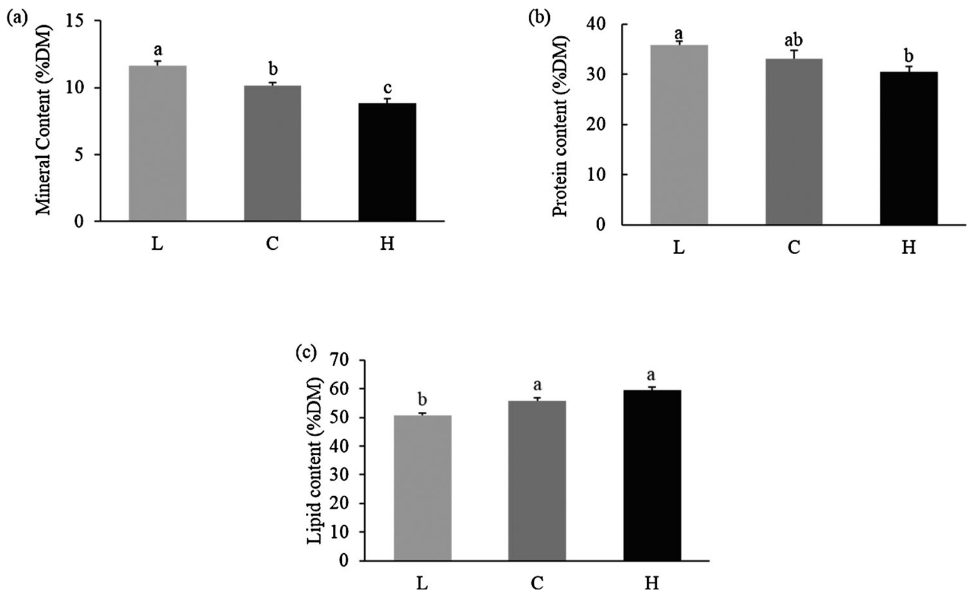

Figure 3. Mineral content (a), protein content (b) and lipid content (c) at mid- gestation in carcasses of goats fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age [a–b]Means within a row with different superscripts differ ($P < .05$).

Table 3. Reproduction parameters at first parturition in goat kids fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age.

	L	C	H	SEM	$P > F$ Feeding
Goats at mating (*n*)	25	25	23		
Pregnancy rate (%)	100	100	100	–	–
Duration between billy goat introduction and parturition (days)	168^{a}	166^{ab}	160^{b}	2.54	*
Prolificacy	1.3^{b}	1.7^{a}	1.6^{a}	0.13	*
Total litter weight (kg)	7.0	7.3	7.0	0.27	ns

Notes: *P*-value: $P > .1$: ns, non-significant; t: $P < .1$; *$P < .05$; **$P < .01$; ***$P < .001$. Means within a row with different superscripts differ ($P < .05$).

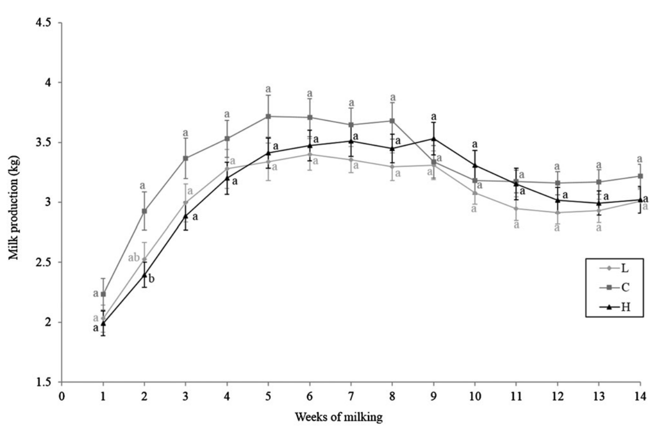

Figure 4. Milk production of goats fed a low (L), control (M) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age [a–b]Means within a row with different superscripts differ ($P < .05$).

Discussion

In dairy goats, early weaning is often associated with *ad libitum* feeding post-weaning to achieve growth compensation (Palma and Galina 1995; Ferreira and Thornton 2004). However, high feeding level during the rearing period can impair mammary gland development and *in fine* milk production in first lactation (Bowden et al. 1995; Sejrsen and Purup 1997). The objective of our study was to evaluate the impact of three levels of concentrate after early weaning on growth, reproduction parameters and milk production in kids.

Table 4. Milk production at first lactation in goats fed a low (L), control (C) or high (H) level of concentrate between weaning (30 days of age) and 235 days of age.

	L	C	H	SEM	$P > F$ Feeding
Number of goats	19	17	17		
Milk yield for the first 100 days of lactation (kg)	301.6	327.7	308.3	11.41	ns
Milk production (kg/day)	3.0	3.3	3.1	0.11	ns
Fat content (%)	3.8	3.9	4.0	0.09	ns
Protein content (%)	3.1	3.1	3.1	0.05	ns

Notes: *P*-value: $P > .1$: ns, non-significant; t: $P < .1$; *$P < .05$; **$P < .01$; ***$P < .001$. [a–c]Means within a row with different superscripts differ ($P < .05$).

During this experiment, kids were submitted to an abrupt weaning at 10 kg. There was no drop in growth after early weaning in any of the three groups. Measurement of their feed consumption showed that the kids ate between 30 and 115 g of concentrate the day of weaning. Morand-Fehr (1981) observed that an abrupt weaning at 10 kg, after *ad libitum* milk feeding, induced a very marked diminution of the growth rate two weeks after weaning due to a reduction in solid feed intake (Morand-Fehr 1981). However, with early weaning (10 kg), an intake of 30–50 g of concentrate per day before weaning seems sufficient to reduce the weaning shock (Morand-Fehr 1981). Therefore, we could assume that the kids ate enough concentrate before weaning not to exhibit weaning shock. Indeed, Panzuti et al. observed no weaning shock after having weaned Alpine goats at 12 kg and 40 days of age as shown also by Ferreira and Thornton (2004) in Saanen kids weaned at 42 days of age (Panzuti et al. 2018). We could assume that the improvement of feed quality (milk replacer and concentrate), since 1980, had a beneficial impact on solid feed intake. It has been shown that free access to water during the rearing phase stimulated concentrate intake in young calves (Kertz et al. 2017). In billy goats, water restriction compared to free access has been shown to reduce solid food intake (Prasetiyono et al. 2000). Water intake is a key factor in relation to concentrate consumption and therefore to growth. However, few studies have been conducted on the impact of water availability on concentrate consumption and the growth of the young.

The C and H groups had the same body development and very similar carcass composition at mid-gestation, which was 2 months after the reduction of concentrate supply for the H group. At mid-gestation, the only difference between the two groups was the heart girth. Moreover, the L group is the group with the higher protein content and the lower lipid content but with the lower morphometric parameters even after the increase in concentrate supply. In other species, increasing feeding level increased body development, mainly the heart girth which is highly correlated to the BW (Le Cozler et al. 2010; Villeneuve et al. 2010). The lack of differences between the C and H groups suggested that increasing the concentrate level during the rearing period over the control level was beneficial neither for body development nor for body composition in kids. It appears that the C diet offered a compromise between body development and fat deposition. In France, the recommendation is to give 400 g of raw matter of concentrate at 4 months of age (PEP Caprin 2011b) which corresponds to our low level of concentrate. We could hypothesize that French recommendations do not allow to achieve maximal body development of kids.

In dairy goat farms, the objective is to achieve first parturition at one year of age. This objective is highly influenced by birth season and weight at first breeding (Amoah and Bryant 1984; Papachristoforou et al. 2007). In our experiment, the progesterone level showed that the first oestrus of goat kids appeared at the same age independently of the level of concentrate offered. First estruses were observed at the end of September and beginning of October, when the day length decreased in the North hemisphere. At first oestrus (231 ± 1.9 days of age), the L group weighed 50% more than the average adult BW, which was 60 kg in our experimental farm. Other studies in goats and sheep are in agreement with this observation. In Spanish Payoya goat, the level of feeding did not affect the age at first oestrus whatever the birth period (Zarazaga et al. 2009). Zarazaga et al. (2009) observed that goats fed to achieve 100 g/day of ADG from 200 days of age until the end of the reproduction period had their first ovulation on the same date as goats fed to achieve 50 g/day of ADG. In ewes, Forcada et al. (1991) showed also that the age at puberty was not affected by the nutritional level applied from 3 months of age to 1 year of age. BW is often considered to have a great impact on the attainment of puberty and it is advised to delay breeding until the kids reached 60–75% of their mature body weight (Shelton 1978). However, numerous studies showed that kids could achieve the onset of puberty before the attainment of 60% of their adult BW. Indeed, Saanen kids could reach puberty as early as at 36% of their adult BW (Amoah and Bryant 1984). More recent studies showed that kids could reach puberty at around 50% of their adult BW (Papachristoforou et al. 2007; Zarazaga et al. 2009). In small ruminants, our results, as well as other studies, showed that the season was probably the main factor influencing the onset of reproductive activity in goat kids. The photoperiod plays an essential role and the seasonal oestrus occurs when the day length decreases. The reduction in day length is associated with the observation of oestrus and a resumption of ovarian activity in adult dairy goats (Chemineau et al. 2010).

Goats from the C or H groups had a higher body weight at mating and were more prolific than goats from the L group. The C and H groups presented also a shorter duration between billy goat introduction and parturition than group L. Therefore, we assume that groups C and H were fertilized before group L. Nutrition seems to have only a small impact on ovulation rate (Zarazaga et al. 2009) which seems to be more related to the body weight at first oestrus (Zarazaga et al. 2009). In ewes, the heaviest ewes had a higher ovulation rate (Bizelis et al. 1990). In addition, the ovulation rate is the highest at first oestrus and declines from the second oestrus (Edey et al. 1978; Bizelis et al. 1990). The differences in prolificacy observed in our study could be due to the level of feeding through its effect on body weight.

In dairy animals, milk production is depended on body development achieved during the rearing period (Morand-Fehr et al. 1996). Group L was the only group that was mated at less than 50% of their adult body weight. However, no reduction in milk production was observed in group L compared to groups C and H. In goats, Shelton (1978) suggested that mating kids at less than 60% of the adult BW affected future milk production adversely. However, Alpine kids weighing at least 27 kg at mating seemed to express all their potential milk production in first lactation (Morand-Fehr et al. 1996). Therefore, the fact that kids have reached the minimal weight to ensure milk production could explain the absence of effect of the feeding levels on milk production. Nevertheless, more investigations are needed to establish the link between weight at breeding and milk production in first lactation.

In dairy herds, rearing management is known to have a great incidence on milk production in first lactation. The negative impact of enhancing growth by high feeding level during the rearing period is well described in heifers (Le Cozler et al. 2008; Lohakare et al. 2012). A high level of feeding during the rearing period could impair milk production in first lactation by increasing the fat pad development at the expense of parenchyma (Sejrsen and Purup 1997; Sejrsen et al. 2000). We observed that the three groups produced the same amount of milk during the 100 first days in milk. In dairy goats, the effect of high feeding level and/or high ADG during rearing on milk production has been rarely studied. Interestingly, an *ad libitum* feeding from weaning to parturition highly reduced milk production in first lactation compared to restricted feeding management in Alpine goats (Aubry et al. 2012). On the contrary, milk production was not affected by a high feeding level of the same concentrate from weaning until the mating period in another experiment performed in the same laboratory (Panzuti et al. 2018). The only difference between the two studies was the duration of the *ad libitum* feeding period. These two studies already suggested that the level of feeding during the rearing period did not affect milk production in first lactation. Together with our results, it can therefore be hypothesized that, in dairy goats, the rearing period is not a critical period for the establishment of the lactation function and per se for the mammary gland development. This hypothesis needs to be confirmed by mammary gland sampling before puberty to study the impact of feeding management on parenchyma development.

To conclude, the level of concentrate supplied after early weaning affected the growth of goat kids. Nevertheless, no long-term effects were observed in this study on reproduction or milk yield in first lactation. The control diet seems to appear as a good way to reduce the cost related to the rearing period in goat kids and to meet the optimal growth to ensure milk production.

Acknowledgements

We gratefully acknowledge IEPL (Domaine de Méjusseaume, Le Rheu, France) support of this work, the staff of the experimental farm, the staff of the laboratories of UMR MoSAR and Saint-Gilles, as well as Laurent Drouet (MixScience, France), Jessie Guyager (Neovia,France), Cédric Faure (CCPA, France), Romain Bidaux (Cargill, France) and Christophe Garnier (Techna, France) for their help and support of this study.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was support by the Agence National de la Recherche Technologie (ANRT) under convention n° 2015/0305.

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