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Dipartimento di Scienze Zootecniche e Ispezione degli Alimenti.
Università di Napoli "Federico II", Italy.

Corresponding author: Dr. Fulvia Bovera. DISCIZIA. Facoltà di Medicina Veterinaria, Università di Napoli "Federico II". Via F. Delpino 1, 80137 Napoli, Italy - Tel. +39 081 4421914 - Fax: +39 081 292981 - Email: bovera@unina.it

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ABSTRACT

In order to enhance our knowledge of milk sheep rationing, 30 Sarda primiparous ewes, for which single birth was diagnosed by ultrasonography prior to lambing, were divided into two homogeneous groups (L-NSC and H-NSC) and fed isoproteic diets containing different amounts of non-structural carbohydrates (NSC, 36 vs 40 % DM). The lambs were weighed both at birth (between February and March 2002) and at sale (about one month later) in order to estimate milk produced by their mothers during the lactation period, by using a specific equation developed on Sarda ewes. Individual milk yield and quality were then monitored monthly until the ewes dried off (July 2002). Our results showed that group H-NSC (which received the diet with the highest NSC content) was associated to the highest milk yield ($P<0.01$) during the suckling period. In contrast, in the milking period group L-NSC showed significantly higher ($P<0.05$) mean milk yield (996.2 vs 899.8 g/d) and fat and protein corrected milk yield (979.6 vs 877.7 g/d). Dietary treatments did not significantly affect milk composition.
In conclusion, considering the milk production of each group as a function of the lactation month, group H-NSC had its best performance during the first two months of lactation, while group L-NSC was more productive during the remaining months. Also the percentage of protein, fat and casein of the milk during milking showed a similar trend. While the latter parameters were higher in the H-NSC group during the first two months of milking, from the 4th control onward higher levels were observed in the L-NSC group. These results suggest, at least for Sarda primiparous ewes, the adoption of diets with different contents of non-structural carbohydrates according to the productive period (40 %, DM basis, in the first two months of lactation, 36 %, DM basis, in subsequent months).

Key words: Non-structural carbohydrates, Sarda ewes, Milk production.

RIASSUNTO

INFLUENZA DEL CONTENUTO DI CARBOIDRATI NON STRUTTURALI DELLA DIETA SULLE PERFORMANCES PRODUTTIVE DI PECORE PRIMIPARE DI RAZZA SARDA.

Allo scopo di migliorare le conoscenze sul razionamento della pecora da latte, un mese prima del parto 30 pecore primipare di razza Sarda, per le quali, mediante tecnica ultrasonografica, era stato diagnosticato parto singolo, sono state divise in due gruppi omogenei (L-NSC e H-NSC) alimentati con due diete isoproteiche ma a diverso contenuto di carboidrati non strutturali (NSC, 36 vs 40 % s.s.). Gli agnelli sono stati pesati alla nascita (fine febbraio – inizio marzo 2002) e al momento della vendita (circa un mese più tardi) in modo da stimare il latte prodotto dalle madri durante il periodo di *allattamento, utilizzando una specifica equazione messa a punto per pecore di razza Sarda. Successivamente, è stata controllata con cadenza mensile la produzione quanti-qualitativa di latte individuale fino alla messa in asciutta delle pecore (fine luglio 2002).*

Dai risultati ottenuti è emerso che il gruppo alimentato con la dieta a maggior contenuto di NSC (H-NSC) ha presentato produzioni più elevate (P < 0,01) durante il periodo dell'allattamento, mentre nei mesi di mungitura il gruppo L-NSC ha mostrato produzioni medie significativamente (P < 0,05) più elevate di latte sia reale (996,2 vs 899,8 g/d) che corretto in funzione del contenuto percentuale di grasso e di proteine (979,6 vs 877,7 g/d). Non sono, invece, emerse differenze significative tra i parametri della composizione chimica del latte imputabili alle due diete in esame. Considerando, infine, la produzione di latte di ciascun gruppo in funzione del mese di lattazione, le migliori performance sono state fornite durante i primi due mesi di lattazione dal gruppo (H-NSC) alimentato con la maggiore concentrazione di NSC, successivamente da quello L-NSC. Andamento simile hanno fatto registrare anche i contenuti percentuali di proteine, grasso e caseina determinati sul latte munto: infatti essi, risultati più elevati nel gruppo H-NSC durante i primi due mesi di mungitura, sono stati a partire dal 4° controllo, maggiori nel gruppo L-NSC. Tali risultati suggeriscono, per pecore primipare di razza Sarda, l'adozione di diete a differente contenuto di carboidrati non strutturali in funzione della fase produttiva (40 % s.s. nei primi due mesi di lattazione, 36 % s.s. nella fase successiva).

Parole chiave: *Carboidrati non strutturali, Pecore di razza Sarda, Produzione di latte.*

Introduction

Sarda sheep are the most numerous of the three main milk breeds recorded in the 1999 genealogical book (Sarda, Comisana and Massese). There are about 4,700,000 (ASSONAPA, 2002) head raised above all in Sardinia and Sicily (about 81 % of the Italian population) although the last few years have seen an increase in the centre-south (about 17 % of the Italian population). Genetic selection implemented for Sarda ewes long ago has contributed greatly to increasing milk production that was 137 ± 62 1itres per 110 ± 34 days of milking for primiparous animals in 1999 (Sanna et al., 2000). Knowledge of milk ovine rationing, with beneficial effects for the productive potential of the sheep raised, has also improved. Indeed, during the last few years, researchers in Italy and abroad have focused on the effects of non-structural carbohydrate diet contents of ewe production during each period in the productive cycle. However, such research has been scant or characterized by conflicting outcomes. Brown and Hogue (1985) noted in Finnish sheep during the first lactation weeks that rations with a forage (F) to concentrates (C) ratio of 60 to 40 induced milk production much lower than rations with a 20 to 80 F to C ratio. In East Friesian ewes intake and milk production were higher (from the 120th day of lactation) in the animals receiving 20 % of non-structural carbohydrates (NSC) than in those receiving 35 % NSC (Cavani et al., 1990). Equally, in Sarda ewes with more than three months of lactation fed diets with different protein and NSC concentrations (14 vs 21 % and 29 vs 40 %, respectively), Cannas et al. (1998) noted that the group receiving a diet with the lower concentration of non-structural carbohydrates showed a higher intake and milk production. Since all the above-mentioned publications studied the effect of NSC only in single parts of the lactation, the aim of the present study was to extend our knowledge of this interesting topic, evaluating the influence of two different non-structural carbohydrate concentrations in diets during the whole lactation period on the milk yield and quality of Sarda primiparous ewes.

Material and methods

Diets and feeding plan

The study was carried out on a Sarda sheep farm in the province of Caserta, Italy, where the animals were divided into groups based on their production level and kept indoors. The study concerned 30 pregnant sheep, for which single births had been diagnosed by echography. One month before lambing, they were divided into two homogeneous groups (L-NSC and H-NSC) by estimated date of birth and body weight (39.8 kg ± 5.6 vs 39.6 ± 6.8, respectively). The groups received two different diets, identified as L-NSC and H-NSC, respectively. The ingredients of the diets are reported in Table 1. The diets had the same forage to concentrate ratio (47.5 to 52.5) but they differed in concentrate composition: diet L-NSC (low NSC) consisted only in a commercial concentrate, while diet H-NSC (high NSC) was a mix of the same commercial concentrate (40 %) with corn meal (38.3 %) and soybean meal (21.7 %). In the calculation of forage to concentrate ratio, corn silage was considered as 50 % forage and 50 % concentrate.

The chemical and nutritional characteristics of each ingredient (corn silage, oat hay, concentrate, corn meal and soybean meal), shown in Table 2, were determined as follows:

- dry matter (DM), ash, crude protein (CP), ether extract (EE) and crude fiber, following ASPA (1980) indications;
- neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (ADL), according to Van Soest et al. (1991);
- soluble protein (SP), non-protein nitrogen (NPN), nitrogen bound to NDF (NDIP) and nitrogen bound to ADF (ADIP), according to Licitra et al. (1996);
- starch with the polarimetric method described by Martillotti et al. (1987).

The nutritive value (as Milk Forage Unit, MFU) was estimated following INRA (1988). The NSC concentration was calculated according to Sniffen et al. (1992):

$$NSC = 100 - [(NDF - NDIP) + CP + EE + ash]$$

The chemical-nutritional characteristics of the two diets, also reported in Table 2, were based on the analysis done on each of the ingredients.

After lambing, due to complications not related to the treatments, two sheep from group L-NSC and three from group H-NSC were eliminated from the experiment. Under the feeding scheme described in detail in Table 3, different quantities of DM were supplied, in the same quantity, twice per day (7 a.m. and 6 p.m.) as total mixed ration in proportion to body weight (BW) (from 2.2 % of BW during the 5th month of gestation, to 5 % of BW from the 15th to the 94th day of lactation). Every day, before the morning feed, the orts, generally consisting only of hay residues, were weighed. Their amount ranged from 7 to 14% of the amount supplied.

Lambs

At birth, which occurred in all cases in the 15 days after 20 February 2002, the lambs were weighed and left in a separate box with their mothers in order to monitor colostrum intake and

Table 1. Ingredients (% DM) of the two diets.

	L-NSC	H-NSC
Corn silage	35.0	35.0
Oat hay	30.0	30.0
Concentrate[1]	35.0	14.0
Corn meal[2]	-	13.4
Soybean meal	-	7.6

1 *Ingredients: corn meal, toasted soybean meal, barley meal, sunflowers meal, wheat middling, beet pulp, ground carob beans, cotton seeds meal, molasses, dehydrated dicalcium phosphate, calcium carbonate, sodium bicarbonate, salt, magnesium oxide. Min-vit integration per kg: Vit. A 40,000 U; Vit. D_3 4000 U; Vit. E 85 mg; Vit B_1 4 mg; Vit. B_2 4 mg; Vit. B_{12} 0.05 mg; Vit. K_3 10 mg; Vit. PP 200 mg; pantotenic acid 6 mg; colin 800 mg; Mn 170 mg; Co 2.6 mg; Zn 180 mg; I 6 mg; Se 0.26 mg.*

2 *Min-Vit integration per kg: Vit. A 65,000 U; Vit. D_3 6500 U; Vit. E 130 mg; Vit B_1 6 mg; Vit. B_2 6 mg; Vit. B_{12} 0.08 mg; Vit. K_3 15 mg; Vit. PP 300 mg; pantotenic acid 9 mg; colin 1250 mg; Mn 260 mg; Co 4 mg; Zn 280 mg; I 9 mg; Se 0.4 mg.*

their health. The male to female ratio among lambs was 54 to 46 in L-NSC group and 50 to 50 in H-NSC group. After 4 - 5 days, the mothers and lambs were reintroduced into the experimental group, where they stayed until sale (about 30 days old). Before sale they were weighed again to calculate their weight gain during the suckling period.

These measurements allowed the estimation of the mean amount of milk suckled by the lambs using the equation developed by Pulina et al. (1986) for Sarda sheep:

$$IM = 140.6 + 4.25 \times WG - 0.705 \times BW^{0.75}$$

where IM is the milk intake of lambs (g/d) in the period 0 – 30 days, WG the daily weight gain of the lambs (g/d) and $BW^{0.75}$ (kg) the metabolic weight of the lambs at sale.

Milk yield and quality

Milk production of each ewe was monitored from the first few days of April, when the lambs were sold, until dry-off (end of July 2002) on monthly basis. The ewes were milked twice daily. At production controls, individual milk samples (n = 125; about 20% of milk produced but in no case less than 60 ml, to obtain representative final samples of daily production) were collected. The samples were used for the following measurements:

- fat and total nitrogen concentrations by using a milk analyser (Milko Scan 133 B.N. Foss Electric, Hillerod, Denmark) calibrated with an appropriate sheep milk standard;
- non-casein nitrogen (NNC) and non-protein nitrogen (NPN) with the Kjeldhal method, following the indications of the ASPA (1995);
- total casein, calculated as: (total nitrogen – non-casein nitrogen) x 6.38 (ASPA, 1995);
- serum proteins, calculated as: (total proteins – casein – non-protein nitrogen x 6.38) (ASPA, 1995);
- somatic cells count, using FOSSOMATIC 90/215 (Foss Electric, Hillerod, Denmark).

The somatic cells count was converted into a base ten logarithm in order to normalize the distribution of the data.

From the recorded milk production and from fat and protein contents, the production of milk

Table 2. Chemical and nutritional characteristics of the ingredients and of the two diets.

		Ingredients					Diets	
		CS	OH	C	CM	SM	L-NSC	H-NSC
Dry Matter	%	32.17	89.26	88.52	86.63	88.22	69.02	68.74
Crude protein	% DM	8.48	11.62	21.73	8.22	45.39	14.06	14.05
Crude fiber	"	20.76	25.78	9.48	4.80	8.30	18.31	18.16
Ether extract	"	3.20	1.71	3.23	2.91	0.65	2.77	2.51
Ash	"	6.00	11.17	9.73	1.67	8.42	8.86	7.68
NDF	"	44.47	57.96	22.24	11.29	13.23	40.74	38.59
ADF	"	29.07	36.34	14.30	5.50	9.00	26.06	24.49
ADL	"	3.08	4.89	0.94	1.65	2.42	2.87	3.10
Soluble protein	"	5.90	3.47	4.48	2.05	3.81	4.68	4.28
NPN	"	4.85	2.65	2.90	1.00	2.98	3.52	3.23
NDIP	"	1.23	3.89	2.16	1.65	8.40	2.37	2.75
ADIP	"	0.84	1.83	1.05	0.94	2.88	1.21	1.33
Starch	"	28.63	12.10	20.25	66.50	20.74	20.74	26.10
NSC	"	39.08	21.44	45.26	77.57	40.71	35.94	39.92
NSC/CP		4.61	1.84	2.08	9.44	0.90	2.56	2.84
MFU per kg DM		0.86	0.70	0.89	1.25	1.14	0.82	0.90

CS: corn silage; OH: oat hay; C: concentrate; CM: corn meal; SM: soybean meal corrected to 6.5% of fat and 5.8% of protein (FPCM) was calculated using the equation reported by Serra et al. (1998):

$$FPCM\ (g) = (0.255 + 0.085 \times F + 0.035 \times P) \times DMP$$

where: F is the percentage of fat, P the percentage of protein and DMP daily milk production (g).

Statistical analysis

All the obtained results were analyzed with the GLM procedure of SAS (2000) following the model:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$$

where y_{ijk} is the single observation, μ the general mean, α_i the diet effect (i = 1, 2), β_j the effect of sex (lamb weight and weight gain) or milking month (milk production and quality; j = M, F or 1,…5), $\alpha\beta_{ij}$ is the interaction (diet x sex or diet x milking month) and ε_{ijk} the error.

The "intra-effect" comparison among the means was performed by Tukey test (SAS, 2000).

Table 3. Dry matter supplied to the ewes by distance from lambing

Period		DM, % BW
Before lambing		2.2
Days from lambing:		
	until 5th	3.7
	6th – 14th	4.5
	15th – 94th	5.0
	95th –118th	4.5
	119th – 148th	3.7

BW = body weight; DM = dry matter

Results and discussion

As shown in Table 2, the diets were isoproteic while diet L-NSC had the lowest non-structural carbohydrate (35.9 vs 39.9% of DM) and starch (20.7 vs 26.1 % of DM) contents and hence the lowest nutritive value (0.82 vs 0.90 MFU/kg DM).

Table 4. Weight at birth (WB), weight at sale (WS), daily weight gain (WG) and milk consumed by lambs (CM) classified by diet and sex.

	WB, kg	WS, kg	WG, g/d	CM, g/d
	Diet Effect (DF = 1)			
L-NSC	3.56	10.32^B	217.1	1112.7^b
H-NSC	3.47	11.52^A	253.5	1282.7^a
	Sex Effect (DF = 1)			
F	3.05^B	9.66^B	201.7^B	1050.8^B
M	4.25^A	12.24^A	270.2^A	1357.3^A
	Significance			
D	ns	**	ns	*
S	**	**	**	**
DxS	ns	ns	ns	ns
	Variance of error (DF = 47)			
	0.24	1.43	2407.8	12789.4

D = diet effect; S = gender effect; DxS = interaction diet per gender;
*A, B and **: P < 0.01; a, b and *: P < 0.05; ns: not significant*

Table 5. Yield, some chemical characteristics and somatic cell contents (SC) of milk classified by diet and month in milk.

	Yield g/d	Fat %	CP %	FPCM g/d	Casein %	NPN %	SP %	SC log_{10}
	Diet effect (DF = 1)							
L-NSC	996.2a	6.69	5.02	979.6a	3.98	0.15	0.89	5.32
H-NSC	899.8b	6.71	4.99	877.7b	3.93	0.16	0.90	5.29
	Month in milking effect (DF = 4)							
1	1334.4A	5.59E	4.67E	1187.9A	3.76B	0.17A	0.73Bb	4.46B
2	1191.6B	6.14D	4.76D	1123.7A	3.90B	0.13C	0.73Bb	4.61B
3	940.8C	6.36C	4.96C	910.0B	3.88B	0.16Aab	0.88Ba	5.78A
4	750.9D	6.93B	5.15B	740.4Ca	3.92B	0.14BCb	1.08A	5.91A
5	532.0E	8.48A	5.48A	614.4Cb	4.31A	0.13C	1.08A	5.76A
	Significance							
D	*	ns	ns	*	ns	ns	ns	ns
M	**	**	**	**	**	**	**	**
I	*	*	*	*	**	ns	ns	ns
	Variance of error (DF = 115)							
	61274	0.47	0.22	51063	0.001	0.158	0.04	0.37

CP = crude protein; FPCM = fat and protein corrected milk; NPN = non-protein nitrogen; SP = soluble protein.
D = diet effect; M = month in milking effect; I = interaction D x M.
*A, B and **=P<0.01; a, b and *=P<0.05; ns = not significant.*

Besides, the diet with the highest non-structural carbohydrate content (diet H-NSC) had a slightly lower concentration of protein fractions quickly degradable in the rumen (non-protein nitrogen and soluble protein).

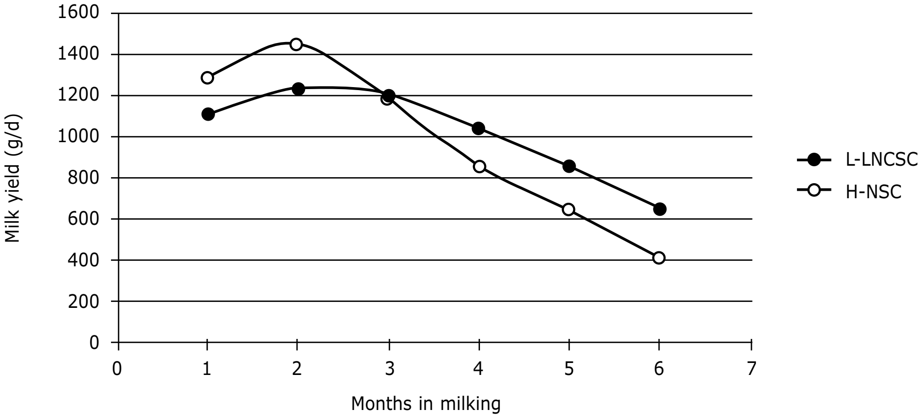
Lambs

Table 4 reports mean weight at birth and at sale, daily weight gain, and the amount of milk suckled by lambs. The lambs were slaughtered when they were about 32 days old (31.77 vs 32.33, for groups L-NSC and H-NSC, respectively); the females reached the slaughter weight a little later (32.80 vs 30.90 days).

The different content of non-structural carbohydrates of the diets did not affect the weight of lambs at birth, in agreement with the findings of Ronchi et al. (1993), who fed three groups of Sarda ewes from weaning throughout the first lactation with three diets differing in energy value. In this experiment daily weight gains (on average 253.7 g/d) were very close to those observed in our experiment (217.1 vs 253.5 g/d, respectively for groups L-NSC and H-NSC) and not statistically different among the experimental groups. In subsequent milk yield controls at 3 and 30 days from lambing, the authors observed that the group fed the diet with the lowest energetic concentration showed higher milk production, albeit not statistically different from the other two groups. They attributed the results to the uncorrected development of the mammary gland due to the high energetic concentrations of the diets received in pre-puberty.

The higher weight at sale and higher daily weight gain in the lambs of group H-NSC (Table 4) were the results of their mothers' greater milk production, as estimated on the basis of lamb growth (1282.7 vs 112.7 g/d, for groups H-NSC and

Figure 1. Milk production of the two experimental groups throughout lactation. The value for the first month was estimated based on lamb growth with the equation of Pulina et al. (1986), while the value for the other months milk production was directly measured at milking.

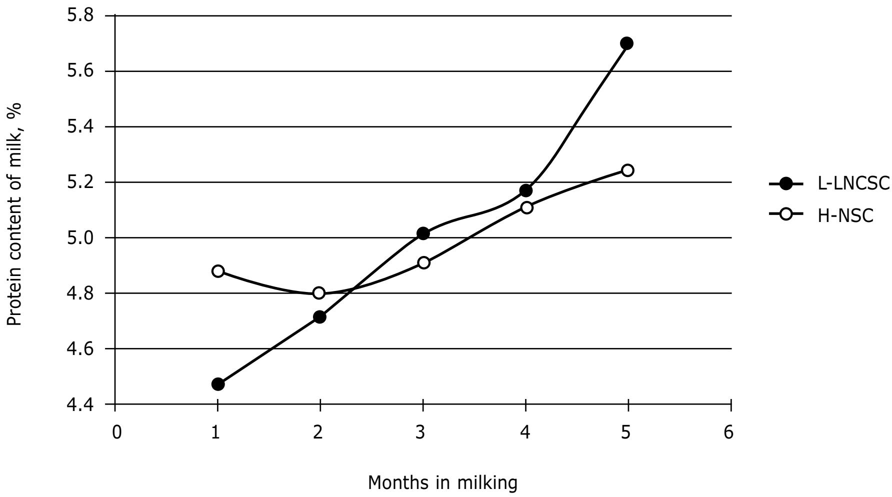


L-NSC, respectively; P < 0.05). As regards gender differences, all the examined parameters were significantly higher in males (P < 0.01). The interaction between diet and gender was in no case statistically significant.

Milk yield and quality

Table 5 reports milk production (actual and FPCM), milk fat content, protein, protein fractions (casein, NPN and serum proteins), as well as the somatic cells count expressed in $\log_{10}$. Actual milk production was significantly higher (P < 0.05) in the group fed the diet with the lowest NSC content and, as there were no differences in milk fat and protein contents between groups, the FPCM production showed the same trend. Non-protein nitrogen, SP and casein represented on average 3 %, 18 % and 79 % of milk total protein, respectively.

Figure 2. Milk protein content of the two experimental groups throughout lactation.



While the latter two values are in agreement with those reported for Sarda sheep by Pulina (1990), the NPN contents are lower than those reported by the same author (3 % vs 5 %). The other examined parameters showed no statistically significant differences between the two groups. As expected, production fell progressively during the lactation from 1188 g/d of FPCM to about 600 in the dry period; the percentage of fat, protein, casein, SP and the somatic cell contents had the opposite trend.

The higher milk yield of group H-NSC, as estimated during the suckling period, and the significant interaction between diet and month of lactation ($P < 0.05$) suggested separate analysis for the two groups of the pattern of milk production during lactation (Figure 1). The data of the first point for each curve represent the milk production estimated during suckling, while the following points are pertinent to the milk production controls. In both the groups maximum milk production was recorded at the first production control (about 60 days in milk; 1218.7 ± 126.3 g/d vs 1444.1 ± 168.9 g/d respectively for groups L-NSC and H-NSC). In the other controls, milk production decreased physiologically, even if some differences were found between the groups. The milk production of the H-NSC group decreased very rapidly (Figure 1), while for group L-NSC the lactation curve showed a longer plateau phase. Indeed, at the third month of lactation average milk production of group L-NSC was close to those of the second month of control (1198 ± 135.8 g/d). Interestingly, during the first two months of lactation, the ewes of group H-NSC, fed the diet with the highest NSC content, had higher milk production. By contrast, the ewes of the L-NSC group had higher milk production during the remaining part of lactation. Probably, as suggested by Cannas et al. (1998), this particular production trend is due to the different NSC content, hence energy, use in sheep according to the lactation period. During the first two months of lactation the high concentrations of the somatotrope hormone, probably high in this stage, could have directed the energy (derived from NSC utilization) to milk production rather than body fat deposition. By contrast, subsequently, the likely haematic low levels of the somatotrope hormone favoured body fat deposition and had a negative effect on milk production.

Figures 2, 3 and 4 show the trend of protein, fat and casein percentages determined on milk of the two groups by month in milking. All the three examined measurements showed in the first

Figure 3. Milk fat content of the two experimental groups throughout lactation.

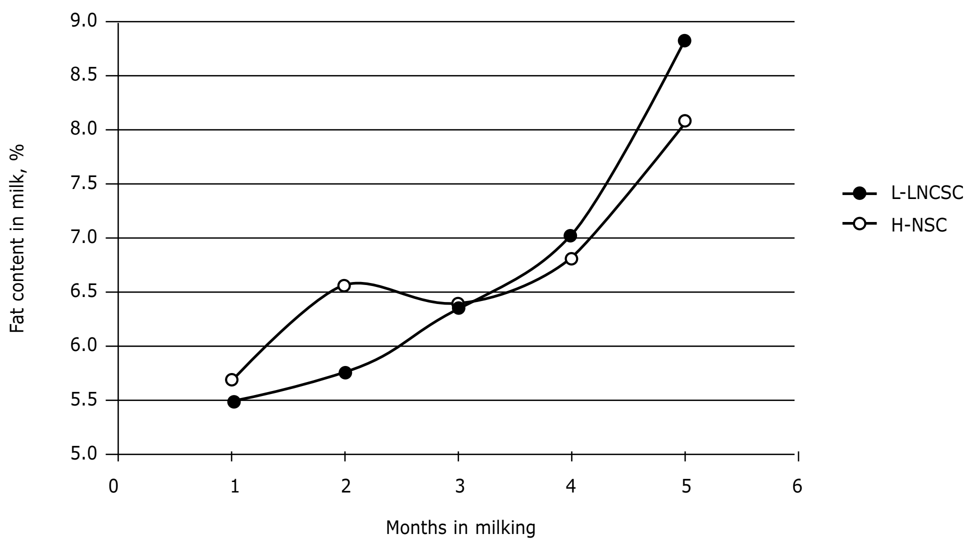
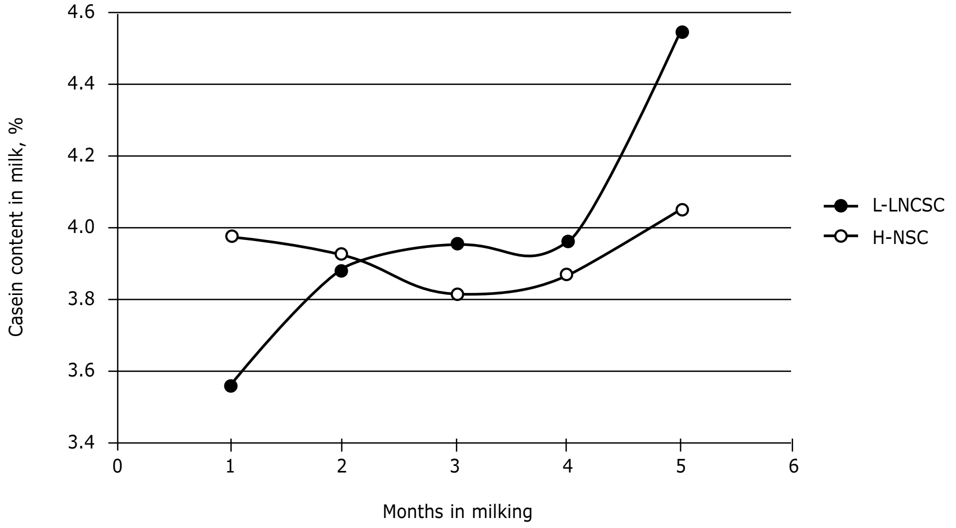


Figure 4. Milk casein content of the two experimental groups throughout lactation.



month of milking higher concentration in group H-NSC (for groups L-NSC and H-NSC: 4.48 % ± 0.48 vs 4.88 % ± 0.48; 5.50 % ± 0.62 vs 5.69 % ± 0.32; 3.56 % ± 0.51 vs 3.98 % ± 0.54 respectively for protein, fat and casein). At the other four controls, these parameters were very close for the two groups, except the fat percentage at the second month of milking (5.76 % ± 0.53 vs 6.55 % ± 0.24 respectively for groups L-NSC and H-NSC) while at the last control the L-NSC group showed the highest values (for groups L-NSC and H-NSC: 5.70 % ± 0.54 vs 5.24 % ± 0.63; 8.84 % ± 0.94 vs 8.10 % ± 0.49; 4.56 % ± 0.40 vs 4.05 % ± 0.28 respectively for protein, fat and casein).

Our observations fully agree with those suggested by Cannas (2002). This author proposed, for ewes bred in the stall system, the use of diets with NSC concentrations around 40 – 42 % of DM during the first two months in lactation and around 35 % of DM during mid lactation.

Conclusions

The obtained results suggest, at least for primiparous Sarda ewes, the use of rations differing in non-structural carbohydrate contents according to the lactation period. Undoubtedly, such results require further research. Indeed, in order to better determine feeding plans for lactating ewes it could be important to define the exact moment of lactation during which energy partitioning changes (from milk production to fat deposition) and whether various types of feeds, or their chemical composition, could stimulate this trend differently.

Part of the results reported in this paper was presented at the 15th ASPA Congress (Parma, June 18-20, 2003).

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