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Feeding management and production factors affecting goat milk composition and quality. I. Titratable acidity and rennet-coagulation

P. Superchi, A. Summer, A. Sabbioni, M. Malacarne, P. Franceschi and P. Mariani
Dipartimento di Produzioni Animali, Biotecnologie Veterinarie, Qualità e Sicurezza degli Alimenti
Università degli Studi di Parma, Italy

SUMMARY – Individual milk samples representing the overall morning milking were collected monthly (from April to September) from 24 Saanen goats, uniformly distributed into two herds in Northern Italy, with the aim to evaluate the factors affecting titratable acidity and rennet-coagulation parameters. Herds differed in feeding management system: "Traditional" and "Total Mixed Ration". Delivery date, parity number (primiparous or pluriparous), delivery type (single or twin) were considered. In correspondence of test days, lactation stage and milk yield data were recorded. All milk samples were analysed for fat, protein, lactose, urea, somatic cells, pH, titratable acidity and rennet-coagulation parameters. Herd type significantly affected titratable acidity. Titratable acidity showed a positive relationship with milk yield and protein content and a negative one with pH. Milk from primiparous goats had a higher titratable acidity and a better clotting time. Milk from single delivery goats was characterised by a higher titratable acidity. Lower values of titratable acidity were accompanied by a worsening of curd firming time and curd firmness. Among rennet-coagulation parameters, herd type influenced only curd firming time. An increase of protein content was related to a worse clotting time, a lower k_{20} and a higher a_{30}. An increase of lactose content was related to an improvement of rennet-coagulation parameters. Curd firming time worsening was related to increased somatic cells and pH; pH was also related to an increase of clotting time.

Keywords: Feeding management, production factors, titratable acidity, rennet-coagulation properties, goat milk.

RESUME – *"Conduite alimentaire et facteurs de production infuençant la composition et la qualité du lait de chèvre. I. Acidité titrable et coagulation par présure". Des échantillons individuels de lait représentant la traite entière du matin ont été prélevés (à partir d'avril jusqu'en septembre) sur 24 chèvres Saanen, uniformément distribuées en deux troupeaux situés dans le nord de l'Italie, dans le but d'évaluer les facteurs affectant l'acidité titrable et les propriétés de coagulation. Les troupeaux étaient différents quant au régime d'alimentation : "traditionnel" et "ration complète". Le nombre de mises bas (primipares ou multipares), et le type de mise bas (simple ou double) ont été considérés. En correspondance des jours de prélèvement, le stade de lactation et les données de production laitière ont été enregistrées. Pour tous les échantillons ont été analysés gras, protéine, lactose, urée, cellules somatiques, pH, acidité titrable, et paramètres de coagulation. Les troupeaux influencent significativement l'acidité titrable. L'acidité titrable a montré une relation positive avec la production de lait et la teneur en protéines, et une relation négative avec le pH. Le lait des chèvres primipares a montré une acidité titrable plus élevée et un meilleur temps de coagulation. Le lait des chèvres à mises bas simples s'est caractérisé par une acidité titrable plus élevée. Les valeurs plus basses d'acidité titrable ont été accompagnées d'une détérioration du temps d'affermissement du caillé et de la fermeté du caillé. Le type de troupeau a influencé, parmi des paramètres de coagulation, seulement le temps d'affermissement du caillé. Une augmentation de la teneur en protéines a été liée à un plus mauvais temps de coagulation, un temps inférieur d'affermissement du caillé et une fermeté plus élevée du caillé. Une augmentation de la teneur en lactose a été liée à une amélioration des paramètres de coagulation. Un plus mauvais temps d'affermissement du caillé a été lié à l'augmentation des cellules somatiques et du pH; le pH a été lié également à une augmentation du temps de coagulation.*

Mots-clés : *Régime d'alimentation, facteurs de production, acidité titrable, propriétés de coagulation, lait de chèvre.*

Introduction

Goat milk composition shows a marked variability, due to the breed and to the different climate and breeding conditions (Jenness, 1980). The effects of lactation stage (Veinoglou *et al.*, 1982; Castagnetti *et al.*, 1984) and feeding and management factors (intensive or semi-intensive) (Haenlein, 1980; Bailoni and Andrighetto, 1985; Pitti *et al.*, 1988; Morand-Fehr *et al.*, 1991; Sanz Sampelayo *et al.*, 1999; Schmidely *et al.*, 1999; Bava *et al.*, 2001) were studied. Among production factors sampling

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Table 3. Relationships of feeding management and production factors with titratable acidity and rennet-coagulation properties

		Titratable acidity, °SH/50 ml			Clotting time, r, min			Curd firming time, k_{20}, min			Curd firmness, a_{30}, mm		
Parameter		Estimate	SE	P	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Intercept		26.2680	1.4033	0.0000	-275.302	31.2201	0.0000	-212.427	92.5552	0.0238	61.2527	56.9582	0.2848
Milk yield, kg/d per goat		0.0876	0.0289	0.0030	-0.1140	0.5813	0.8449	2.3239	1.7232	0.1805	-0.2525	1.0513	0.8107
Fat, %		-0.0123	0.0166	0.4618	0.2474	0.3663	0.5009	0.8423	1.0860	0.4398	-1.0987	0.6620	0.1002
Protein, %		0.2285	0.0494	0.0000	4.8040	1.3320	0.0005	-8.7232	3.9488	0.0295	7.1833	2.4661	0.0044
Lactose, %		-0.0247	0.0637	0.6991	-10.4814	1.4802	0.0000	-12.3100	4.3881	0.0060	10.9345	2.7842	0.0002
SCC, x1000/ml		0.0000	0.0000	0.3276	0.0002	0.0002	0.2909	0.0016	0.0006	0.0120	-0.0004	0.0004	0.3126
pH		-3.5578	0.2019	0.0000	48.9401	4.6552	0.0000	44.2407	13.8009	0.0018	-15.0419	8.5616	0.0820
Urea, mg/100 ml		0.0003	0.0017	0.8680	-0.0442	0.0359	0.2205	-0.0837	0.1063	0.4326	0.0636	0.0648	0.3288
Parity number	1	0.1241	0.0353	0.0007	-1.5804	0.7289	0.0325	-2.7056	2.1609	0.2135	2.2790	1.3155	0.0863
	2	0			0			0			0		
Lactation months	1	-0.2717	0.2281	0.2364	-0.8786	4.7031	0.8522	8.8302	13.9427	0.5280	-1.1647	8.4908	0.8912
	2	-0.2400	0.2035	0.2411	-2.4397	4.2093	0.5635	9.2343	12.4790	0.4610	-3.3548	7.5975	0.6598
	3	-0.2779	0.1635	0.0921	-1.3371	3.3685	0.6923	7.5248	9.9862	0.4529	-1.1784	6.0854	0.8469
	4	-0.2651	0.1320	0.0472	-0.4356	2.7221	0.8732	5.5740	8.0699	0.4913	-3.0767	4.9180	0.5330
	5	-0.1582	0.0968	0.1052	-1.0526	1.9790	0.5960	3.0935	5.8669	0.5992	-0.4715	3.5780	0.8954
	6	0.0100	0.0685	0.8841	0.4155	1.4145	0.7696	1.6279	4.1936	0.6987	-0.3443	2.5567	0.8931
	7	0			0			0			0		
Month of sampling	April	-0.0311	0.2025	0.8783	-3.5990	4.2150	0.3952	-12.7161	12.4959	0.3113	4.6709	7.6078	0.5407
	May	-0.1858	0.1786	0.3006	2.2619	3.7064	0.5431	-10.2099	10.9880	0.3550	5.8277	6.6879	0.3857
	June	-0.4184	0.1234	0.0010	0.1193	2.5441	0.9627	-2.7416	7.5424	0.7170	0.9814	4.5980	0.8314
	July	-0.3073	0.0971	0.0020	2.5851	2.0265	0.2050	13.5153	6.0079	0.0267	-11.3982	3.6659	0.0024
	August	-0.3871	0.0720	0.0000	0.1822	1.4844	0.9025	9.9651	4.4007	0.0257	-5.4966	2.6839	0.0432
	September	0			0			0			0		
Delivery type	Single	0.1100	0.0435	0.0129	-0.0933	0.8797	0.9157	2.1169	2.6078	0.4189	-1.7019	1.5881	0.2865
	Twin	0			0			0			0		
Herd type	"Traditional"	-0.1819	0.0480	0.0003	-1.3077	1.0328	0.2084	-6.1395	3.0617	0.0476	0.6154	1.8767	0.7437
	"TMR"	0			0			0			0		
Delivery month	February	-0.0543	0.1478	0.7138	-2.4420	3.0504	0.4253	4.3586	9.0433	0.6309	-2.1250	5.5051	0.7003
	March	-0.0803	0.1241	0.5189	-2.3588	2.5179	0.3511	2.5383	7.4647	0.7345	-4.4170	4.5514	0.3342
	April	-0.0112	0.1158	0.9234	0.7639	2.3354	0.7443	0.1164	6.9235	0.9866	1.4351	4.2157	0.7343
	May	0			0			0			0		

month (Grappin *et al.*, 1981; Mariani *et al.*, 1987), parity number (Bhattacharya, 1980; Maraval and Vignon, 1982), delivery month, single or twin delivery were considered. Remeuf *et al.* (1989) and Clark and Sherbon (2000) studied the effects of feeding management and production factors on milk rennet-coagulation. The introduction of "Total mixed ration" ("TMR") in goat herds could lead to a improving in milk quality. In this research the feeding management and production factors affecting titratable acidity and rennet-coagulation Saanen goat milk have been studied.

Materials and methods

The study was carried out into 2 dairy goat herds, located in Alessandria province (Northern Italy), different for management, semi-intensive or intensive. In particular the two herds differed for feeding management system: "Traditional" (hay, pasture, mixed feed, DMI 2.9 kg/d) and "TMR" (hay, mixed feed, DMI 2.3 kg/d); the chemical composition of the two rations is reported in Table 1. In both herds a group of 12 Saanen dairy goats was considered; the two groups were comparable for number of twin deliveries (17.39%) and for parity number (5 primiparous, 7 pluriparous). Lactation stage, at the beginning of the research, was 50 ± 19 d. Individual goat milk samples, representing the morning milking, were monthly collected (from April to September) from each goat.

Table 1. Chemical composition of the diet

		Traditional	Total mixed ration, TMR
Dry matter	%	77.69	89.60
Ash	% DM	9.43	7.31
Crude protein	"	11.40	17.80
Ether extract	"	2.52	3.13
Crude fibre	"	27.90	22.25
Starch	"	18.19	24.26
NDF	"	54.66	42.35
ADF	"	38.54	26.07
ADL	"	6.03	5.38
NPN	% CP	18.28	24.05
Soluble N	% CP	38.44	28.86
Milk FU	% DM	72	80

Delivery date, parity number (primiparous or pluriparous) and delivery type (single or twin) were considered. In correspondence of test days, lactation stage and milk yield data were recorded. On each milk sample the following analyses were carried out: fat, protein and lactose by means of mid infrared lectures with Milko-Scan 134A/B (Biggs, 1978); urea, by enzymatic reaction catalysed by urease (Pecorari *et al*., 1993) by means of Bun Analyzer apparatus; somatic cells, by fluoro-opto-metric method with Fossomatic 250 (Schmidt-Madsen, 1975); pH with a potentiometer; titratable acidity (°SH) with 0.25 N NaOH according to the Soxhlet-Henkel method (Anonymous, 1963) by means of the automatic titrator Crison Compact D; coagulation properties by means of Formagraph (Annibaldi *et al.*, 1977): clotting time (r), curd firming time (k_{20}), curd firmness measured 30 min after rennet addition (a_{30}). To the samples that did not coagulate into the technical time of analysis (30 min), with the aim to obtain mean values representing the overall group of observations, was arbitrarily attributed a value of 31 min to clotting time; the same value was attributed to curd firming time for milks that in 30 min of analysis did not reach a value finite of k_{20}; for these latter the a_{30} value was assumed as zero mm (Mariani *et al*., 1990). Data were submitted to analysis of covariance (Fixed effects: herd type; parity number; month of lactation; month of sampling; type of delivery; month of delivery. Covariates: milk yield, kg; fat, %; protein, %; lactose, %; somatic cells, 10^3/ml; pH; urea, mg/100 ml) by means of SAS statistical software (SAS, ver. 9.1, 2002-2003).

Results and discussion

Mean values and standard deviations

In Table 2 mean values and standard deviations for milk yield, fat, protein lactose, somatic cells, pH, urea, titratable acidity and rennet-coagulation parameters are reported. Few data are disposable in literature for rennet-coagulation properties. Fat content registered in this research is similar to data reported by Espie and Mullan (1990) and a little greater with respect to Grappin *et al*. (1981). Data in literature, for protein and lactose, are variable (Jenness, 1980; Fantuz *et al*., 2001; Leitner *et al*., 2004), depending mostly on the breed and on the lactation stage; Grappin *et al*. (1981) report protein values comparable with results of the present research. Our pH values are similar to Grandpierre *et al*. (1988). The registered somatic cell value corresponds to the value found by Castagnetti *et al*. (1984) and is lower than values observed by Piasentier *et al*. (2000); Leitner *et al.* (2004), for goats with mammary gland infections, report values similar to our somatic cell data. Urea content measured in this research is higher than values reported in literature (Grappin *et al*., 1981; Brun-Bellut *et al*., 1984); urea content, however, depends mostly from nutritional factors. Titratable acidity values substantially agree with Castagnetti *et al*. (1984), while they are lower than those observed by Mariani *et al*. (1987) and higher than data reported by Piasentier *et al*. (2000). Titratable acidity is correlated to the casein content, and for this reason the differences in literature are related to protein content and, probably, to phosphorus content. Discordant values are registered in literature for rennet-coagulation properties, probably due to the different instruments and methodologies utilised.

Table 2. Production factors, titratable acidity and rennet-coagulation properties for the 2 diets. Mean and SD

	Traditional		TMR		Total	
	Mean	SD	Mean	SD	Mean	SD
Milk yield, kg	3.62	1.25	3.06	1.39	3.31	1.35
Fat, %	3.49	1.11	3.70	1.31	3.61	1.22
Protein, %	2.40	0.22	2.86	0.52	2.65	0.47
Lactose, %	4.19	0.29	4.39	0.34	4.30	0.33
SCC, x1000/ml	1451	1686	1849	2053	1672	1902
pH	6.69	0.08	6.66	0.10	6.67	0.09
Urea, mg/100 ml	42.12	7.55	49.61	11.65	46.27	10.67
Titratable acidity, °SH/50 ml	2.54	0.33	2.94	0.41	2.76	0.42
Clotting time, r, min	13.91	4.98	12.06	5.55	12.92	5.35
Curd firming time, k_{20}, min	7.51	6.55	4.78	3.25	16.32	12.98
Curd firmness, a_{30}, mm	17.96	8.91	23.31	9.90	20.81	9.79

Effects of feeding management and production factors on titratable acidity and rennet-coagulation properties

Herd type significantly affected titratable acidity (P<0.001), lower values being observed in the "Traditional" (Table 3). Titratable acidity showed a positive relationship with milk yield (b = 0.09; P<0.01) and milk protein content (b = 0.02; P<0.0001) and a negative relationship with pH (b = -3.6; P<0.0001). Milk from primiparous goats had a higher titratable acidity (P<0.001) and a better clotting time (P<0.05). Milk from single delivery goats was characterised by a higher titratable acidity (P<0.05). Lower values of titratable acidity, observed for milk sampled in July (b = -0.31; P<0.01) and in August (b = -0.39; P<0.0001) with respect to September, were accompanied by a worsening of curd firming time (July: b = 13.51, August: b = 9.97; P<0.05) and of curd firmness (July: b = -11.40; P<0.01; August: b = -5.50; P<0.05). Herd type influenced, among rennet-coagulation parameters, only curd firming time (P<0.05), lower values being observed in the "Traditional". An increase of protein content was related to a worse clotting time (b = 4.8; P<0.001), a lower curd firming time (b = -8.7; P<0.05) and a higher curd firmness (b = 7.2; P<0.01). The improvement of curd firming time and curd

firmness is ready to explain, in fact, their correlation with the protein content is well known, while is more difficult to explain the worsening of clotting time, probably due to a major effect of pH. An increase of lactose content was related to an improvement of rennet-coagulation parameters, i.e. a lower clotting time ($b = -10.48$; $P<0.0001$), a lower curd firming time ($b = -12.31$; $P<0.01$), a higher curd firmness ($b = 10.93$; $P<0.001$). Curd firming time worsening was related to increased somatic cells ($b = 0.002$; $P<0.05$) and pH ($b = 44.2$; $P<0.01$); pH was related also to clotting time ($b = 48.94$; $P<0.0001$).

Conclusions

This study partially confirms the results reported in literature about the influence that production factors have on Saanen milk goat quality and, moreover, it evidences that the adoption of the Total Mixed Ration instead of the "Traditional" feeding technique improved the dairy-technological aptitude of Saanen goat milk. This fact assumes a particular relevance, because most of goat milk is destined to cheesemaking. The different titratable acidity for the two herds and the different rennet-coagulation properties are probably related mainly to the different content of protein and mineral salts. The higher protein content in the milk of TMR herd goats can be explained with the fact that these goats have a higher protein intake (409.4 *vs* 330.6 g/d) with respect to the "Traditional" herd goats.

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Table 3. Relationships of feeding management and production factors with titratable acidity and rennet-coagulation properties

		Titratable acidity, °SH/50 ml			Clotting time, r, min			Curd firming time, k_{20}, min			Curd firmness, a_{30}, mm		
Parameter		Estimate	SE	P	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Intercept		26.2680	1.4033	0.0000	-275.302	31.2201	0.0000	-212.427	92.5552	0.0238	61.2527	56.9582	0.2848
Milk yield, kg/d per goat		0.0876	0.0289	0.0030	-0.1140	0.5813	0.8449	2.3239	1.7232	0.1805	-0.2525	1.0513	0.8107
Fat, %		-0.0123	0.0166	0.4618	0.2474	0.3663	0.5009	0.8423	1.0860	0.4398	-1.0987	0.6620	0.1002
Protein, %		0.2285	0.0494	0.0000	4.8040	1.3320	0.0005	-8.7232	3.9488	0.0295	7.1833	2.4661	0.0044
Lactose, %		-0.0247	0.0637	0.6991	-10.4814	1.4802	0.0000	-12.3100	4.3881	0.0060	10.9345	2.7842	0.0002
SCC, x1000/ml		0.0000	0.0000	0.3276	0.0002	0.0002	0.2909	0.0016	0.0006	0.0120	-0.0004	0.0004	0.3126
pH		-3.5578	0.2019	0.0000	48.9401	4.6552	0.0000	44.2407	13.8009	0.0018	-15.0419	8.5616	0.0820
Urea, mg/100 ml		0.0003	0.0017	0.8680	-0.0442	0.0359	0.2205	-0.0837	0.1063	0.4326	0.0636	0.0648	0.3288
Parity number	1	0.1241	0.0353	0.0007	-1.5804	0.7289	0.0325	-2.7056	2.1609	0.2135	2.2790	1.3155	0.0863
	2	0			0			0			0		
Lactation months	1	-0.2717	0.2281	0.2364	-0.8786	4.7031	0.8522	8.8302	13.9427	0.5280	-1.1647	8.4908	0.8912
	2	-0.2400	0.2035	0.2411	-2.4397	4.2093	0.5635	9.2343	12.4790	0.4610	-3.3548	7.5975	0.6598
	3	-0.2779	0.1635	0.0921	-1.3371	3.3685	0.6923	7.5248	9.9862	0.4529	-1.1784	6.0854	0.8469
	4	-0.2651	0.1320	0.0472	-0.4356	2.7221	0.8732	5.5740	8.0699	0.4913	-3.0767	4.9180	0.5330
	5	-0.1582	0.0968	0.1052	-1.0526	1.9790	0.5960	3.0935	5.8669	0.5992	-0.4715	3.5780	0.8954
	6	0.0100	0.0685	0.8841	0.4155	1.4145	0.7696	1.6279	4.1936	0.6987	-0.3443	2.5567	0.8931
	7	0			0			0			0		
Month of sampling	April	-0.0311	0.2025	0.8783	-3.5990	4.2150	0.3952	-12.7161	12.4959	0.3113	4.6709	7.6078	0.5407
	May	-0.1858	0.1786	0.3006	2.2619	3.7064	0.5431	-10.2099	10.9880	0.3550	5.8277	6.6879	0.3857
	June	-0.4184	0.1234	0.0010	0.1193	2.5441	0.9627	-2.7416	7.5424	0.7170	0.9814	4.5980	0.8314
	July	-0.3073	0.0971	0.0020	2.5851	2.0265	0.2050	13.5153	6.0079	0.0267	-11.3982	3.6659	0.0024
	August	-0.3871	0.0720	0.0000	0.1822	1.4844	0.9025	9.9651	4.4007	0.0257	-5.4966	2.6839	0.0432
	September	0			0			0			0		
Delivery type	Single	0.1100	0.0435	0.0129	-0.0933	0.8797	0.9157	2.1169	2.6078	0.4189	-1.7019	1.5881	0.2865
	Twin	0			0			0			0		
Herd type	"Traditional"	-0.1819	0.0480	0.0003	-1.3077	1.0328	0.2084	-6.1395	3.0617	0.0476	0.6154	1.8767	0.7437
	"TMR"	0			0			0			0		
Delivery month	February	-0.0543	0.1478	0.7138	-2.4420	3.0504	0.4253	4.3586	9.0433	0.6309	-2.1250	5.5051	0.7003
	March	-0.0803	0.1241	0.5189	-2.3588	2.5179	0.3511	2.5383	7.4647	0.7345	-4.4170	4.5514	0.3342
	April	-0.0112	0.1158	0.9234	0.7639	2.3354	0.7443	0.1164	6.9235	0.9866	1.4351	4.2157	0.7343
	May	0			0			0			0		

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