Milk production and quality of dairy goats fed Sulla or Alfalfa based-diet

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Abstract

Hedysarum flexuosum which is a forage legume with high production potential can contribute to increase the production and improve the quality of desirable fatty acids in ruminant products. Production, chemical composition and fatty acid profile of Beni Aouss goat milk were studied to evaluate the effect of substitution of Medicago sativa with the *Hedysarum flexuosum* L. (Sulla) based diet, harvested at the beginning of flowering. Two homogeneous groups of fourteen goats were used to out this experiment. The roughage distributed in both groups is made up of Sulla forage (Sulla group) and Medicago sativa (control group). The same concentrated feed is distributed to both groups of goats. Milk yield was determined weekly during the first three months of lactation and milk samples were collected every week. The incorporation of Sulla in goat's diet had a significant and positive effect on milk production (+15%). No significant differences were observed for milk pH and acidity. Sulla group milk was characterized by slightly higher lactose content (5.23% vs. 5.13%, $P < 0.05$) and defatted solid content (10.31% vs. 10.12%, $P < 0.05$), while their protein and fat contents were not affected. Milk fatty acid profile revealed that the levels of unsaturated fatty acids and medium chain fatty acids were higher in the Sulla milk than in the alfalfa group. ω3 fatty acids (0.39% *vs* 0.21%), ω6-fatty acids (3.42% vs. 2.79%), polyunsaturated fatty acids (3.96% vs. 3.15%), unsaturated fatty acids (43.00% vs. 41.11%) and medium chain fatty acids (25.00% vs. 23.82%) were significantly more present in the Sulla milk. Sulla forage may be an interesting alternative in goat's feeding for diversifying feed resources and improving milk production and quality.

Keywords: Goat (indigenous), milk yield, *Hedysarum flexuosum*, milk quality, Medicago sativa

Le fourrage *Hedysarum flexuosum* L. (Sulla) améliore la production et la qualité nutritionnelle du lait de chèvre

Résumé

L'Hedysarum *flexuosum* qui est une légumineuse fourragère à haute potentialité de production peut contribuer à augmenter la production et améliorer la qualité des acides gras désirables dans les produits des ruminants. La production, la composition chimique et le profil des acides gras du lait de chèvre Beni Arouss ont été étudiés afin de mettre en évidence l'effet de substitution de l'aliment grossier à base de *Medigago sativa* par l'Hedysarum *flexuosum* L. (Sulla). Deux lots homogènes de sept chèvres ont été constitués. L'aliment grossier distribué dans les deux lots est constitué par le fourrage de Sulla (lot Sulla) et de *Medicago sativa* (lot témoin). Le même aliment concentré est distribué dans les deux groupes de chèvres. La production de lait a été déterminée chaque semaine pendant les trois premiers mois de la lactation et des échantillons de lait ont été prélevés chaque semaine. L'incorporation de Sulla dans l'alimentation des chèvres a eu un effet positif et significatif sur la production de lait (+15%). Aucune différence significative n'a été observée pour le pH et l'acidité du lait. Le lait du groupe Sulla était caractérisé par une teneur en lactose légèrement plus élevée (5,23 % contre 5,13 %, $P < 0,05$) et une teneur en solides dégraissés (10,31 % contre 10,12 %, $P < 0,05$), tandis que leurs teneurs en protéines et en matières grasses n'étaient pas affectées. Le profil des acides gras du lait a révélé que les niveaux d'acides gras insaturés et d'acides gras à chaîne moyenne étaient plus élevés dans le lait Sulla que dans le groupe luzerne. Les acides gras ω3 (0,39% vs 0,21%), les acides gras ω6 (3. 42% vs 2,79%), les acides gras polyinsaturés (3,96% vs 3,15%), les acides gras insaturés (43,00% vs 41,11%) et les acides gras à chaîne moyenne (25,00% vs 23,82%) étaient significativement plus présents dans le lait Sulla. Le fourrage Sulla peut être une alternative intéressante dans l'alimentation des chèvres pour diversifier les ressources alimentaires et améliorer la production et la qualité du lait.

Mots clés : Chèvre (indigène), production laitière, *Hedysarum flexuosum*, qualité du lait, *Medicago sativa*.

كلأ الفويلة الإكليلية (سولا) يحسن الإنتاج والجودة الغذائية لحليب الماعز

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الملخص

يمكن أن تساهم الفويلة الإكليلية (السولا) وهي من بين البقوليات العلفية ذات إمكانات إنتاجية عالية في زيادة الإنتاج وتحسين جودة الأحماض الدهنية المرغوبة في منتجات المجترات. تمت دراسة الإنتاج والتركيب الكيميائي والأحماض الدهنية لحليب الماعز فصيلة بني عروس لتقييم تأثير استبدال الفصة بالفويلة الإكليلية الذي تم حصاده في بداية الإزهار. تم استخدام مجموعتين متجانستين من أربعة عشر ماعز للقيام بهده التجربة. تكون الكلأ الخشن الموزع في كلا المجموعتين من علف سولا (مجموعة سولا) و الفصة (مجموعة الشاهد). تم توزيع نفس العلف المركز على مجموعتي الماعز. تم تحديد إنتاجية اللبن أسبوعياً خلال الأشهر الثلاثة الأولى من الرضاعة وجُمعت عينات اللبن كل أسبوع. كان لإدخال السولا في النظام الغذائي للماعز تأثير معنوي وإيجابي على إنتاج الحليب (+ 15٪). لم يلاحظ أي فرق معنوي بالنسبة لدرجة الحموضة وpH الحليب. تميز حليب مجموعة سولا بمحتوى أعلى قليلاً من اللاكتوز (5.23٪ مقابل 5.13٪ ، P <0.05) والمستخلص الجاف المنزوع الدهن (10.31٪ مقابل 10.12٪ ، P <0.05) ، بينما لم يتأثر محتوى البروتين والدهون. أظهرت بيانات الأحماض الدهنية للحليب أن مستويات الأحماض الدهنية غير المشبعة والأحماض الدهنية متوسطة السلسلة كانت أعلى في حليب السولا منها في مجموعة الفصة. حيث أن الأحماض الدهنية ω3 (0.39٪ مقابل 0.21٪)، والأحماض الدهنية ω6 (3.42٪ مقابل 2.79٪)، والأحماض الدهنية متعددة غير مشبعة (3.96٪ مقابل 3.15٪) ، والأحماض الدهنية الغير المشبعة (43.00٪ مقابل 41.11٪) و الأحماض الدهنية المتوسطة التسلسل (25.00٪ مقابل 23.82٪) كانت أكثر تواجدًا بشكل معنوي في حليب السولا. ان كلأ السولا يمكن أن يكون بديلاً هاما في تغذية الماعز لتنويع موارد الأعلاف وتحسين إنتاج الحليب وجودته.

الكلمات المفتاحية: الماعز (الأصلي)، إنتاج الحليب، الفويلة الإكليلية، جودة الحليب، الفصة.

Introduction

In northwestern Morocco, which is largely mountainous, goat farming dominates with an estimated 700,000 heads (14% of the national herd and 40% of the region's total herd). This breeding consists of heterogeneous local populations of which the Beni Arouss breed is one. It is traditionally oriented towards very extensive milk and kid production. The production of farms located near transportation routes or cheese dairy is oriented towards dairy production. The goat zootechnical unit in this region produces 104 kg of milk for a lactation period of 147 days (Hacib, 1994). The gross margin per goat per year is estimated at 67 € (Chentouf et *al.*, 2011). This margin remains lower than those recorded in the northern shore of the Mediterranean. This shows the possible room for improvement in milk production.

Hedysarums commonly called Sulla or Spanish sainfoin are members of the legume family native to the western Mediterranean and North Africa, where they have been established as livestock fodder in several countries (Benguedouar et *al.*, 1997). It is a short-lived, semi-erect to erect biennial plant with a height of 0.3 to 1.5 m.

In Morocco, the Sulla (*Hedysarum* spp.) is mainly represented by H. flexuosum, which is spontaneous. It was subject of a collection and preliminary assessment that showed similar productions to the Italian varieties of H. coronarium (Noutfia et *al.*, 2014; El Mourabit et *al.*, 2013; Ayadi et *al.*, 2015). The use of sulla in small ruminants has shown good performance in pasture or hay or silage (Molle et *al.*, 2004; Di trana et *al.*, 2015). The species belonging to the genus Hedysarum, of which the most widespread species is commonly called Sulla (Boussaid et *al*. 1995), are pastoral fabaceae that develop naturally in northern Morocco (Slim and Ben Jeddi, 2011). They constitute a valuable pastoral and ecological phytogenetic heritage due to their potential for production and quality of forage bran. Indeed, they play an essential role in the direct or indirect improvement of pastures and in animal feed (Mbaye et *al*., 2002). The feeding of dairy goats through the integration of this forage resource will significantly, rapidly and irreversibly modify the production and chemical composition of milk, particularly in fat (Amegée, 1984).

Despite the low milk production performance, there is a growing interest in goat milk due to its specific biochemical properties that contribute to improve human nutrition and health (Kompan and Komprej, 2012). Goat's milk has been identified as a viable alternative for consumers sensitive to cow's milk (Haenlein, 2004). The fat in goat's milk is more digestible than cow's milk. This may be related to the smaller size of milk fat globules, the high fatty acids concentration (C8:0 to C10:0), high short and medium chain fatty acids proportions, which contribute in part to the specific flavor of goat's milk (Bernard et *al*., 2009).

The quality of dairy goat feeding is the most important factor that can significantly, rapidly and reversibly change the production and composition of milk especially protein and fat contents (Soryal et *al.*, 2004; Bernard et *al*., 2009). In fact, fat content is one of the most important parameters for evaluating the quality of goat milk (García *et al*., 2014).

Currently, the physiological effects of all fatty acids are not fully understood. According to Chilliard et *al.* (2007), fatty acids (FA) are not harmful to human health, although their excess in the daily diet may have negative health effects (. However, good quality milk contains less saturated fatty acids (SFA), few Trans fatty acids and especially high in omega-3. These fatty acids are essential for human health.

For this reason, improving the nutritional quality of milk is an asset for an efficient dairy system to cope with increasing consumer demand. Thus, some studies aimed to show that legumes could contribute to increase the polyunsaturated fatty acids content in ruminant products (Couvreur et *al.*, 2006; Scollan, 2006).

Sulla is a promising forage legume which is adapted to the local environmental conditions. Therefore, in order to develop goat dairy sector, this study is conducted to investigate the effects of integrating Sulla's forage into the goat feeding system on the production performance and quality of indigenous Beni Arouss goat milk.

Material and methods

Test groups and diet

The study was conducted on two groups of Beni Arouss goats which are in the lactation phase just after the kidding (n = 14). The goats in both groups are selected identically in terms of milk production, weight, age and number of kidding. The trial was conducted during the first three months of lactation. Regarding the basic roughage ration, the control group received alfalfa (70.65%) and the test group received Sulla (71.42%) of total raw material of feed. The Sulla was used as green forage in the early flowering stage, whereas alfalfa is used as hay. The concentrate rations, distributed in the two batches, are isoprotein and isoenergetic with the proportions 29.63% and 28.56% respectively for the control and the test. The total quantity of the ration distributed varied from 2700 to 2800 g/day/goat. The distributed forage was harvested at the beginning of flowering phase (5 à 10% of flowers in the field, Table 1 and Photo 1).

Table 1: Nutritive composition of Sulla and Alfalfa diets

	Ingredients	DM distributed (g/day/goat)	UFL (Unité)	PDI (g/kg DM)	NDF (g)	MG (g)
Sulla group	Sulla	182.00	0.16	23.00	67.85	5.70
	Barley grains	178.00	0.19	15.8	117.81	4.45
	Wheat bran	139.36	0.12	14.24	88.90	5.57
	Corn	143.20	0.17	13.92	89.87	6.16
	Faba bean	253.96	0.26	33.88	151.77	2.89
	Total	896.52	0.90	100.84	516.20	24.77
Alfalfa group	Alfalfa	210.90	0.17	23.75	97.86	5.06
	Barley grains	178.00	0.19	15.8	117.81	4.45
	Wheat bran	139.36	0.12	14.24	88.90	5.57
	Corn	143.20	0.17	13.92	89.87	6.16
	Faba bean	253.96	0.26	33.88	151.77	2.89
	Total	925.42	0.91	101.59	546.21	24.13

Photo 1: Sulla field installed at the experimental station of INRA, Boukhalef in Tangier

Production and the composition of Milk

Milk yield was determined early in the morning once time per day every week during the experimental period. Milk samples were collected every week at the morning milking time. Immediately after the milking of the goats, the milk samples are collected in 250 ml plastic bottles and then placed directly in a cooler and finally transported to the laboratory after approximately one hour's journey. Milk samples were Samples were analyzed for milk protein, fat, lactose and defatted solid contents using Milkoscan apparatus (MilkoScan Minor 4). The pH was determined using a pH-meter and titratable acidity (expressed in degrees Dornic) was measured using 0.1M sodium hydroxide solution containing 1% phenolphthalein (Guiraud, 1998). Individual milk production is estimated by measuring the weight of the quantity of milk milked per goat each morning before the newborns breastfeeds their mothers.

Determination of fatty acids

After extraction with petroleum ether, the glycerides were saponified with a solution of NaOH/methanol (0.5 M), and the fatty acids formed were esterified to methyl esters with an excess of boron trifluoride as catalyst (Christie, 1993). The fatty acid composition was analyzed using a VARIAN CP3800 gas chromatograph equipped with a capillary column (100 m, 0.25 mm, 0.2 µm) and a flame ionization detector (FID). The injection volume was 1.5 µl. The temperature gradient was initially programmed to 140 °C and maintained for 5 minutes, then increased at a rate of 4 °C/min to 240 °C and maintained at this temperature for 20 minutes. Fatty acids expressed as the methyl ester were identified by comparison with commercial standards of methyl ester (FAME C4-C24).

Statistical analysis

The two treatments (diet) were compared using analysis of variance and multiple means comparison. Milk production, physicochemical composition and fatty acid profile were analyzed with the program (SAS, 2002) using the Generalized Linear Model (GLM) procedure. The model used (yij =μ+Ti + εij) includes the overall mean (μ), diet as a factor of variation (Ti), and the residual error (εij). The difference between the means was considered significant at a probability level of $P < 0.05$. Comparison of means was performed using the last square deviation or (LSD).

It should be noted that the “milk collection period” factor was not considered, since its effect on the variation in production is obviously well known. Repeating the measurements over time aims to increase the number of degrees of freedom to obtain a more reliable statistical result.

Results

Production and chemical composition of Milk

The same milk yield trend was observed for both groups throughout the experimental period, with the Sulla group being superior (Figure 1).

For both groups, the highest milk production was registered in the second month of lactation. According to this result, Sulla has a highly significant effect ($P < 0.001$) with an average milk production 848 g compared to only 727 g in the control group (Table 2). Indeed, the Sulla based diet allowed an increase in milk production of about 15% compared to alfalfa.

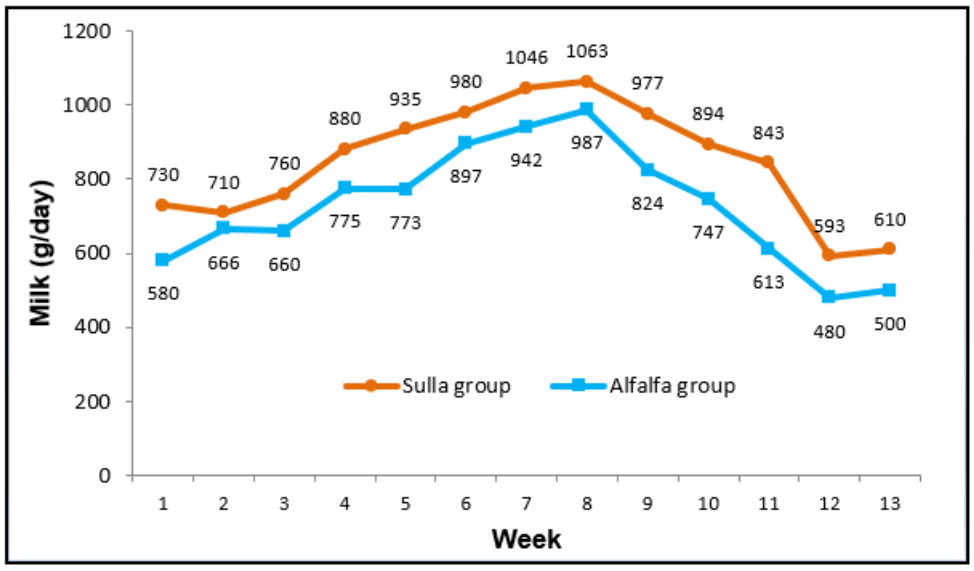

Figure 1: Effect of Sulla diet on milk production (g/day/goat)

Table 2: Milk production and composition of goats fed Sulla or Alfalfa based diet (n=7).

	Dairy production (g / day / goat)	pH	Dornic acidity (°D)	Fat (%)	Protein (%)	Lactose (%)	Defatted Dry Extract (DDE%)
Alfalfa group	727 ± 24^{b}	6.42 ± 0.08	17.57 ± 0.64	1.98 ± 0.08	3.80 ± 0.05	5.13 ± 0.04^{b}	10.12 ± 0.06^{b}
Sulla group	848 ± 29^{a}	6.47 ± 0.07	17.33 ± 0.33	1.99 ± 0.10	3.85 ± 0.04	5.23 ± 0.03^{a}	10.31 ± 0.05^{a}
Probability	0.0004	0.6589	0.8143	0.9603	0.4170	0.0285	0.0164

a, b and c: within the same column, the values followed by the distinct letters are statistically different at 5%.

In general, *Hedysarum flexuosum* based diet has no effect on the pH of the milk. The pH values varied between 6.3 and 6.7 with an average of 6.54. No significant difference was observed regarding the acidity of the milk (17.45 °D on average).

The protein content ranged between 3.61% in the 12th week and 4.10% in the third week for the Sulla group (Figure 2). It was found that diet had no significant effect (P>0.05) on protein content. The mean values for this parameter were very close in both groups (3.80 vs. 3.85%, Table 2).

In general, the fat content varied between 1.39% and 2.71% obtained at week 10 and week 3, respectively, for the Sulla group (Figure 3). It can also be noted that this parameter had the same evolution for both groups.

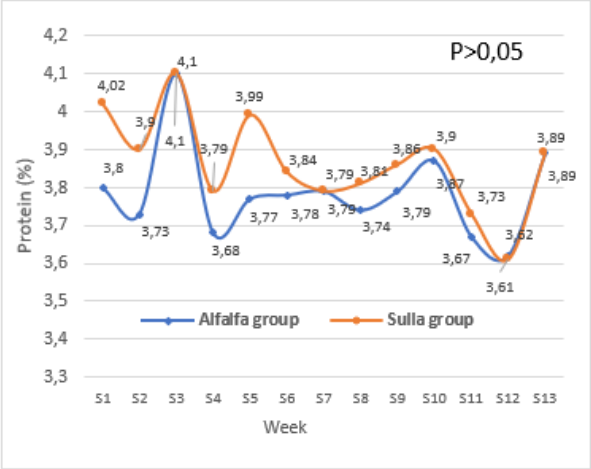

Figure 2: Protein content of milk from the "Sulla" and "Alfalfa" groups

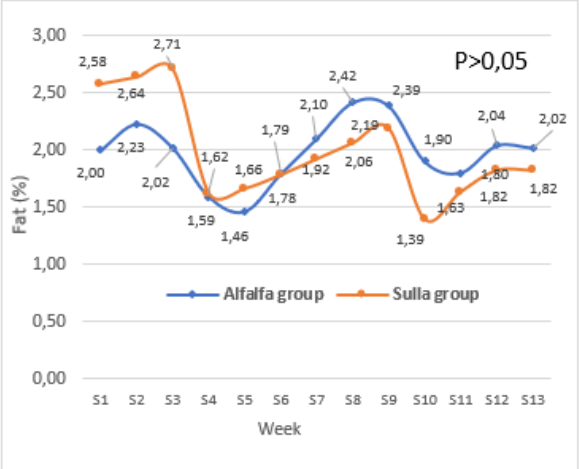

Figure 3: Fat content of milk from the "Sulla" and "Alfalfa" groups

The lactose percentage varied between 4.78% and 5.53%, which were found in the 13th and third weeks, respectively for the Alfalfa group. This parameter was significantly influenced by the diet (P < 0.01, Figure 4). It is also noted that the lactose content for the Sulla group varied slightly throughout the experimental period (from 5.16% to 5.41% in the first and second weeks, respectively). Indeed, Sulla had a significant positive effect on the lactose content (P < 0.05, Table 2 and Figure 4).

On the other hand, it is observed that the defatted dry matter content is significantly higher in the Sulla group (10.31% versus 10.12%) (Table 2 and Figure 5).

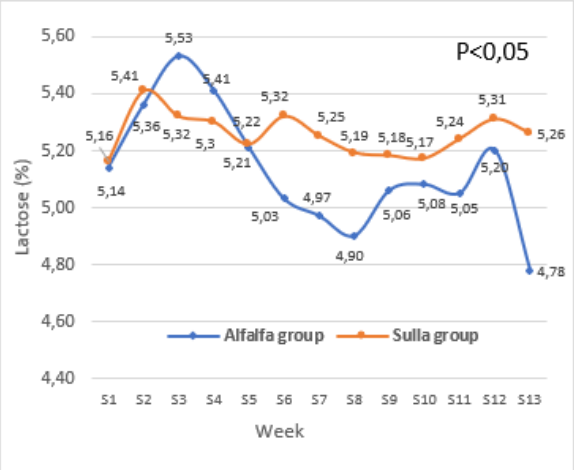

Figure 4: Lactose content of milk from the "Sulla" and "Alfalfa" groups.

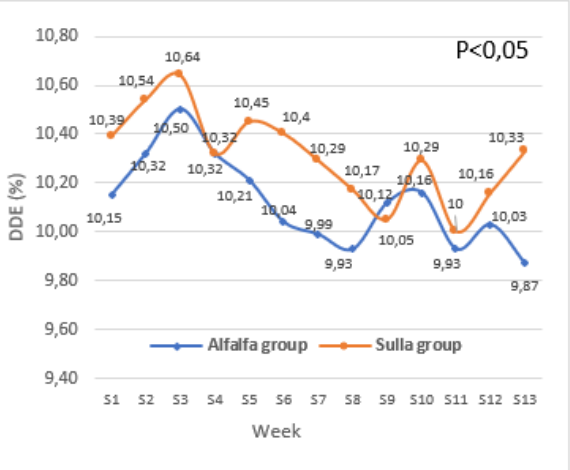

Figure 5: Defatted dry extract content of milk from Alfalfa and Sulla groups.

Milk Fatty acid profile

Table 3 shows that the milk of the two groups of goats is relatively comparable and has approximatively the same fatty acid composition, although there are differences depending on the composition and type of diet.

In both, the Alfalfa and Sulla groups, the most abundant fatty acids were C16:0 (26.18% vs. 23.43%, P < 0.01) and C18:1n-w9 cis (23.41% vs. 24.47%, P > 0.05). In addition to C16:0 acid, significant differences were also observed for stearic acid (C18:0) and arachidic acid (C20:0), with (23.43% vs. 26.19%), (1.81% vs. 0.56%), and (0.90% vs. 0.11%) contents respectively (P < 0.05, Table 3). In addition, Sulla milk was higher significant contents of unsaturated and long-chain unsaturated fatty acids such as linolenic acid “C18: 3n3” (0.23% vs. 0.10%), eicosapentaenoic acid “C20: 5n-w3” (0.19% vs. 0.07%) and eicosatrienoic acid “C20: 3n-3” (0.20% vs. 0.04%) (Table 3).

Table 3: Composition of milk fatty acids of goats fed Sulla or Alfalfa based diet (in % total fatty acids) (n=7).

Fatty acid	Alfalfa group	Sulla group	Probability
C4 :0	0.781 ± 0.034	0.738 ± 0.044	0.4590
C6 :0	1.583 ± 0.070	1.394 ± 0.073	0.0783
C8 :0	2.518 ± 0.089	2.492 ± 0.129	0.8681
C10 :0	9.535 ± 0.259	9.842 ± 0.190	0.3603
C11 :0	0.289 ± 0.010	0.301 ± 0.016	0.5445
C12 :0	4.223 ± 0.191	4.230 ± 0.179	0.9774
C13 :0	0.183 ± 0.010	0.197 ± 0.014	0.4063
C14 :0	9.002 ± 0.322	8.573 ± 0.333	0.3683
C14 :1	0.469 ± 0.116	0.327 ± 0.018	0.2657
C15 :0	1.250 ± 0.042	1.185 ± 0.054	0.3585
C15 :1	0.355 ± 0.029^{a}	0.254 ± 0.011^{b}	0.0060
C16 :0	26.185 ± 0.552^{a}	23.434 ± 0.482^{b}	0.0014
C16 :1	0.769 ± 0.068	0.710 ± 0.033	0.4586
C17 :0	0.386 ± 0.105	0.528 ± 0.074	0.2969
C17 :1	12.756 ± 0.603	12.414 ± 0.489	0.6687
C18 :0	0.563 ± 0.056^{b}	1.814 ± 0.192^{a}	<0.0001
C18 :1n-w9 trans	0.193 ± 0.022	0.217 ± 0.015	0.3739
C18 :1n-w9 cis	23.418 ± 0.559	24.472 ± 0.665	0.2379
C18 :2n-w6 trans	1.644 ± 0.102	1.665 ± 0.075	0.8758
C18 :2n-w6 cis	0.379 ± 0.031	0.488 ± 0.108	0.3275
C20 :0	0.111 ± 0.019^{b}	0.902 ± 0.220^{a}	0.0014
Y-C18 :3n-w6	0.811 ± 0.127	0.947 ± 0.031	0.3314
C20 :1	0.139 ± 0.041	0.220 ± 0.034	0.1499
C18 : 3n-w3	0.104 ± 0.017^{b}	0.233 ± 0.015^{a}	<0.0001
C21 :0	0.208 ± 0.034	0.206 ± 0.031	0.9594
C20 :2	0.056 ± 0.012	0.042 ± 0.006	0.3388
C22 :0	0.267 ± 0.041	0.214 ± 0.023	0.2768
C22 :1n-w9	0.266 ± 0.011	0.331 ± 0.052	0.2155
C20 :3n-w6	0.320 ± 0.100	0.193 ± 0.050	0.2858
C20 :4n-w6	0.148 ± 0.022	0.213 ± 0.041	0.1746
C23 :0	0.184 ± 0.026	0.237 ± 0.038	0.2658
C22 :2	0.110 ± 0.012	0.119 ± 0.029	0.7759
C24 :0	0.098 ± 0.035	0.144 ± 0.032	0.3510
C20 : 5n-w3	0.072 ± 0.031^{b}	0.189 ± 0.014^{a}	0.0041
C24 :1	0.110 ± 0.040	0.083 ± 0.010	0.5389
C22 :6n-w3	0.475 ± 0.055^{a}	0.274 ± 0.009^{b}	0.0029
C20 :3n-w3	0.039 ± 0.003^{b}	0.198 ± 0.013^{a}	<0.0001

Regarding the fatty acid groups (FA) (Table 3), the ω3 and ω6 type fatty acids, polyunsaturated fatty acids (PUFA) and unsaturated fatty acids (UFA) are significantly ($P < 0.05$) more present in milk of Sulla group than in the Alfalfa group (0.39% vs. 0.21%), (3.42% vs. 2.79%), (3.96% vs. 3.15%), and (42.98% vs. 41.91%), respectively. The Sulla-based diet allowed the production of ω3 more than that of ω6. Indeed, the ω3/ω6 ratio was significantly higher in the milk of the Sulla group than in the Alfalfa group (0.11% vs. 0.08%, $P < 0.05$).

Table 4: Fatty acids groups of milk of goats fed Sulla or Alfalfa based diet (in % total FA, n=7).

Fatty acid group	SFA	MUFA	PUFA	UFA	ω3	ω6	ω3/ω6
Alfalfa	58.25±1.35	38.40±1.38	3.15±0.31^{b}	41.11±0.16^{b}	0.21±0.07^{b}	2.79±0.09^{b}	0.08±0.02^{b}
Sulla	57.53±1.89	38.71±1.93	3.96±0.28^{a}	43.00±0.17^{a}	0.39±0.14^{a}	3.42±0.08^{a}	0.11±0.01^{a}

SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids, ω3: FA Omega 3, ω6: FA Omega 6.

Analysis of the different fatty acid carbon chain lengths (Figure 6) showed that the Sulla affected significantly and positively the medium fatty acid chain (MCFA) (24.89 vs. 23.82%) ($P < 0.05$), while there was no significant difference in the short and long fatty acid (SCFA and LCFA).

We can remember that Sulla improved the fat quality of goat milk by providing milk low in palmitic acid and richer in omega-3 fatty acids (Table 4).

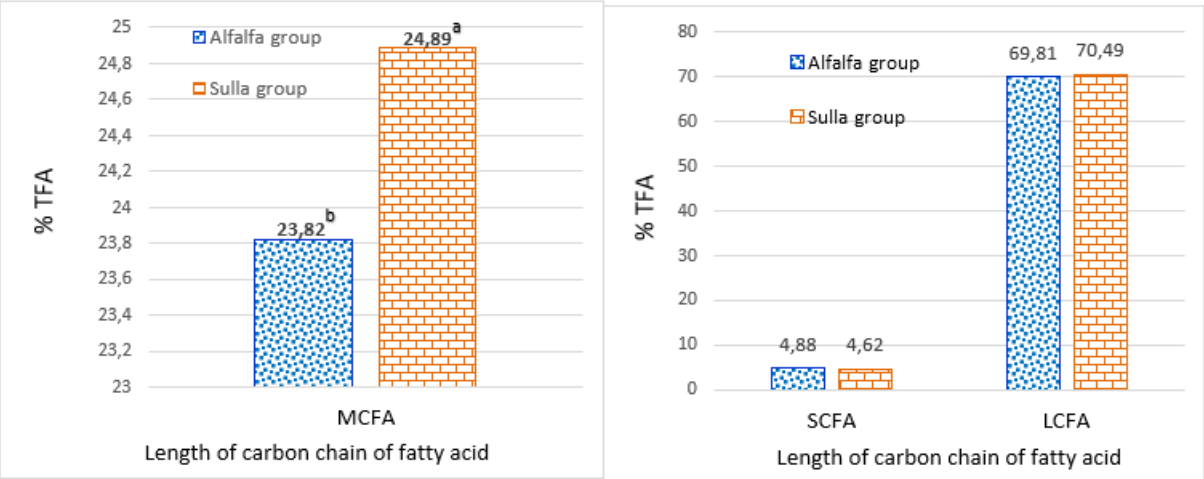

Figure 6: Fatty acid length of milk of goats fed Sulla or Alfalfa based diet.

(SCFA: short chain FA: C4 to C8, MCFA: medium chain FA: C10 to C15, LCFA: long chain FA C16 to C24).

Discussion

Production and chemical composition of Milk

Sulla based diet allows an increase in production of about 15% compared to alfalfa, which is recognized as an excellent source of protein. The positive effects of Sulla on goat production can be attributed to its high protein content and the ratio between degradable and structural carbohydrates (Terril et *al.*, 1992).

Milk is a good source of protein for human. Sulla allowed an increase in goat milk production of about 15% compared to alfalfa. This positive effect can be attributed to Sulla high protein content and degradable to structural carbohydrates ratio (Terril *et al*., 1992). In addition, according to Molle *et al.* (2009), the moderate condensed tannins content in this legume has no negative effect on dry matter intake.

No effect of feeding on milk pH was found. The average pH value varied between 6.3 and 6.7 which was in agreement with those (6.50 and 6.80) reported by Pellegrini *et al*. (1994). Furthermore, Remeuf et *al.* (1989) confirmed that the pH goat milk is generally between 6.45 and 6.90.

The small variation no significant in acidity between Sulla and Alfalfa groups is due to the unhygienic conditions of milk collection and the time between milking and collection of the samples, which is generally between 1 and 2 hours. All these conditions can

promote the development of lactic flora and consequently the increase of acidity. The increase of this parameter is, in fact, an indication of poor quality of milk preservation.

According to FAO (1990), fresh goat milk should have an acidity of 14-18°D. Moreover, the price of milk is dependent on its protein and fat contents. On the other hand, these two parameters play a crucial role in cheese making because they are responsible for cheese consistency and flavor.

Fat content varied between 1.39% and 2.71% in Sulla milk. This result was significantly lower than the values reported by several authors, namely Jenot *et al.* (2012) (4.1%) and Remeuf *et al.* (1989) (3.3%) and Chilliard *et al*. (2007) (2.87% and 3.79%), for multiple diet.

Zantar *et al*. (2014) also reported higher fat content (3.6%) for the same breed and feed. This difference can be explained by season, feed and lactation number. In addition, we noted that the evolution of this parameter during the experimental period was not well defined. In contrast, Zahraddeen *et al*. (2007) observed a significant decrease in fat content with the goat stage lactation (from 5.35% to 4.13% at 12th and 13th lactation week of lactation). According to Chillard *et al.* (2007), the fat content in goat milk reaches the highest levels immediately after kidding and then decreases gradually during most of lactation. This is mainly related to two phenomena: i) dilution effect due to lactation peak and ii) decreasing fat mobilization and reducing availability of non-esterified fatty acids from plasma for mammary lipid synthesis. On the other hand, Beyene and Seifu (2000) have observed a decrease in this parameter.

Averages milk protein content in both groups (3.80% vs. 3.85%) were similar to those reported by Zantar *et al.* (2014) for the same breed and by Zahardeen *et al.* (2007) (3.84%) and Berger et *al.* (2004) (3.70%). But these values were higher than those reported (2.5%) by Jenot et *al*. (2012).

Lactose is fermentable sugar present in all dairy products. Under microorganism's action, it is converted into various products including lactic acid (Zantar *et al.*, 2014). In this study, milk lactose content was positively influenced by diet. For Sulla group, lactose content ranged from 5.16% to 5.41%. This value was higher than reported by Zahraddeen *et al* (2007) with a significant decrease depending on lactation stage (from 5.02% at the beginning to 4.07% at the last lactation stage). In addition, our values were also higher than those reported (4%) by Jenot et *al*. (2012) and Zantar et *al.* (2014) (3.67%).

Milk Fatty acid profile

For two diets, milk contained more C16:0 and C18:1n-w9 cis (23.4% and 24.4%) than other fatty acids. For the same breed of goats, Zantar et *al.* (2014) also reported that C16 and C18:1 were the predominant at 30% and 19%, respectively. Chilliard *et al.* (2007) reported values ranging from 13.2 to 27.7% for goat fed corn silage and sunflower oil or meal.

Omega-3 (ω3) and omega-6 (ω6) fatty acids, polyunsaturated (PUFA) and unsaturated (UFA), are significantly more abundant in Sulla milk (0.39%, 3.42%, 3.96%, and 42.98%, respectively). The improvement in the quality of the desirable FAs in the case of Sulla milk can be explained by the moderately high content of condensed tannins in this plant, which protect unsaturated fatty acids from the biohydrogenation process during digestion in the rumen (Cabiddu et *al*., 2009; Vasta et *al*., 2009).

In general, a diet that leads to a decrease in saturated fatty acids (SFA) and an increase in unsaturated fatty acids (UFA) also leads to an increased level of trans fatty acids (Chilliard et *al*., 2007). However, in our case, this increase is negligible, while some authors have reported that the condensed tannins of Sulla distributed in flowering lead to a decrease in trans fatty acids and ω6/ω3 ratio, as well as an increase in linoleic and linolenic acid content (Cabiddu et *al*., 2009).

Legarto et *al*., 2014 reported high levels of short fatty acids SFA with 75.92% in goats fed a ration containing milled dried legume hay (as 45% main feed), dehydrated alfalfa and straw as supplementary feed with 40-50% concentrate. These authors also obtained higher levels of C16:0 (29.58%) but lower levels of C18:1n9c (16.17%) and comparable levels of polyunsaturated fatty acids PUFAs (3.92%). Volkmann et *al.* (2014) also reported a higher SFA content of 73.4% (for goats fed on pasture and also fed 100 g of concentrate per day) and a much lower content of monounsaturated fatty acids MUFA (19.5%), which was comparable to that of the Sulla group for PUFA (4.10%).

Conclusions

This work highlights the positive effect of a Sulla-based diet (*Hedysarum flexuosum*L.) on milk yield of Beni Arrouss goats in northwestern Morocco. No significant differences were found in milk protein and fat contents. However, ω3, ω6, unsaturated and medium chain fatty acids were improved by Sulla fodder. This improvement milk quality can make Sulla suitable for use in feeding lactating goats.

Conflicts of interest

The authors declare no conflicts of interest.

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