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Assessment of the main factors affecting goat milk yield and composition in the North West region of Tunisia

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Abstract

This study aimed to assess the main factors affecting goat milk yield and composition from the Northwest region of Tunisia. A survey and a sampling campaign were conducted over four months (February-May, 2018), within 112 farms in 3 regions. Individual daily milk yield (DMY) was registered and milk samples were taken in duplicate to be analysed for fat (FC), protein (PC), solid not fat (SNF), density and lactose contents. Results showed that the Alpine breed allowed the highest DMY and PC, and the Damasquine presented the highest FC. The third lactation allowed the highest DMY (0.95 $Lday^{-1}$) and FC (6.68 %), however the highest PC, SNF and density are recorded for primiparous. Concerning the birth weight of kids, DMY increased significantly with the weight of the kids at birth, and it resulted in a significant effect on the FC. The assessment of the region effect showed that the highest DMY was obtained in the region of Jendouba and Ghardimaou. For milk composition, when breed effect was eliminated and focused only on the local breed, we found the highest FC in Sedjnen/Nefza. The analysis of the goat feeding allowed identifying 5 types of rations. Also, statistical analysis showed that the highest DMY resulted from the rations T4 and T5 (averaged 1.06 $Lday^{-1}$). No effect of ration type on FC and density was found. Concerning PC, SNF and lactose, the ration effect had no significant effect, but a trend of highest values was noted for T3. It was concluded that dairy performances were low, focusing only on the local goat population. However, the produced milk is of good quality regarding the determined chemical composition. Indeed, there is a negative correlation between milk production and the chemical composition of milk. Substantial improvements are potentially possible through actions (improvement of the quality of the ration, milk hygiene, milk collection pattern, training of breeders, etc) to develop a value chain in the region and improve farmer incomes.

Keyword: goat; NorthWest of Tunisia; milk; variation factors

Introduction

Goat farming is an integral part of the oldest agricultural tradition in the countries of the Mediterranean basin. This activity plays an important socio-economic role in maintaining the fragile structure of the rural population, which needs income resources, by protecting them against the vagaries of life and providing food and financial security (Gaddour et al., 2008). In Tunisia, since the 1960-ies the goat has been considered as an agent of natural resource degradation due to the excessive exploitation of forests and rangelands, despite its socio-economic role (Ressaissi, 2019). The prohibition of goat farming in the northern and central regions (Jort, 1958) was the origin of the regression of goats in country. Recent statistics for the last decade 2010-2020 showed that the number of female units varies between 708 and 740 thousand (DGPA, 2020). Goat heads are distributed through out the territory as 27, 22, and more than 50 % in the North, Centre, and South of the territory, respectively (DGPA, 2019). According to Nafti et al. (2009), goat farms are well adapted to the different Tunisian climatic conditions and are located in mountainous areas, natural rangelands, and southern oases. The main goat farming systems encountered in the country are (i) systems integrated into farms, (ii) livestock systems in mountainous and forest regions, (iii) oasis ecosystems and (iv) transhumant livestock systems.

The agro-sylvo-pastoral goat farming system is predominant in the mountainous regions of Northwest and is most often associated with the local bovines (ODESYPANO, 2003). In this context, Ammar et al. (2011) reported that herds are located mainly in the hills and mountainous and are conducted in extensive mode. This system is traditionally based on grazing and the use of fodder crops and spontaneous vegetation and is adopted mainly for the local goat, since it allows animals to satisfy most of their needs requirements in winter and spring. The needs of the animals are also/sometimes met by cultivated green forages and supplementation using mainly farm concentrate and barley (ODESYPANO, 2018).

The evolution of goat meat production in Tunisia is very weak. It varied from 9.2 to 10.7 tons between 2011 and 2020 (DGPA, 2021) and contributes at only 7 % covering the need for red meat. Likewise, goat meat consumption per person in Tunisia is one of the lowest in the Mediterranean countries. Also, goat milk production is still low compared to southern Mediterranean countries (FAO, 2007). Despite the several development programs carried out in Tunisia (Khemiri et al. under publication) and even so goat farming is one of the main income-generating activities for rural populations (ODESYPANO, 2016), this sector is left to its own devices; it is marginalized, extensive and family-oriented and not yet properly valued in the development strategies of breeding in this region (ODESYPANO, 2021). The constraints of the sector are mainly the variation of the quality and availability of fodder, as well as the low level of technicality, both in terms of feeding and reproduction or health monitoring. Also the national herd is composed mostly of local breeds with low dairy potential and milk production doesn't exceed 98 kg per lactation, which was crossed since 1980 by improver breeds (Alpine, Damasquine, Murciana Grenadina, and Boer) resulting in some improved performances (Gaddour et al., 2008). Unfortunately, the initiated programs on genetic selection and biodiversity conservation have never been completed, especially for milk (Gaddour et al., 2008). Also, it is worthy to note that the imported breeds registered limited productivity, compared to which noted in their origin countries, due to climate and feeding changes (Gaddour and Najari, 2009; Najari et al., 2005). Another constraint is that in these regions breeders are very little integrated into local structures and organizations and do not benefit from great technical support concerning the management of livestock and the promotion of products.

Recently, in the region of the Northwest of Tunisia, there has been a renewed interest in goat breeding, given its economic and social role, and the real opportunities that it could provide for rural population. Indeed, goat dairy products including goat cheese are of high quality and goat milk has the best nutritional quality compared to other ruminants (Utza et al., 2018). Also, it is defined as one of the most complete and balanced foods (Jenot et al., 2000). However, the promotion of this goat milk farming can only be done by a deep better characterization of the production capacity, the control of animal management and the understanding of the main factors effecting goat milk productivity and composition. To our knowledge, currently, there is no national standards on the quality of goat milk and research on goat milk production in the context of agro-sylvo-pastoral farming system in Tunisia are very scarce and the most known studies concerned the oasis and the southern regions (Jemali and Villemot, 1996; Gaddour et al., 2007; Gaddour et al., 2008; Gaddour and Najari, 2009; Gaddour and Najari, 2011).

In the current study we aimed to investigate the main factors affecting goat milk performance and milk composition, through the individual characteristics of animals and feeding mode, in representative areas of the Tunisian North-west region.

Materials and methods

Study area

The study was carried out in the North-West region of Tunisia, which extends over four governorates (Beja, Jendouba, Siliana and Kef) and covers 10.8 % of the national territory. The climate is of a Mediterranean type, with sub-humid and humid stages. Rainfall is poorly distributed, with large fluctuations from one year to another (from 240 to 2250 mm/year). The relief is rugged, difficult, characterized by mountain ranges and

hills that drop towards the east. It is the most important agricultural region in the country for wheat, red meat, and milk production (respectively 54, 40 and 30 % of the national production). The North-West region gathers 22 % of the agricultural employment and 22 % of the rural population. Furthermore, it is the region with the highest water potential and the best forestry resources (31.5 % of the national used agricultural area). The total number of goats in the North of Tunisia is estimated to 209 120 female goats (DGPA, 2021).

Data collection and milk sampling

Data collection was based on a global farmers' survey, carried out from February to May 2018. Survey and milk sampling concerned 112 small and medium farmers from the main goat farming areas (Ain Draham and Tabarka, Jendouba and Ghardimaou, Nefza and Sejnen). The choice of farms was based on the number of goats, the receptivity of the herder and the accessibility of the farms, which must belong to the intervention zones of the ODESYPANO. The survey included sections of data concerning mainly the farmer, the farm, the flock (composition and characteristics), some technical parameters (Daily milk yield and live weight of kids birth weight and feeding mode (type of ration). In the current article, we focused on technical parameters and type of ration as related to milk yield and composition.

Identified type of ration

The survey allowed defining the main types of rations used in goat feeding within farmers. These rations were based on combinations of forest pasture (*Erica arborea, Phillyria media, Calicotome spinose, Acacia Cyanophilla and Myrtus communis*), dry fodder (hay), green forages (barley, ray-grass, triticale, or alfalfa) and concentrate (Barley, Faba bean), which result in 5 types of ration.

Milk sampling and analysis

In each farm, two milk samples were taken per goat. Milk was collected in 30 mL capacity flask, containing a conservator based on potassium dichromate and stored at 4 °C. They were labeled to ensure their identification (farm, breed, and lactation number) and sent to the National Agronomic Institute of Tunisia (INAT), Research unit of ecosystems and aquatic resources laboratory. Milk analysis was performed using a Lactoscan (Milkotester Ltd serial n°23884, PRO TOUCH Europe). It allows determining the contents of fat (FC), protein (PC), the solids not fat (SNF), density and Lactose.

Statistical analyses

The analysis of the main factors of variation in the quantity and composition of milk (daily milk yield: DMY, Fat Content: FC, Protein Content: PC, Solids Not Fat: SNF, Density and Lactose) was carried out using an analysis of variance through the GLM procedure of the SAS system (2009) according to the model:

$Y_{ijkl} = \mu + TR_i + LN_j + B_k + KBW_l + R_m + E_{ijklm}$, with:

μ: Overall average; TR_i: Type of ration (i = 1 to 5); LN_j: Lactation number (d = 1 to 5); B_k: Breed (k = 1 to 6); KBW_l : Range of kid birth weight (l = 1 to 4); R_m: Region (m = 1 to 3); E_{ijklm}: Residual error.

Means relative to factor levels were compared using the test of Duncan.

Result and discussion

Some farm and farmer characteristics

Table 1 shows main characteristics of the investigated holders. It reveals that 36.8 % of farmers are over 61 years old and 47.8 % of them have no formal education. For 84 % of them, livestock is considered as their main activity. Most of the respondents (68.4 %) had less than five family members. In almost cases, family members participate in the tasks of the farm. Concerning the farms, 77.1 % of them have an agricultural area ranging between 0.25 and 5 ha and 50 % of the crops are conducted in dryland, with only 6 % located in the irrigated area. About 48.9 % of breeders have herds larger than 25 head of goats, while (68.9 %) raise less than 5 heads of sheep and about 60 % of farms have sheepfolds.

The analysis of the rearing of females revealed that 67.5 % practice steaming and 45.9 % flushing. The age of mating is between 9 and 12 months (72.5 %). For males, 40.8 % are from the renewal. 69.6 % of breeders practice flushing. In 43.5 % of the cases, the bucks stay three years on the farm. Regarding the sale of animals, in 72.5 % it is done at an age between 9 and 12 months, a weight between 15 and 20 kg (43.1 %) and a price between 11 and 13 dinars per kg (1TD=0,31 euros) of live weight (43.2 %).

Characteristics of rations

The analysis of data based on the five defined types of ration (table 2) showed that the majority of surveyed farmers use rations of type T3 and T5 (33 and 35 % respectively).

This distribution allows affirming that grazing is the main practice in goat rising in the studied areas. This confirms the extensive character of the goat breeding in the region; since almost all the surveyed farmers are installed in the region rely on natural grazing (98 %). According to Jemaa et al. (2016), regardless of the type of livestock, natural

Table 1. The main farm characteristics and data

Variable	Frequency	Percentage (%)
Respondents characteristics		
Age (years)		
<30	41	4.8
31-40	100	11.7
41-50	165	19.32
51-60	233	27.28
>61	315	36.8
Education background		
No Formal education	153	47.81
Primary School education	135	42.19
Secondary School education	30	9.37
Higher Education	2	0.62
Occupation		
Farming	273	84.78
Another occupation	49	15.21
Family size (Ha)		
<5	219	68.4
6-8	95	29.7
9-11	6	0.01
Farm characteristics		
UAA (Ha)		
<0.25	14	6.28
0.25-5	172	77.13
5-10	24	10.76
>11	13	5.82
Irrigation source		
Dry land	57	50
River	15	13.16
Water dam	21	18.42
Water source	14	12.28
Irrigated area	7	6.14
Number of goats kept		
<5	9	5.11
6-10	21	11.93
11-15	25	14.2
16-24	35	19.87
25-50	50	28.40
>50	36	20.45
Number of sheep kept		
<5	93	68.89
6-10	9	6.67
11-15	13	9.63
16-24	12	8.89
>25	8	5.92
Livestock building		
Building		
Sheepfold	104	59.43
Enclosure	71	40.57
Steaming		
Yes	114	67.45
No	55	32.54
Flushing		
No	93	54.07
Yes	79	45.93
Age at first breeding (Month)		
5-9	36	28.12
10-12	88	68.75
>12	4	3.12
Buck origin		
Purchase	50	28.73
Exchange	53	30.46
Renewal	71	40.80
Buck flushing		
No	42	30.43
Yes	96	69.56
Career length of the goat		
1 year	11	10.18
2	31	28.70
3	47	43.52
>4	19	17.59
Age at Sale (month)		
<8	34	20.36
9-12	121	72.45
>12	12	7.18
weight at sale (kg)		
<11	25	17.36
12-14	36	25
15-20	62	43.05
>20	21	14.58
selling price (TD) *		
6-10	13	29.54
11-13	19	43.18
14-25	12	27.27

**TD:Tunisian Dinars: 1TD=0,31 euros*

Table 2. Identified types of ration and their frequency

Ration	Ration's composition	Use frequency
Type 1 (T1)	Forest pasture	19 %
Type 2 (T2)	Forest pasture + hay	8 %
Type 3 (T3)	Forest+ hay + supplementation	33 %
Type 4 (T4)	Forest +hay+ green forage +supplementation	5 %
Type 5 (T5)	Forest pasture + supplementation	35 %

vegetation rangelands and cereal stubble pastures remain the basis of small ruminant feeding in Tunisia. Grazing lasts an average of 6.5 hours per day and varies according to the season and the availability of fodder. On the other hand, following the drought and the successive fires in the forests, 73 % of the surveyed farmers have resorted to supplementation to cover the animals' feed requirements. This complementation can be either in the form of barley grain, or faba bean alone, or as a set of raw materials (2 or 3). According to Jemaa et al. (2016), supplementation with concentrates is systematic, at least six months a year. Some farmers supplement only part of the year, starting

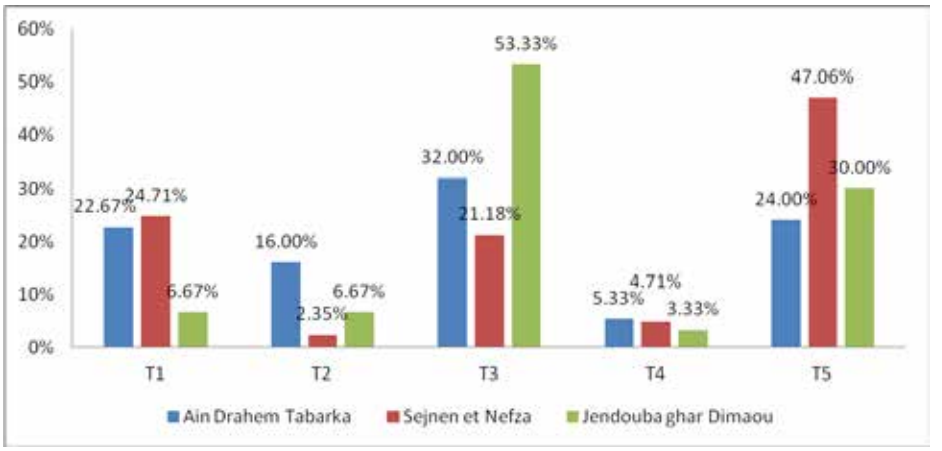


Figure 1. Distribution of the different types of ration (T1-T5) by region

in June, when the spring pastures have already been consumed, as well as the cereal stubbles. The autumn rains allow only a small amount of regrowth of vegetation, so supplementation continues until January.

The farmers in the different governorates are attempting to adapt their practices as well as possible to the climatic conditions characterizing the region and to the feeding needs of their flocks. The used rations differ from one farmer to another and from one delegation to another according to the availability and the diversification of resources (Figure 1) and the prices when some forage or concentrates are purchased. In central Tunisia, the farming system of some large-scale livestock farmers is intensive and characterized by the dominance of fodder crops in the humid region and legumes in the sub-humid region (Ben Salem and Ben Hammouda, 1995).

When comparing with other goat regions, for example, in the south of the country, Ammar et al. (2011) identified two types of goat farming systems in Tataouin region. The first one is the pastoral system based on grazing and transhumance and the second is the agro-pastoral system based on grazing and fodder crops. Intensive fodder crops are generally based on a rotation between short-cycle crops grazed directly in winter and spring cereal crops. According to Najari and Gaddour (2008) and Gaddour et al. (2014) in the "peri oasis" system the animals receive a supplementation of barley, bran and by-products of market gardening.

Global results for milk yield and composition

The average values relative to milk physico-chemical characteristics are presented in table 3. The average goat's milk production is 0.85 $Lday^{-1}$. This value is higher than that reported in Tunisia (0.76 $Lday^{-1}$) for goat southern population (Gaddour et al., 2008). This level of production is low as compared to goats in the other Mediterranean countries. Indeed, Sandrucci et al. (2019) recorded an average milk production of about 1.25 kg/milking in Italy. According to Morales et al. (2019), goats in Spain and France produce higher quantity of milk per day in the order of 1.79 and 3.15 kg/day respectively.

The fat content averaged 6.2 %. This value is higher than that reported for goat by Sboui et al. (2016) in Tunisia and Yangilar (2013) in the United Kingdom, France, Italy, Greece, Cyprus and Spain, who cited values not exceeding 5.6 %. This can be explained either by the high fibre rate in the rations from the rangelands in the Tunisian study areas (El Gallad et al., 1988) and/or by the negative correlation between milk production and fat content (El Gallad et al., 1988) since milk yield is low in Tunisia.

The average protein content is 3.32 %, it is higher than values reported for the Alpine (3.2 %), (Yangilar, 2013) and British Saanen (2.6 %), (Yangilar, 2013) breeds, but close to the values reported for the local breed in Morocco (3.9 %), (Zantar et al., 2016).

Table 3. Average milk yield and characteristics in the studied areas

	Average	Standard deviation	Min	Max
DMY ($L\ day^{-1}$)	0.86	0.62	0.1	3
FC (%)	6.20	2.62	1.56	12.93
PC (%)	3.32	0.65	2.11	6.99
SNF (%)	10.07	1.65	6.78	17.86
Density ($kg\ m^{-3}$)	1026.3	6.15	1014.9	1053.2
Lactose (%)	4.61	0.9	2.82	8.91

DMY: daily milk yield; FC: Fat Content, PC: Protein content, SNF: Solids not fat

The average percentage of SNF, which corresponds to all components of dry matter except fat, is approximately 10.1 %. This value is higher than the values cited by Hilal et al. (2016), Mahmoud et al. (2014) and Ayeb et al. (2016) who found 9.5 %, 8.8 % and 9.8 % respectively in Morocco, Sudan and Tunisia.

The average lactose content (4.6 %) is slightly lower than the averages reported by Adewumi et al. (2017) for the Boer breed in Nigeria (4.99 %) and Hilal et al. (2016) for the Beni Arouss breed of Morocco (4.82 %). It's worthy to note that both for milk daily yield and composition parameters; standard deviations are high, traducing a high variability in feeding systems and management.

Factors affecting milk yield and composition

Effect of breed

The effect of goat breed on the milk yield and composition is summarized in table 4. Milk production is significantly ($p<0.0001$) higher for Alpine (1.92 L) compared to other breeds (Local goat, Local cross bred goat, Damasquine, Saanen, Malta) which were similar (averaged 0.86 L). These results are in agreement with those found by Gaddour et al. (2008), who reported a value of 1.85 L for the same breed. However, Alpine is known as dairy performing breed, and yields are much lower than those recorded in its origin country. This difference could be due to the breed's difficulty in adapting (Najari et al., 2005) and the feeding systems, which are mostly extensive. The local goat presented the lowest productivity (0.65 $Lday^{-1}$). This result is in line with the values found by Najari et al. (2005) and Gaddour et al. (2008). These authors explained the low performance by the low genetic potential of the animals and the restriction of pastoral resources. The amount of milk produced by the local cross-bred goat is slightly higher than that of the local goat. This observation corroborate the results published by Gaddour et al. (2008), which claimed that the absorption crossbreeding of the local breed improves milk performances.

The fat content is significantly ($p<0.01$) higher in the Damascus breed (7.11 %) compared to the Maltese breed (3.66 %) and the local crossbred goat (5.25 %). For the protein rate, the Alpine breed shows a significantly ($p<0.01$) higher value (3.56 %) compared to the local (3.26 %) and local crossbred (3.14 %) populations. These results are in line with those of Croguennec et al. (2008) who reported that the goat breed effect mainly concerns protein. The difference between breeds traduces mainly the genetic differences in goat production aptitudes (Yangilar, 2013) and to the degree of rusticity and adaptation of the goats in relation to the mountainous and forest character of the investigated region (Morgan et al., 2000).

Effect of lactation number

Table 5 illustrates the variation in milk composition according to the lactation number. The highest milk yield ($p<0.05$) was observed in the 3rd lactation (0.95 $Lday^{-1}$). A lower yield was noted in the 4th lactation (0.84 $Lday^{-1}$), and lowest, but equivalent, values were noted in the others (averaged 0.77 $Lday^{-1}$). This trend of variation in milk yield according to lactation number agrees with several published studies on dairy goats (Ciappesoni et al., 2004; Arnal et al., 2018 and Zamuner et al. 2020). According

Table 4. Effect of goat breed on milk composition

	Local goat	Local cross bred goat	Damasquine	Alpine	Saanen	Malta	SEM
DMY**	0.7^{b}	0.82^{b}	0.91^{b}	1.92^{a}	1.2^{b}	0.69^{b}	0.04
FC *	5.82^{ab}	5.25^{b}	7.11^{a}	6.32^{ab}	6.37^{ab}	3.66^{b}	0.17
PC *	3.26^{b}	3.14^{b}	3.38^{ab}	3.56^{a}	3.74^{ab}	3.44^{ab}	0.04
SNF*	10.06^{b}	9.61^{b}	10.26^{ab}	10.72^{a}	10.95^{ab}	10.40^{ab}	0.11
Density*	1025.6^{b}	1025.2^{b}	1026^{ab}	1028.2^{a}	1028.6^{ab}	1029.5^{ab}	0.41
Lactose	4.61	4.38	4.73	4.97	5.19	4.81	0.06

a, b: different letters on the same line indicate statistically different values; SEM: standard error of the mean;
**: p<.05; **: p<.01. DMY: daily milk yield ($Lday^{-1}$); FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, Lactose (%)*

Table 5. Variation of milk yield and composition with lactation number

	1	2	3	4	>5	SEM
DMY*	0.78^{c}	0.75^{c}	0.95^{a}	0.84^{bc}	0.79^{c}	0.04
FC**	6.55^{ab}	5.65^{b}	6.68^{a}	5.77^{ab}	5.32^{b}	0.17
PC *	3.5^{a}	3.35^{ab}	3.2^{b}	3.23^{ab}	3.34^{ab}	0.04
SNF*	10.75^{a}	10.08^{ab}	9.77^{b}	9.88^{b}	10.01^{ab}	0.11
Density *	1028.5^{a}	1026.7^{a}	1024.8^{b}	1025.9^{ab}	1027.3^{ab}	0.41
Lactose	4.98	4.6	4.56	4.53	4.69	0.06

a, b, c: different letters on the same line indicate statistically different values; SEM: standard error of the mean;
**: p<.05; **: p<.01. DMY: daily milk yield ($Lday^{-1}$); FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, Lactose (%)*

to Lérias et al. (2014), the greater milk production in multiparous goats can be explained by older goats tending to have a higher proportion of alveoli developed in the previous lactation added to those developed in subsequent lactations, increasing secretory parenchyma and udder volume compared with primiparous goats.

Fat content followed approximately the same trend of milk yield. Indeed, the highest ($p<0.01$) value was noted in the third lactation (6.68 %). This observation is in agreement with those of Ciappesoni et al. (2004) who found that in the first lactation goats had a significantly lower fat content than goats in 2nd, 3rd and 4th and further lactations. Bhosale et al. (2009) found the same observation; they recorded an augmentation of FC by about 22 % between the first and the fourth lactation. However, Carnicella et al. (2008) reported an opposite effect of parity on fat content; thus goats in their first parity produced milk higher in fat compared to other groups (3.6 and 3.5 %, respectively).

The protein content significantly ($p<0.05$) decreases progressively with parity. This result is in agreement with those of Carnicella et al. (2008) who reported that goats in their first lactation yielded milk richer in protein (3.5 %) as compared to other groups (3.4 %). In contrast, Zamuner et al. (2020) reported that parity did not affect contents of milk fat and protein in early lactation.

The primiparous provide significantly ($p<0.05$) higher SNF content than animals in third and fourth lactation. This result traduces the highest protein rate and maybe mineral salts in the first lactation.

Effect of kid birth weight

The results regarding the effect of birth weight of kids on milk yield and composition are presented in table 6. Daily milk production increases significantly ($p<0.01$) with the weight of the kids at birth. The same trend was observed by Carnicella et al. (2008) for Maltese goats and Zamuner et al. (2020) for Australian goats. They claimed that goats delivering single kid had lower cumulative milk yield.

For weights above 2 kg, FC is significantly higher than C2 (between 1.2 and 1.4 kg) and C3 (between 1.5 and 1.9 kg), but equivalent to C1. This observation is in line with which of by Moujahed et al. (2009) in Sicilo-Sarde ewes, noted in the same region. The high FC noted for weights not exceeding 1kg (C1: 6.64 %) may be due to the low quantity of milk produced for this category (0.7 L) of goats. The same trend was found by Zamuner et al. (2020). No effects of kid weight at bird were noted for PC, SNF and Lactose contents. They claimed that goats delivering single kid had higher rates of fat, and protein in milk than goats delivering multiple kids. In contrast, Carnicella et al. (2008) advanced that Maltese goats kidding twins yielded more milk and had longer lactation ($p<0.001$) but don't affect protein and fat contents.

Effect of the sampling region

The variation of the physico-chemical variables of milk as related to the different sampling delegations from the Northwest region is summarized in table 7. Jendouba and Ghardimaou region presented the highest ($p<0.01$) daily milk production (0.93 $Lday^{-1}$) which is the highest in fat (6.65 %, $p<0.01$), PC (3.5 %, $p<0.05$) and lactose (4.8 %, $p<0.05$). This can be explained by the breeds available in these delegations, the availability and the quality of fodder and especially by the climatic conditions related to the regions. To eliminate the breed effect, we studied the variation in milk quality only in the local goats in

Table 6. Variation in the composition of goat's milk according to the birth weight of the kids

	C1 :1 kg	C2: 1.2-1.4 kg	C3: 1.5-1.9 kg	C4>2 kg	SEM
DMY**	0.70^{b}	0.68^{b}	1.01^{a}	1.25^{a}	0.04
FC**	6.64^{a}	5.07^{b}	5.2^{b}	6.69^{a}	0.17
PC *	3.38^{a}	3.21^{ab}	3.16^{b}	3.25^{ab}	0.04
SNF *	10.20^{a}	9.80^{ab}	9.66^{b}	9.90^{ab}	0.11
Lactose	4.72	4.48	4.39	4.52	0.06

a, b, c: different letters on the same line indicate statistically different values; SEM: standard error of the mean;
**: p<.05; **: p<.01. DMY: daily milk yield ($Lday^{-1}$); FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, Lactose (%)*

Table 7. Variation in the chemical composition of milk according to the region

	Jendouba and Ghardimaou	Sejnen and Nefza	Ain Drahem and Tabarka	SEM
DMY**	0.93^{a}	0.8^{ab}	0.7^{b}	0.04
FC**	6.65^{a}	6.81^{a}	5.35^{b}	0.18
PC*	3.50^{a}	3.4^{ab}	3.2^{b}	0.04
SNF*	10.5^{a}	10.2^{ab}	9.65^{b}	0.12
Density	1027.4	1026.3	1025.4	0.44
Lactose*	4.80^{a}	4.7^{ab}	4.4^{b}	0.06

a, b: different letters on the same line indicate statistically different values; SEM: standard error of the mean;
**: p<.05; **: p<.01. DMY: daily milk yield ($Lday^{-1}$); FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, Lactose (%)*

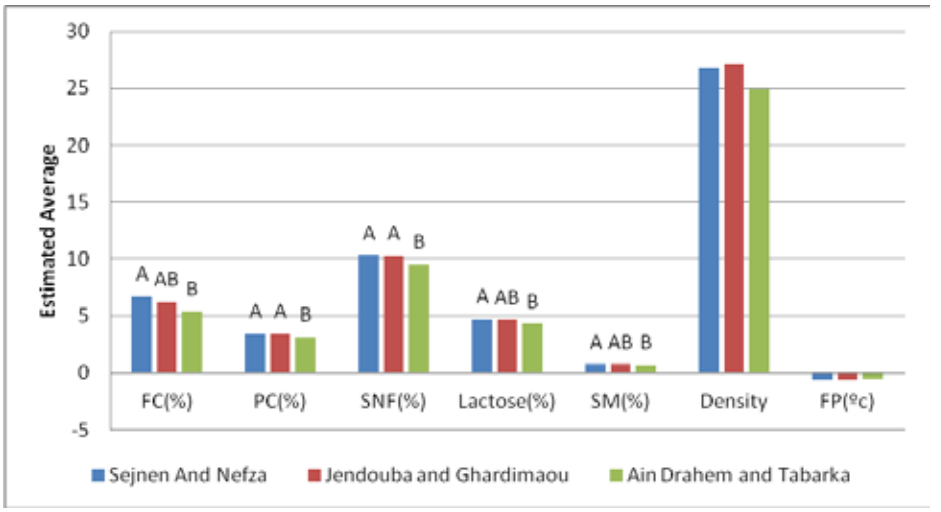


Figure 2. Variation in the physico-chemical quality of local goat's milk in different regions

A, B: different letters on the same line indicate statistically different Values, FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, FP (°C): Freezing point.

the different regions. The results are shown in figure 2. The highest fat content is noted in Sejnen/ Nefza and is significantly ($p<0.05$) higher than the milk content of Ain Drahem and Tabarka. On the other hand, there is no significant effect between the mean fat content in Jendouba, Ghardimaou, Tabarka and Ain Drahem. This confirmed the hypothesis that results obtained were mainly due to the effect of breeds available in each region.

Effect of feeding type

Table 8 illustrates the variation in milk yield and composition according to the type of ration. The rations T3, T4 and T5, characterised by the use of concentrate supplementation allowed the similar highest ($p<0.0001$) milk production (averaged 0.97 $Lday^{-1}$). However, the lowest production is recorded by T1 and T2 rations (averaged 0.65 $Lday^{-1}$), which are mainly based on pasture and, pasture plus hay respectively. Dietary characteristics influence milk yield and milk composition of dairy goats. Indeed, Min et al. (2005) found that a ration composed of concentrate and hay allowed goats to produce 22 % more milk than those receiving a ration containing only green forage (3.84 and 2.98 $Lday^{-1}$ respectively). Also, Carnicella et al. (2008) reported that the forage/concentrate ratio significantly affected milk yield. The goats fed with a ratio of 35/65 improved milk yield of about 3.2 % compared to goats fed with a ratio of 50/50 or a ratio of 65/35, following the increase of ration concentrate rate. The same trend was revealed by Morand-Fehr and Sauvant (1980) who advanced that the green forage and hay pellets allows a highest milk production. However, using hay of medium quality reduced milk yield to 25 %.

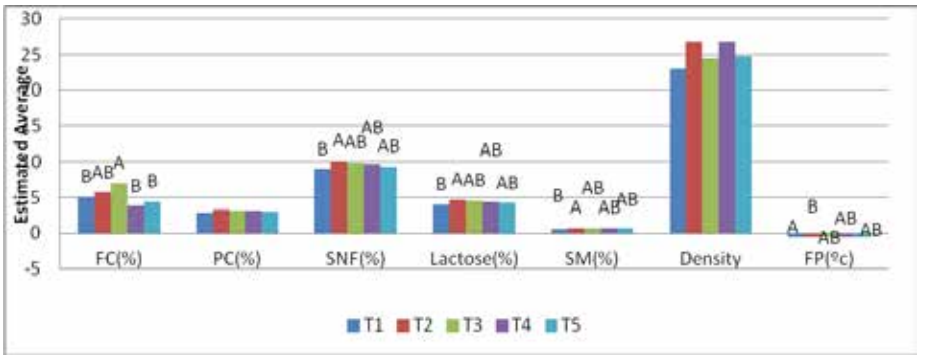
The type of feed did not affect significantly FC and density of milk (averaged 6.16 % and 1026 respectively). However, a trend of higher but not significant rate of FC was noted in including-concentrate rations (T3, T4 and T5, averaged 6.31 %) as compared to non-supplemented ration (T1 and T2, averaged 5.93 %). Our results seem to agree with those of Min et al. (2005), who registered higher milk yield and FC in goat receiving concentrate supplementation, comparatively with non-supplemented group. However, Fernandez et al. (1997) reported that milk fat percentage was not affected by different protein levels in goats.

Contents of PC, SNF and lactose in goat milk presented the same trends of variations with ration types. Indeed, the highest ($p<0.01$) values were noted in T3 (3.46, 10.4 and 4.77 % respectively for the 3 parameters). However, the lowest values were noted for the other type of ration (averaged 3.25, 9.94, and 4.55 respectively for PC, SNF and Lactose). Contrary to our results, Rúa et al. (2017) found

Table 8. Variation in the chemical composition of milk according to the type of feed

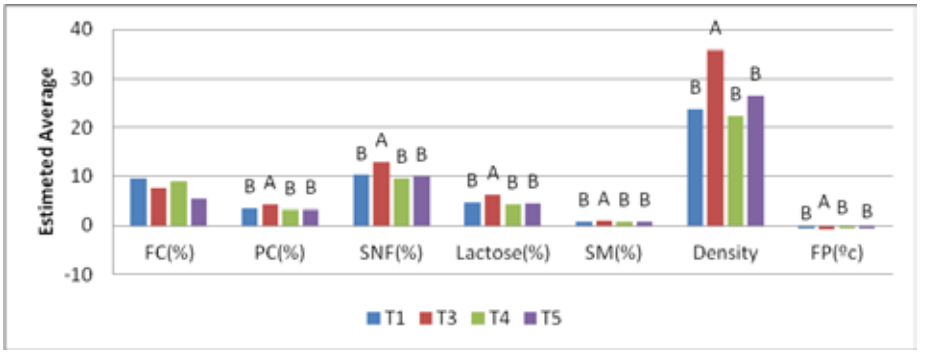
	T1	T2	T3	T4	T5	SEM
DMY**	0.611^{b}	0.695^{b}	0.797^{ab}	1^{a}	$1,118^{a}$	0.04
FC	5.97	5.88	6.37	6.39	6.17	0.17
PC**	3.17^{b}	3.24^{ab}	3.46^{a}	3.28^{ab}	3.31^{ab}	0.04
SNF**	9.68^{b}	9.92^{ab}	10.4^{a}	9.93^{ab}	10.05^{ab}	0.11
Density	1025	1025.8	1027.3	1025.7	1026.2	0.41
Lactose**	4.38^{b}	4.51^{ab}	4.77^{a}	4.57^{ab}	4.61^{ab}	0.06

*a, b: different letters on the same line indicate statistically different values; SEM: standard error of the mean; **: p<.01. DMY: daily milk yield ($Lday^{-1}$); FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, Lactose (%)*



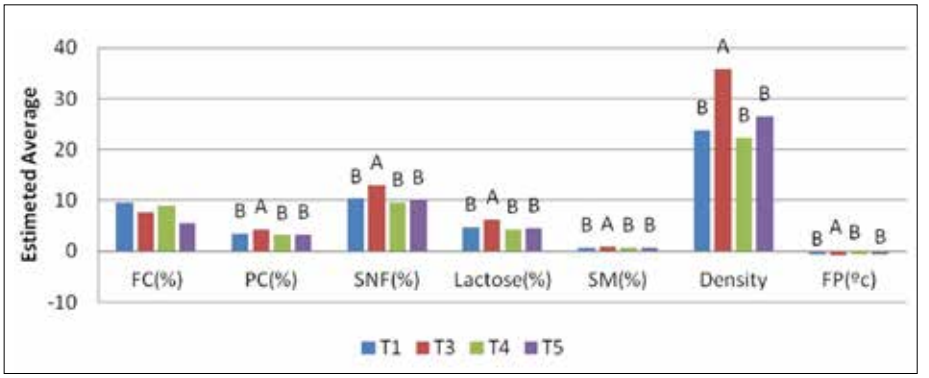
A, B: different letters indicate statistically different values; FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, FP (°C): Freezing point.

Figure 3. *The effect of feeding type (T1, T2, T3, T4, T5) on the milk composition of local cross-breed*



A, B: different letters indicate statistically different values; FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, FP (°C): Freezing point.

Figure 4. *The effect of feeding type (T1, T2, T3, T4, T5) on the milk composition of Damascus breeds*



A, B: different letters indicate statistically different values; FC (%): Fat Content, PC (%): Protein content, SNF (%): Solids not fat, FP (°C): Freezing point.

Figure 5. *The effect of feeding type (T1, T3, T4, T5) on the milk composition of Alpine breeds*

that the highest values of FC, PC and SNF are observed in the sylvo-pastoral production system, based on natural succession, which could be attributed to a larger possibility of selection of the forages by the animals. However, Vargas-Bello-Pérez et al. (2020) reported that the supplementation with whole seeds in grass silage-based diets of goats does not affect milk yield and milk composition. In our case, the T1 ration correspond to the extensive system and the breeders only use the forest resources for feeding the herd, resulting in the lowest values of milk composition. In connection with this, the study by Arroum et al. (2016) showed that the extensive system gives lower values for fat (4.5 %) and protein (1.9 %) in goat milk.

To mitigate the breed effect, we analysed the variation in quality as a function of feeding type for each separate breed (Figure 3; 4; 5). For the local population and Damascus, the feeding type had not any significant effect on milk composition, except a slight variation in fat content. However, the use of T3 for the local crossbred

goat allowed a significant high rate of FC ($p<0.01$). The feeding effect is more pronounced for the Alpine breed. Indeed, the combination of hay and supplementation (T3) showed a better quality in terms of SNF (12.9 %; $p<0.01$), PC (4.36 %; $p<0.01$) and lactose (6.2 %; $p<0.01$).

Conclusions

This study has enriched the national repertory, which to our knowledge is very little provided with results concerning the composition of goat's milk and its sources of variation, particularly in the Northwest region. Analyses of different samples of goat's milk have shown that daily milk yield varies according to birth weight of the kids, the breed and the type of diet. It's worthy to note that supplementation and the balance and the ration could result in improved milk yield as it was noted in T5. Whereas the lactation number factor had not a significant effect on milk production, but it can be noted that it is higher in the third lactation. The same factors influence to different extents the main constituents of milk. In fact, the fat content is rather influenced by the breed, the lactation number, and the type of ration. Similarly, the differences in protein levels are due to factors such as lactation number and breed, type of diet and the region of sampling. Although there are breed differences in both milk production and composition, the quality of goat milk in the study area remains rich and provides high nutritional quality. Also, the results showed that it is possible to control the composition, likely for cheese production, by acting mainly on the ration, by introducing green fodder and/or supplementation. In this trend it could be suggested that development of the milk goat sector in region is promising and that there is a potential for this development, possibly through the goat milk cheese value chain.

Određivanje glavnih čimbenika koji utječu na prinos i sastav kozjeg mlijeka u sjeverozapadnoj regiji Tunisa

Sažetak

Cilj ovog istraživanja bio je odrediti glavne čimbenike koji utječu na prinos i sastav kozjeg mlijeka iz sjeverozapadne regije Tunisa. Istraživanje i uzorkovanje provedeni su tijekom dva mjeseca (ožujak-travanj 2018.) na 112 farmi u 3 regije. Bilježen je pojedinačni dnevni prinos mlijeka (DMY) te su uzorci mlijeka uzeti u duplikatu za analizu udjela masti (FC), proteina (PC), suhe tvari bez masti (SNF), gustoće i udjela laktoze. Rezultati su pokazali da je alpina pasmina imala najveći DMY i PC, a damaška najveći FC. U trećoj laktaciji je utvrđen najveći DMY (0,95 $Ldan^{-1}$) i FC (6,68 %), dok su najveći PC, SNF i gustoća zabilježeni kod prvojarki. Uzimajući u obzir porođajnu masu jaradi, DMY se značajno povećao s masom jaradi pri jarenju, što je značajno utjecalo na FC. Analiza učinka regije pokazala je da je najveći DMY postignut u regiji Jendouba i Ghardimaou. Kada je o sastavu mlijeka riječ, nakon što se eliminira učinak pasmine, i usredotoči samo na lokalnu pasminu, najveći FC utvrđen je u regiji Sedjnen/Nefza. Analiza hranidbe koza omogućila je identificiranje 5 vrsta obroka. Također, statistička analiza pokazala je da je najveći DMY rezultat omjera T4 i T5 (prosječno 1,06 $Ldan^{-1}$), dok nije utvrđen utjecaj vrste obroka na FC i gustoću. Utjecaj vrste obroka nije značajno utjecao na PC, SNF i udio laktoze, ali je zabilježen trend najviših vrijednosti za T3. Zaključeno je da su mliječne performanse bile niske, ako se u obzir uzme samo lokalna populacija koza. Međutim, kvaliteta proizvedenog mlijeka je bila dobra uzimajući u obzir utvrđeni kemijski sastav. Također, utvrđena je negativna korelacija između proizvodnje mlijeka i kemijskog sastava mlijeka. Značajna poboljšanja potencijalno su moguća primjerice kroz poboljšanje kvalitete obroka, higijene mlijeka, obrasca prikupljanja mlijeka i obuke uzgajivača za razvoj lanca vrijednosti u regiji te tako i povećanje prihoda farmera.

Ključne riječi: koza; sjeverozapad Tunisa; mlijeko; faktori varijacije

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