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Original article

Goats' Milk Production and Kids' Growth: Effects of Supplementation Type Under Forest Pasture System

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Abstract

The objective of this study was to evaluate the effect of concentrate type on goat's milk yield and quality under forest grazing conditions as well as on their kids' growth performances during pre-weaning. The experiment was conducted in the Ain Drahem region using a total of 26 local breed goats, divided into two groups, each managed by a breeder. Within each farm, the goats were divided into three homogeneous sub-groups based on their milk production levels. The first diet: farmer's feed (FF) represented the control and the traditional diet combining forest grazing with occasional supplementation of fresh forage (barley, oats, and triticale). The second diet (CC) composed by forest grazing and a conventional concentrate consisting of 80% barley, 17.5% soybean meal, and 2.5% mineral-vitamin mixture. The third diet: rosemary concentrate (RC) included forest grazing and a concentrate incorporating distilled rosemary leaves (DRL) (73.5% DRL, 22.5% wheat bran, and 4% soybean meal). Each goat received 400 g of concentrate daily. During the trial, the goats had free access to water throughout the day. Goats 'milk yield and composition, and kids' growth parameters were recorded.

The milk yield was affected neither by the diet nor by the breeder; the average milk production was 352, 293, and 338 ml for FF, CC, and RC groups, respectively. The protein content remained unchanged among groups (3.8, 3.6, and 3.5% for FF, CC, and RC, respectively; $P > 0.05$). Similarly, the fat content did not vary with DRL inclusion (4, 4, and 3.8% for FF, CC, and RC, respectively; $P > 0.05$) nor with the breeder. Despite a lower initial body weight (7 kg), kids in the RC group reached a final body weight comparable to those in the other groups. This was supported by similar average daily weight gain values (86 g/day; $P > 0.05$). It could be concluded that DRL incorporation in concentrate resulted in comparable milk production and kids' growth, highlighting the potential of substituting barley with DRL in goat feeding strategies without altering the animals' performances.

Keywords: Distilled Rosemary Leaves, Goat, Milk Yield, Fat, Protein, Kids, Growth.

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INTRODUCTION

Goat production in Tunisia plays an essential role in supporting rural livelihoods and ensuring food security, particularly in arid and semi-arid regions. However, this sector faces several significant challenges that hinder its development. The low productivity of local goat breeds is one of the primary constraints. These breeds, while well-adapted to harsh environments, tend to have limited milk and meat yields compared to improved breeds (Najari and Ouni, 2008; Gadour and Najari, 2009). Another major challenge is the decline of pastoral resources. Extensive farming practices, combined with overgrazing and land degradation, have significantly reduced the availability of quality pasture. This is further exacerbated by climate variability, which leads to uncertain pasture availability and frequent feed shortages, especially during dry seasons (Smeti et al., 2021). Despite these limitations, goat milk production holds considerable potential for economic development, as it plays a vital role in both kid growth and the burgeoning local and national markets for fresh and processed dairy products. Enhancing milk production and overall dairy performance could significantly contribute to revitalizing the goat farming sector (Yener, 1989). Recently, the contribution of rangelands and pastures to livestock diets has dramatically decreased due to recurrent droughts and overgrazing. Then to meet animal feed requirements, farmers are increasingly using imported and expensive concentrate ingredients (corn, barley, soybean meal, etc.) which exert substantial pressure on the country's balance of payments (Kayouli, 2000). Tunisia’s unique geographical position offers a wide range of climates that promotes the development of a rich and diverse flora comprising over 2,160 plant species, including more than 350 recognized for their medicinal properties (Zaouali, 2005). This biodiversity positions Tunisia as a leading producer of aromatic plants and their derivatives, offering an opportunity to integrate locally available resources into livestock feeding strategies. Among these plants, species rich in secondary compounds like essential oils, tannins, and saponins have gained attention. These compounds have been shown to enhance ruminant feed efficiency (Maamouri et al., 2011; Bhatta et al., 2013) and improve meat quality (Nieto et al., 2010; Smeti et al., 2013). Consequently, the use of secondary compounds as additives in animal feed is becoming increasingly common, and their mechanisms of action are increasingly understood (Wallace et al., 2002). For instance, rosemary (*Rosmarinus officinalis L.*), a plant widely found in the Mediterranean region, is rich in bioactive compounds with antimicrobial properties that can boost ruminant production efficiency (Smeti et al., 2015). These findings underscore the potential for integrating such plant-based additives into goat feeding programs to optimize their productivity.

Research focusing on the specificities of local goat breeds in Tunisia, particularly regarding their nutritional management, remains relatively scarce. It is therefore crucial to develop feeding programs tailored to their physiological needs and production cycles. This study aims to evaluate the effect of two types of supplementation (a conventional concentrate based on barley and a concentrate based on

distilled rosemary leaves) on milk yield and quality of goats, as well as on the growth of their kids raised in a forest pasture system.

MATERIALS and METHODS

Study area, animals, diets and experimental design

The study was carried out at private farms in the region of "Ain Draham" of the Jendouba Governorate located in the Northwest of Tunisia. This area is characterized by a significant rainfall gradient, averaging 1521 mm, and belongs to the upper humid bioclimatic zone. The study was conducted on two herds of goats, belonging to the local breed, with a total of 26 goats (4 years-old, 3rd lactation) divided on two groups for two breeders. Breeder 1's goats gave birth to a total of 14 kids, while those of Breeder 2 had 12. At the beginning of the experiment, the goats were vaccinated against internal and external parasites as well as enterotoxemia. For each breeder, goats were then divided into three homogeneous groups according to the first 2 days milking control. The characteristics of all groups and the different details are presented in Table 1.

Table 1. Characteristics of experimental groups

Breeder	Groups	Number of goats	Milk production yield (48h), ml	Number of kids	
				Male	Female
1	FF	4	342	3	1
	CC	5	315	2	3
	RC	5	368	1	4
2	FF	4	558	1	3
	CC	4	570	4	0
	RC	4	506	2	2

FF: farmer's feeding group; CC: conventional concentrate group; RC: rosemary concentrate group

The goats' feeding relied primarily on forest rangeland grazing. The first group received supplementation based on green barley, oats, or triticale, referred to as Farmer's Feed (FF). For the other two groups, supplementation consisted of 400 g per head per day of two different concentrates: a conventional concentrate (CC) composed of barley (80%), soybean meal (17.5%), and a mineral-vitamin supplement (2.5%); and a rosemary concentrate (RC) containing distilled rosemary leaves (73.5%), wheat bran (22.5%), and soybean meal (4%). During the trial, goats were housed in collective pens equipped with feeders and had free access to water throughout the day.

The characterization of the shrub vegetation of the maquis grazed by animals is presented in Tbale 2).

Table 2. Characterization of the shrub vegetation of the maquis of the region of Ain Draham

	Species	**Scientific name**
Pastoral plants		
Strawberry Tree	Ericaceae	*Arbutus unedo*
Cork Oak	Fagaceae	*Quercus suber*
Algerian Oak	Fagaceae	*Quercus canariensis*
Myrtle	Myrtaceae	*Myrtus communis*
Mock Privet	Oleaceae	*Phillyrea angustifolia*
Green forage		
Oat	Poaceae	*Avena sativa*
Barley	Poaceae	*Hordeum vulgare*
Triticale	Poaceae	*Triticum secale*

The grazed species were sampled during two periods (March and July) to determine the biomass production, its chemical composition and the seasonal variations. The estimated biomass included cultivated forages and pastoral species. To monitor the production of green barley, oats, and triticale (the main forage crops), two samples were collected from each plot. During each sampling, all samples were immediately weighed to estimate production and to determine their chemical composition: dry matter (DM), ash, organic matter (OM), crude protein (CP), crude fiber (CF), calcium (Ca), and phosphorus (P).

Kids growth

The kids were weighed weekly prior to morning feeding using a scale with a maximum capacity of 25 kg and a precision of 100 g to calculate the average daily gain (ADG) as follow:

$$ADG = \mathbf{1000} * (\mathbf{Final\ body\ weight - initial\ body\ weight}) / \mathbf{number\ of\ days\ of\ control}$$

Milk production and analyses

Milk samples were collected weekly through hand milking, after removing the kids for 12 hours. For each control milking, an individual milk sample of 50 ml was collected in tubes containing potassium dichromate to determine the chemical composition of the milk, particularly fat and protein content. The analyses were conducted at the Genetic Improvement Center of the Livestock and Pasture Office in Sidi Thabet. The pH value of the milk sample was directly measured using a pH meter, with the electrode immersed in the milk. The milk's chemical composition (fat and protein content) was determined using a Lactoscan milk analyzer (CombiFoss 5300, Foss Electric, Hillerød, Denmark).

Laboratory analyses

The dry matter content of the feed was determined by drying it in an oven at 105°C until a constant weight was achieved. Ash content was measured by calcination in a muffle furnace at 550°C for 5 hours. The organic matter content was calculated as the difference between the dry matter and the ash. Crude protein was analyzed using the Kjeldahl method. Phosphorus content was measured using a colorimetric assay with a UV spectrophotometer, while calcium content was determined by atomic absorption spectrometry at a wavelength of 422.7 nm. Crude fiber content was assessed using the Weende method. All analyses were performed according to the official methods of the AOAC (1995).

Statistical analysis

The data related to milk yield and quality and kids' growth parameters were subjected to a two-factor analysis of variance (ANOVA) to test the effect of the diet and the breeder, as well as their interactions on these parameters using the following model:

$$Yijk = \mu + Di + Bj + Di*Bj + eijk,$$

where:

Yijk: represents the observed value of the dependent variable (milk yield, milk quality, or kids' growth parameters) for the k^{th} observation in the i^{th} diet and j^{th} breeder

μ = The overall mean;

Di = Diet effect (i = FF, CC or RC);

Bj = Breeder effect (j = breeder 1 or breeder 2);

Di*Bj = interactions between i^{th} diet and j^{th} breeder;

Eijk: residual error

The means were compared using a Duncan's multiple range test and the significance was declared at 5%.

RESULTS and DISCUSSION

Feed intake

The dry matter (DM) content of the forest plants was high but variable. It ranged from 58% for myrtle during the dry season to 83% for the cork oak. In this diet, straw had a maximum DM content of around 95% but a minimum and a protein content of 4%. The highest protein proportion (10%) was recorded in cork oak (Table 3). These results are consistent with those found by Boubaker et al. (2005) in a study on the effect of supplementation blocks on goats grazing forest pastures. In fact, the study

showed that the rumen pH and ammonia nitrogen levels were optimal for microbial activity in the rumen of goats grazing Tunisian pastoral species. Supplementation blocks did not affect the goat population grazing shrubs during the growing season, possibly due to either the sufficiency of nutrients consumed in the pasture or the inability of the supplementation blocks to deactivate the tannins present in the forest pasture.

Table 3. Chemical **c**omposition of trees, shrubs and grazed forage

	Estimated Biomass (kg/ha)	DM (%)	OM (%)	CC (%)	CP (%)	N (%)	Ca (%)	P (%)
Mock Privet *		71.97	96.43	36	6.3	1.008	0.55	0.072
Mock Privet **		81.62	96.97	36	6.91	1.105	0.44	0.081
Myrtle*		58.22	96.3	25	6.3	1.008	0.74	0.076
Myrtle**		83.2	95.83	24	6.91	1.105	1.29	0.068
Cork Oak*		65.1	96.57	26	8.83	1.412	0.65	0.12
Cork Oak**		80.76	96.34	31	10.32	1.651	1.55	0.12
Strawberry Tree*		47.45	95.92	27	7.96	1.273	1	0.084
Strawberry Tree**		74.27	95.05	21	6.38	1.02	1.25	0.064
Algerian Oak **		83.06	92.37	28	8.83	1.412	1.9	0.11
Oat **	15045	15.18	88.38	26	10.85	1.736	0.36	0.15
Barley **	13340	15.9	86.2	15	10	2.42	0.16	0.12
Triticale**	20570	19.74	88.08	30	9.1	1.456	0.23	0.14
Straw *		94.65	95.68	39	4.11	0.657	0.38	0.073

*: Samples collected in july (mating period); **: Samples collected in Mars (lactation period)

Table 4 shows that the two types of concentrate had similar levels of DM, crude fiber (CF), crude protein (CP), and phosphorus. It is noteworthy that the substitution of barley with rosemary distilled leaves (DRL) and a decrease in CP, CF, and OM. This substitution can be valuable as an alternative to the use of commercial concentrate. Indeed, Kayouli (2000) reported that the lack of forage and its poor quality leads in the use of high concentrate quantities for ruminants particularly for dairy cattle. Due to the inadequacy or lack of local raw materials, concentrates heavily depend on imported ingredients. Corn and soybean meal are entirely imported. Barley imports fluctuate greatly depending on climatic events; during droughts, imports increase, and the country also imports hay and alfalfa. Furthermore, this substitution is particularly beneficial since rosemary is one of the most commercially traded medicinal aromatic plants in Tunisia (APIA, 2003). Belkhodja (2011) notes that rosemary oil is defined as the second most important natural product in the country. However, in the past four years, production has increased to over 100 tons, highlighting the importance of large quantities of DRL, often left in nature, causing environmental issues and that could be valorized in animal nutrition as feed alternative.

Table 4. Chemical **c**omposition of experimental concentrate

	DM (%)	OM (%)	CC (%)	CP (%)	N (%)	Ca (%)	P (%)
Conventional concentrate (80% barley + 17,5% soybean meal + 2,5% MVS)	88.7	96.4	26	12.1	1.9	0.2	0.3
Rosemary concentrate (73,5% DRL + 22,5% wheat bran + 4% soybean meal)	91.6	92.9	25	11.2	1.8	1.3	0.3

MVS: mineral vitamin supplement; DRL: distilled rosemary leaves

Milk yield

The milk yield and quality parameters are reported in Table 5. The average milk production (PLm) was 352, 293, and 338 ml for T, CC, and CR, respectively. The effect of rosemary incorporation into the goats' diet showed no significant effect among groups (P> 0.05); however, the effect of the breeder was significant (P <0.01) highlighting probably the differences in management methods between breeders.

Table 5. Milk production and composition

	Treatments			Statistics		
	FF	CC	RC	P diet (D)	P breeder (B)	P D*B
Milk yield (ml)	352	293	338	NS	***	NS
Protein content (%)	3.75	3.64	3.54	NS	NS	NS
Fat content (%)	4	4	3.8	NS	NS	NS

FF: farmer's feeding group; CC: conventional concentrate group; RC: rosemary concentrate group; NS: not significant; ***: P< 0.01

The average milk yield for all groups are approximately the half of the values reported by Smeti et al. (2015) who observed an increase in the milk yield of Tunisian native breed goats supplemented with entire leaves and essential oils of rosemary. These low milk yields could be explained by the farming conditions could partly explain this low production. The genetic potential and inbreeding problems among the animals could also be factors contributing to this lower production. In other studies, levels ranging from 400 to 500 ml/day were recorded with goats receiving cactus and a low supply of concentrate (Atti et al., 2010). Additionally, higher levels (600 to 800 ml/day) were reported (Rouissi et al., 2002, 2006) for animals grazing pastures or hay with moderate supplementation of concentrate. In contrast, the milk yield values recorded in this study were slightly higher to those found by Smeti et al. (2021) after substituting hay with distilled rosemary leaves at 20 and 40% rates. In the current study, the insertion of DRL into the animal diet in proportions did not result in significant differences in goats' milk production. This result agrees with those of Savoini et al. (2003), who supplemented Saanen goats' diet with rosemary extract (6 and 12% of the basal diet), and Jordan et al. (2010), who introduced DRL

(10 and 20% of the basal diet) into the diet of Murciano-Granadina goats and did not record a difference in terms of milk yield. This result aligns with Smeti et al. (2015), who found that the administration of rosemary in both forms (essential oil and leaves) tended to increase milk production and, consequently, the growth of the kids. They attributed this difference to the presence of phenolic compounds in rosemary leaves and concluded that this plant could serve as a natural alternative to improve goat performance, given the ease with which its leaves can be obtained. In this regard, Jordan et al. (2010) added that DRL could be proposed as an ingredient in ruminant diets, as they do not alter milk yield or quality in Murciano-Granadina goats but allow for an increased concentration of polyphenolic components in both the milk of the goats and the plasma of the kids. On the other hand, Chiofalo et al. (2012) observed an increase in the milk yield of Valle del Belice ewes supplemented with 1200 mg/day of rosemary extract.

Milk composition

Protein content

The average protein content was not significantly affected neither by the diet nor by the breeder (Table 5) and remained similar across the different groups ($P > 0.05$). The protein content values for all groups were still above the Tunisian standard (3.1%) mentioned by Gaddour et al. (2013), as well as the international values described by Brugère (2003), Remeuf and Lenoir (1985), and Roudj et al. (2005). The protein content in the milk of the RC group (3.5%) was higher than that found by Smeti et al. (2015) for the same breed (3.2%) but lower than the results of Jordan et al. (2010), who reported values of 6.02 and 5.98% for the groups receiving 10% and 20% DRL, respectively. This difference could be attributed to climatic conditions during the experiment, as well as genetic factors and breed effects (Murciano-Granadina). Jordan et al. (2010) reported that adding DRL to the animals' diet did not affect the protein content of the milk. Similarly, Boutoial et al. (2013) found that incorporating distilled rosemary leaves into goats' diets did not affect protein content, with an average of 3.36%. For the same breed, Smeti et al. (2021) found that the protein content of milk was not affected by DRL incorporation.

Fat content

The average fat content was not significantly affected neither by the diet nor by the breeder (Table 5). The values recorded for all groups were higher than the standard (3.4%) described by Brugère (2003), but similar to that reported by Gaddour et al. (2013), which was around 3.9%. The fat content was higher, though not significantly different, in the milk from the CC group (4.86%) compared to the other groups at the beginning of the experiment (data not shown). This value decreased to 3.91% by the end of the study. The fat content in the milk from the RC group peaked during the second control (4.44%) and then declined to 4.01% at the end of the trial. Conversely, the FF group started with a relatively high fat content (3.65%) and gradually increased to 4.54%. The increase in fat content in the milk of goats

grazing in the forest maquis can be attributed to the sufficient nutrient intake from forest plants (Boubaker et al., 2005) and the selectivity of goats, which is a notable characteristic (ITAB, 2010). According to Le Guillou (2009), goats are not only selective eaters but also enjoy rediscovering familiar flavors, including those from their youth. This taste memory may lead to selective foraging based on their past experiences. The leaves of trees and forest shrubs are rich in anti-nutritional factors, particularly tannins, as noted by Makkar (2003). However, Le Guillou (2009) showed that goats tolerate the bitter taste of certain plants containing alkaloids and tannins and are less sensitive to their toxicity.

Smeti et al. (2021) reported that milk fat content increased with the administration of rosemary extract which underlined the beneficial use of DRL to enhance the quality of goat milk destined to cheese transformation. The high fat content (4.86%) observed in this study, which is a key feature, suggests the potential for valorizing goat milk and transforming it into cheese. In fact, goat milk is rarely valorized on its own; it is either consumed locally or mixed with other milks for cheese production. Nevertheless, it has undeniable advantages, and ongoing research is beginning to highlight its dietary properties (high casein content, hypoallergenic).

Kids' growth performances

The kids' growth parameters are presented in Table 6. The kids started the trial with slightly different body weights, but this difference was not significant (9.2, 8.4, and 7 kg for CC, FF and RC, respectively). At the end of the experiment, kids reached similar body weights which consequently leads to similar weight gains for all groups. The type of supplementation did not affect significantly kids' ADG; however, the breeder effect was significant ($P<0.05$).

Table 6. Kids' growth parameters

	Treatments			Statistics		
	FF	CC	RC	P diet (D)	P breeder (B)	P D*B
Initial BW (kg)	8.4	9.2	7.0	NS	NS	NS
Final BW (kg)	11	11.8	9.2	NS	NS	NS
Total weight gain (kg)	2.7	2.6	2.26	NS	*	NS
ADG (g/j)	91	90	78	NS	*	NS

BW: body weight; **ADG**: average daily gain; FF: farmer's feeding group; **CC**: conventional concentrate group; **RC**: rosemary concentrate group; NS: not significant; *: $P< 0.05$

Kids' growth is closely related to the milk production of their mother (Smeti et al., 2013). Considering this relationship, any factor that influences the mothers' performance will inevitably impact the growth and development of their offspring. Indeed, kids receiving a more nutritionally complete diet (forage and supplement) exhibit higher weight gain (0-40 days) compared to those whose mothers are fed only forage (Alexandre, 1991). However, in the current study, no significant effect of the diet on milk yield was observed. As a result, the growth parameters of the kids were similar across the groups.

The growth rates recorded were relatively high compared to those reported by Rouissi et al. (2002), who used different energy levels in the diet of goats and found that feeding the mothers significantly improved kid growth. Our results also exceeded those reported by Smeti et al. (2021), who found growth rates of approximately 63 g/day after introducing 400 g of FDR. However, these values remain lower than those observed by Smeti et al. (2015), who studied the effect of incorporating rosemary leaves into the goats' diet and found growth rates of around 110 g/day. Similar to the previously mentioned differences in milk production levels, these variations can be attributed to differences in management conditions, such as health status and the genetic characteristics of the flock.

Conclusion

The results of this study indicate that the distilled rosemary leaves incorporation into the goats' diet did not significantly affect milk production or alter the protein and fat content of the milk. However, the observed fat levels remain noteworthy and suggest potential for further exploration of enhancing goat milk quality, particularly for local cheese production. This could lead to increased profitability and reduced production costs for farmers. Regarding the growth performance of the kids, the inclusion of rosemary leaves did not adversely affect their growth rates. Then, the partial substitution of barley with rosemary residues in goat feed is a cost-effective strategy that maintains animal performance. Thus, rosemary residues offer a promising, low-cost alternative that supports sustainable livestock production and enhances the economic efficiency of goat farming.

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Conflicts of interest

No potential conflict of interest was declared by the authors

REFERENCES

AOAC. 1995. Method 991.42 & 993.19. Official methods of analysis (16th ed.). Washington, DC : Association of Official Analytical Chemists.

APIA. (2003). Aperçu sur le secteur des plantes Aromatiques et Medicinales “P.A.M”. AGRO-SERVICES/APIA 2003, pp 122.

Atti, N., Maamouri, O., & Mahouachi, M. (2010). Milk production of ewes in feed lot or on pasture of several forage species. *Options Méditerranéennes, série A, 92,* 75-78.

Belkhouja, C. (2011). Les matières premières naturelles en Tunisie. Les vergers de Tunisie,7p.

Bhatta, R., Enishi, O., Yabumoto, Y., Nonaka, I., Takusari, N., Higuchi, K., Tajima, K., Takenaka, A. & Kurihara M. (2013). Methane reduction and energy partitioning in goats fed two concentrations of tannin from Mimosa spp. *Journal of Agricultural Science*, 151, 119–128.

Boubaker, A.G., Kayouli, C., Buldgen, A., Boukary, A., Ammar, H. & Lopez, S. (2006). Effect of feed block supply on the ruminal ecosystem of goats grazing shrub land in Tunisia. *Animal Feed Science and Technology,* 127, 1–12.

Boutoial, K., Rovira, S., Garcia, V., Ferrandini, E., & López M.B. (2012). Influence of feeding goats with thyme and rosemary extracts on the physicochemical and sensory quality of cheese and pasteurized milk. In: Goats: Habitat, Breeding and Management. *Nova Science Publisher,* New York, USA, pp. 125–136.

Brugère, H. (2003). Physiopathologie de l'acidose latente du rumen. Proc. Journée « Actualités en pathologie bovine », Ecole nationale vétérinaire d'Alfort, Maison-Alfort, France, 5-26.

Gaddour, A., & Najari S. (2009). Pure breeds and crossed caprine genotypes effect in the oases of southern Tunisia. *African Journal of Agricultural Research*, 4, 1203-1207.

Gaddour, A., Najari S., & Abdennebi M. (2013). Relation between goat pigmentary types and daily milking kinetic for some caprine genotypes in Tunisian arid zone. *International Journal of Current microbiology and Applied Sciences*, 2, 324-327.

ITAB, (2010). Institut Technique de l'Agriculture Biologique. Chèvres laitières bio, un guide pratique pour l'éleveur.

Jordan, M.J., Ma˜nino, M.I., Martinez, C., Lafuente, A., & Sotomayor J.A. (2010). Introduction of distillate rosemary leaves into the diet of the murciano granadina goat: transfer of polyphenolic compounds to goats' milk and the plasma of suckling goat kids. *Journal of Agricultural and Food Chemistry*, 58, 8265–8270.

Kayouli C. (2000). Profil fourrager. http://www.fao.org/ag/AGP/AGPC/doc/Counprof/frenchtrad/Tunisie_fr/Tunisia_fr.htm#4.5.Colson, F., C. Kayouli, J.C., Belloin,

Maamouri, O., Atti, N., Kraiem, K. & Mahouachi M. (2011). Effects of concentrate and Acacia cyanophylla foliage supplementation on nitrogen balance and milk production of grazing ewes. *Livestock Science*, 139, 267–270.

Makkar H.P.S. (2003). Effects and fate of tannins in ruminant animals, adaptation to tannins and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Ruminant Research*, 49, 241–256.

Najari S., & Ouni M. (2008). Amélioration de la production laitière par le croisement d'absorption de la chèvre locale dans les oasis du sud Tunisien. *Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux*, 61(1), 57-62.

Nieto, G., Diaz, P., Banon, S., & Garrido M.D. (2010). Dietary administration of ewe diets with a distillate from rosemary leaves (*Rosmarinus officinalis L.*): Influence on lamb meat quality. *Meat Science*, 84, 23–29.

Remeuf, F., & Lenoir J. (1985). Caractéristiques physico-chimiques de lait de chèvre. *Revue Laitière Française*, 446, 32-40.

Roudj, S., Bessadat A., & Karam N-E. (2005). Caractérisation physicochimiques et analyse électrophorétique des protéines de lait de chèvre et de lait de vache de l'Ouest algérien. *Rencontres Recherches Ruminants*, 12, 400.

Rouissi, H., Atti N., Mahouachi M., & Rekik B. (2006). Effet de la complémentation azotée sur les performances zootechniques de la chèvre. *Tropiultura*, 24, 111-114.

Rouissi, H., Mahouachi, M., & Atti N. (2002). Effet de la complémentation énergitique sur les performances de la chèvre locale au cours de la phase d'allaitement. *Annales de l'INRAT*, 75, 223-239.

Smeti, S., Atti, N., Mahouachi, M., & Munoz, F. (2013). Use of dietary rosemary (*Rosmarinus officinalis L.*) essential oils to increase the shelf life of Barbarine light lamb meat. *Small Ruminant Research*, 113, 340–345.

Smeti, S., Hajji, H., Bouzid, K., Abdelmoula, J., Muñoz, F., Mahouachi, M., & Atti. N. (2015). Effects of *Rosmarinus officinalis L*. as essential oils or in form of leaves supplementation on goat's production and metabolic statute. *Tropical Animal Health and Production,* 47, 451-457.

Smeti, S., Hajji, H., Khmiri, H., Bouzid, K., & Atti, N. (2021). Effects of partial substitution of rosemary distillation residues to oat hay on digestive aspects, milk production, and metabolic statute of Tunisian local goats. *Tropical Animal Health and Production*, 53, 1-10.

Wallace, R.J., McEwan, N.R., McIntosh, F.M., Teferedegne, B., & Newbold C.J. (2002). Natural products as manipulators of rumen fermentation. *Asian-Australasian Journal of Animal Sciences*, 15, 1458–1468.

Yener, S.M. (1989). Milk production from goats. In: Tisserand J.-L. (ed.). Le lait dans la région méditerranéenne. Paris: CIHEAM, 149-157.

Zaouali, Y. (2005). Analyse de la variabilité génétique, terpénique et florale chez les populations naturelles de *Rosmarinus officinalis L.* (Lamiaceae) en Tunisie. Thèse, Faculté des Sciences de Tunis, Tunisie: 180 p.Zeller, B. (2005). Le fromage de chèvre: Spécificités technologiques et économiques. Thèse de Doctorat de l'université Paul-Sabatier, Toulouse, France.