Small Ruminant Research 126 (2015) 59–66

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Aseasonal sheep and goat milk production in the Mediterranean area: Physiological and technical insights☆

M. Todaro[a,*], M. Dattena[b], A. Acciaioli[c], A. Bonanno[a], G. Bruni[d], M. Caroprese[e], M. Mele[f], A. Sevi[e], M. Trabalza Marinucci[g]

[a] Department of Agricultural and Forest Sciences (SAF), University of Palermo, viale delle Scienze, 13, 90128 Palermo, Italy
[b] AGRIS Sardegna (Agricultural Research Agency of Sardinia), Department of Animal Science, 07040 Olmedo, Italy
[c] Department of Agri-Food Production Sciences and the Environment (DISPAA), University of Firenze, Via delle Cascine, 5, 50144 Firenze, Italy
[d] Regional Breeders Association of Lombardia, Via Kennedy, 30-26013 Crema, Italy
[e] Department of the Sciences of Agriculture, Food and Environment (SAFE), University of Foggia, Via Napoli, 25, 71122 Foggia, Italy
[f] Department of the Sciences of Agriculture, Food and Environment, University of Pisa, Via del Borghetto, 80, 56124 Pisa, Italy
[g] Department of Pathology, Diagnostic and Veterinary Clinic, University of Perugia, Via S. Costanzo 4, 06126 Perugia, Italy

ARTICLE INFO

Article history:
Available online 31 January 2015

Keywords:
Out-of-season sheep and goat milk production
Male effect
Heat stress

ABSTRACT

Aseasonal or out-of-season milk production for small ruminants raised in Mediterranean areas refers generally to milk having to be produced at a time that corresponds to summer which is when conditions are generally unfavourable with respect to both physiological aspects and nutritional factors related to seasonal climatic trends. In fact, sheep and goat milk production in the Mediterranean basin is mostly based on pasture utilization and thus follows the pasture availability pattern. This causes a strong seasonal pattern to the amount of milk processed by cheese processes plants, with the peak being in the spring, a marked reduction in early summer and nil or low availability of milk from August to October–November (autumn). In this paper, the reproduction cycles and managerial techniques that can be applied in the Mediterranean environment to reduce or eliminate the seasonality of milk production are discussed. The use of the "ram effect" at the end of the anoestrous season and light treatment can be effective and simple tools to maintain milk yield in the summer period. However, even if sheep and goats are considered to be among the most heat-tolerant species, the exposure to high ambient temperatures has a detrimental impact on their production and reproductive performances, immune function and udder health. The use of effective nutritional strategies, the provision of shaded areas and adequate housing density could then reduce the heat stress.

1. Introduction

About 46% of the world sheep milk originates from the Mediterranean area. The most important countries in terms of the number of dairy sheep and goats are Greece, Italy, Spain, France and Turkey in Europe, and Algeria, Egypt and Libya in North Africa (FAOSTAT, 2013). Even if the number of dairy sheep and goats in the European Mediterranean countries are less than in the North African countries, the number of fresh sheep and goat milk yielded in Europe is more (Table 1).

The productive cycle of Mediterranean sheep and goats is very closely linked to the Mediterranean climate which is characterized by a mild winter, with rainfall occurring in

☆ This paper is part of a supplement issue entitled "S.I.P.A.O.C. Congress 2012". Guest Edited by Antonello Carta, Maria Teresa Manfredi, Giuseppe Moniello and Massimo Trabalza-Marinucci.

* Corresponding author. Tel.: +39 0 91 23896061; fax: +39 0 91 6515531.
E-mail address: massimo.todaro@unipa.it (M. Todaro).

http://dx.doi.org/10.1016/j.smallrumres.2015.01.022
0921-4488/

Table 1
Sheep and goats reared in the Mediterranean area, 2011 (FAOSTAT, 2013).

Country	Dairy sheep (no.)	Fresh sheep milk (tonnes)	Goats (no.)
Europe			
Greece	7,254,000	773,000	3,350,000
Italy	5,468,990	417,839	658,800
Spain	2,800,000	519,600	1,260,000
France	1,297,651	273,550	944,210
North Africa			
Algeria	13,848,690	320,000	2,578,950
Turkey	11,561,144	892,822	3,033,111
Egypt	2,260,000	113,000	1,240,000
Libya	2,235,800	60,000	520,000
Morocco	944,300	37,700	1,684,700
Tunisia	320,000	25,000	486,300
Israel	155,000	16,540	36,000

autumn and spring, and a very dry summer. Accordingly, the fresh forage availability is low in autumn and abundant in spring. The typical breeding system in the Mediterranean area implies one lambing per year, with the mating season starting in late spring for mature ewes and in early autumn for young ewes (about 20% of the flock) the latter are successfully mated only when their body weight is about 65–70% of normal adult weight. The lambing period for mature ewes occurs between October and December (autumn to early winter) to exploit the seasonal availability of the natural pastures at their best. Generally, the older the ewes, the earlier the lambing; while, late winter is the lambing period of the primiparous ewes. In general, only 75% of the mated young ewes conceive and lamb; the others are successfully mated only in the next spring and lamb at about 24 months of age in the autumn that is during the lambing season of the mature ewes.

The aseasonal milk production for small ruminants raised in Mediterranean areas means that milk has to be produced at a time that corresponds to the summer and generally in unfavourable conditions with respect to both the physiological aspects and nutritional factors related to the seasonal climate trends. Examples of aseasonal milk production have been recorded with the practice of 3 lambings over 2 years that exists in some regions of Italy such as Tuscany (Secchiari et al., 1988; Biagioli et al., 1989), Castilla-La Mancha and Castilla-Leon in Spain (Milán et al., 2011) and Israel (Galal et al., 2008), where lamb meat makes an important contribution to the farmers' income.

Generally, lambs are slaughtered or weaned after a suckling period of approximately 30 days. After the weaning of lambs, ewes are usually milked twice daily until late spring or early summer. Then despite the different periods of lambing, the young and mature ewes simultaneously stop milk production and become dry when the forage pastures dry up, because of the high summer environmental temperatures.

Under these conditions, the flow of nutrients and energy from the pasture to the grazing sheep show two critical constraints: a feed shortage in winter and a sharp decrease in herbage availability and quality from spring to summer. Thus, although in most situations feeding is still based on grazing natural pastures, forage crops and their supplementation with hay and concentrates have been increasing in importance in areas especially where irrigation is possible. So, for instance, dairy ewes of high producing breeds, such as the Awassi and Assaf, are managed in Israel (Gootwine and Pollott, 2000; Pollott and Gootwine, 2004) and Spain (Caja and Rancourt, 2002) under intensive production systems that are mainly milk orientated based on an accelerated lambing regime, machine milking and a prevalence of zero grazing. Indeed, ewes are fed indoors in loose stalls with rationed forage and concentrates or totally mixed rations.

Nowadays, in the Mediterranean area, dairy sheep and goat farming systems vary from extensive (marked seasonal milk production, dual-purpose breeds, low feed supplementation, transhumance, hand milking, absence of farm facilities, farm-made cheese) to intensive systems (seasonal or continuous milk production, improved local breeds or crosses, exploitation of forage crops, high feed supplementation, machine milking and housing facilities, industrial cheeses) according to the economic relevance of the production chain and the specific environment and breed.

Extensive farms continue to be the reality for the breeding of sheep and goats that are able to take advantage of the marginal areas of agricultural land. Also, in this type of farming system, where milk production is highly seasonal, it is possible to manage the mating activity by techniques of reproduction and plan the lambing periods and obtain fresh milk over the entire year, especially in the summer season.

However, it must be pointed out that in high and medium latitudes, the annual temperature and photoperiod are the two fundamental variables, together with food availability, that control the seasonal reproductive cycle of sheep and goats. Indeed, wide areas of the Mediterranean basin are characterized by ambient temperatures in late spring and summer that often exceed sheep's thermal neutral zone (5–25 °C) (Curtis, 1983; Costa et al., 1992). According to Silanikove (2000), if the ambient temperature at night drops below 21 °C for 3–6 h, the animal has sufficient opportunity to lose all of the heat gained from the previous day. Unfortunately, during the summer nights, the temperatures in some environments often exceed 21 °C. According to Sevi et al. (2001), milk production only decreases in lactating ewes when they are exposed to a temperature humidity index (THI) greater than 80%. The photoperiod is another important factor that affects reproduction and the periods of the year when reproductive activity is absent or high, especially in breeds that originate from geographical areas at high latitudes. Thus, appropriate managerial strategies must be developed to allow sheep and goats to produce milk out of season.

2. The seasonality of the reproductive cycle and possible management strategies

2.1. The reproductive physiology of sheep and goats: an introduction

Sheep and goats are considered to be prolific species, despite the fact that most breeds of both species have seasonal reproductive cycles. During each annual reproductive cycle, there is a season of low or absent reproductive activity (anoestrous season) and a season of high reproductive activity (breeding season).

Several factors are responsible for the regulation of this cyclical activity (Thiéry et al., 2002). In high or medium latitudes, of >30° (Lincoln, 1992), >35° (Malpaux et al., 1996) or >40° (Chemineau et al., 1992) the photoperiod and the annual environmental temperature cycle are the main modulators of this seasonal reproduction. However, reproductive functions in these species are also regulated by other extrinsic factors, such as social and sexual interactions and nutritional status (Álvarez and Zarco, 2001; Bearden et al., 2004; Zarazaga et al., 2005). Reproductive functions are highly demanding in terms of the both the required quality and quantity of nutrients. Therefore, nutritional status is a very important modulator of reproduction in sheep and goats (Blache et al., 2008).

2.1.1. Manifestation of seasonality

Reproductive seasonality in ewes and goats is characterized by the succession at regular intervals, with a mean of 17 and 21 days, respectively, of oestrous behaviour, ovulation and changes in hormonal endocrine levels during the breeding season, and the cessation of most of these events during the anoestrous season.

The transition from the anoestrous state to the breeding season is gradual, with the occurrence of a short cycle not accompanied by oestrus behaviour (silent oestrus and silent ovulation) in both species. As the first corpus luteum (CL) of the season often regresses (50% in sheep, 76% in goats) prematurely 5–6 days after its formation (Chemineau, 1983; Knight, 1983). Thus, it is only after the end of this first ovarian cycle that behavioural oestrous is exhibited. However, it is reported that silent ovulation, which is neither related to the onset nor the end of the sexual season, can occur in some breeds during mid-anoestrus (Land et al., 1973; Ortvant et al., 1988). At the endocrine level, during the anoestrous season, follicle growth and regression occur and follicles as large as those found during the luteal phase of the oestrous cycle may be present in both species (Matton et al., 1977; Webb and Gauld, 1985; Cruz et al., 2005). These follicles produce steroids (oestrogen), and many of the positive and negative feedback effects of the steroids on the secretion of luteinizing hormone (LH) take place, as in the breeding season (Gordon, 1997). LH continues to be released, but in both species, this is at a lower frequency than during reproductive season (Karsch et al., 1984; Chemineau et al., 1988; Thiery and Martin, 1991). A major difference also occurs in the plasma progesterone concentration which is at virtually undetectable levels during the anoestrous period (Karsch et al., 1984; L'Anson and Legan, 1988). To the contrary, follicle-stimulating hormone (FSH) levels seem not to be significantly different from those found during the reproductive season (Gooding et al., 1969; Roche et al., 1970; Walton et al., 1977).

2.2. Sheep and goat breeds with aseasonal breeding activity: examples in the Mediterranean basin

The seasonality of ewe milk production is well known in the dairy sheep industry. However, in some countries of the Mediterranean basin, an intensive management system has been employed in dairy ewes. Examples of this can be found in Israel and Spain, where two breeds are principally reared: the Assaf and Awassi (Gootwine, 2011; Milán et al., 2011). In these systems, ewes are kept indoors all year round, and an accelerated lambing regime is practised with several mating/insemination periods during the year. Ewes are milked from the first day of their lactation, with lambs being removed from the ewe into an artificial rearing unit at birth. This type of milking regime is unique for dairy sheep, as in most other cases lambs are left with their mothers to suck until weaning.

For the Assaf ewes, few matings occur in February and March (early spring), which is considered an "out of season" period as it generally results in a low conception rate and few lambs being born in July and August (summer) (Pollott and Gootwine, 2004). For the same reason, no lactation in the Awassi ewes starts in July and August (Gootwine and Pollott, 2000). In Italy, production of ewe milk is strongly seasonal and this seasonal production system involves most of the dairy breeds. However, under certain environmental conditions, certain breeds are able to mate during different periods.

In the Massese ewe population, the aseasonal milk production is based on a specific reproductive scheme, which is favoured by a continuous oestrus cycle throughout the year (Secchiari et al., 1988; Biagioli et al., 1989). As a consequence, the time between lambings may be reduced obtaining an average of 3 lambing over 2 years (with an average inter-lambing period of 8 months) and a longer lambing season which lasts from the autumn to the beginning of summer (Biagioli et al., 1989). A very specific characteristic of the Massese breed is the different length of the lactation curve, according to the lambing season. Several surveys carried out over the last 30 years have demonstrated that three kinds of lambing season may be noted in the Massese ewe population: (a) early autumn lambing followed by a short lactation period of 5 months; (b) late spring lambing also followed by a short lactation period of 5 months; (c) late autumn lambing followed by an extended lactation of 8 months (Acciaioli et al., 1999, 2011). In general, the lactation curve of Massese sheep is characterized by a high level of the lactation peak and a lower persistence, compared to that of other dairy sheep breeds (Franci et al., 1999; Steri et al., 2007). As a consequence, the intensification of the reproductive rhythm allows the relative proportion of the first part of the lactation in a single year to increase, which is the most productive. This aspect also leads to an increase in the ratio of productive days to presence days for a single ewe in a year (more than 61%) which in turn leads to an increase in the total productivity of the animals in terms of milk and lamb meat during a single year (Acciaioli et al., 1999).

Of the sheep breeds reared in Sicily, the Valle del Belice breed is recognized as the highest milk produced (Giaccone et al., 2004). This is the reason for its growing integration and the corresponding reduction in numbers to other Sicilian sheep breeds. The mating activity of Sicilian sheep traditionally begins on 19th March, the day of the St. Joseph celebration, with the main lambing season being in September and October (autumn). A second lambing period occurs in winter, and generally lasts from December to February. Accordingly, sheep milk production shows a seasonal trend, with a great variability throughout the year and an almost complete termination in the summer particularly linked to the seasonal availability of forage for grazing.

Despite the seasonal fluctuations of pasture feeding resources, the lambing distribution of sheep in Sicily is less seasonal than in other regions of Italy (especially Sardinia) and ewes are more susceptible to mating at different times of the year. This feature is particularly exploited in the valley of the Belice river (on the border of the Agrigento, Trapani and Palermo provinces), where lambing of the Valle del Belice ewes takes place during the entire year although most births occur in July and August, earlier than in the rest of Sicily. A second lambing period occurs in December and January (Giaccone et al., 2004). This lambing distribution implies continuous milk production throughout the year with the highest volume in spring linked to the more abundant forage pastures, and the lowest production in summer, mainly derived from the lambing season of December to May, when ewes are fed hay and grazed crop residues.

This out-of-season lambing distribution of Valle del Belice ewes is then linked to the production of a particular *pasta filata* sheep cheese, the PDO Vastedda della Valle del Belice, which is traditionally made in summer from raw sheep milk, without a starter addition, and consumed fresh a few days after manufacture (Mucchetti et al., 2008). Due to the profitable marketing of this cheese, the farmers generally introduce the rams into the flock in February to produce milk at the end of summer, although the ewes lambing from December to May make a major contribution to the summer milk yield.

2.3. Reproduction management strategies for an aseasonal production cycle applied to sheep and goat breeds in the Mediterranean area

Keeping in mind the reproductive physiology of sheep and goats, it is possible to manage reproduction in such a way as to have a flock with two or more different reproduction periods, allowing farmers to have milk for 365 days a year. This is very true particularly of the Mediterranean areas where the anoestrous period is generally relatively so short, for example, for Sarda dairy sheep in Sardinia the anovulatory season is between March and April (Casu and Manunta, 1968). Seasonality is, however, more marked in the central European areas, where the anoestrous season is longer (due to the higher latitude and greater photoperiod variations between seasons). So, for example, in the Alpine and Saanen dairy goats breeds in France, the anoestrous period lasts for 7 months from March to September (Pellicier et al., 2009).

It is also worth mentioning that certain methods can ensure that a flock is in an efficient reproductive condition all year around without the use of traditional hormonal treatments (progesterone and eCG), which are too expensive and only justified when linked to AI technique for genetic improvement.

The flock needs to be split at least into two groups. In the first group, in the Mediterranean area the "ram effect" is used at the end of the anoestrous period (March, April, May—Spring) to induce breeding and to ensure the synchronization and concentration of the lambing season between September and December, according to the timing of ram introduction. In the second group, the males are introduced at the peak of the breeding season, when the animals ovulate spontaneously during the short days of October, November and December, allowing a natural breeding management, with the lambing season between March and May. In the more northern areas (Northern Italy, France and Central Europe), due to the deep and long anoestrous season, the animals need to be preconditioned by photo treatment, to have these cycling between April and June (Rosa and Bryant, 2002).

2.3.1. Ram effect

The ram effect was first documented by Underwood et al. (1944). However, the first research designed to investigate the nature of this stimulation was carried out by Watson and Radford (1960). Later, Morgan et al. (1972) found that only the deprivation of smell significantly affected the number of ewes showing oestrus. This was later more intensely investigated by Knight and Lynch (1980) and Knight et al. (1983). It is now known that the fleece as well as secretions from the orbital gland due to the presence of pheromones are effective in stimulating the reproductive cycle of ewes and goats (Cohen-Tannoudji et al., 1994).

However, it has been shown that not only pheromones (Rosa and Bryant, 2002), but also behavioural stimuli (Chemineau et al., 1986, 2006; Perkins and Fitzgerald, 1994), pre-isolation of the ram (Lishman and Hunter, 1967; Oldham, 1980; Martin et al., 1986), season, breed (Edgar and Bilkey, 1963; Lishman, 1969) and breeding rhythm—time of mating, lambing and weaning—of the flock studied (Lyle and Hunter, 1965) are also factors that can strongly affect the results of the "ram effect".

However, what happens when the ram or buck is introduced at the right time into a flock? The males may stimulate a high proportion of anovular ewes to ovulate within 3 days. This ovulation results in a CL, which may provide progesterone to prime the ewes to display oestrus, coincident with the next ovulation approximately 16 days later. As many as 50% of the stimulated CL is will be abnormal and may regress within 6 days (Oldham and Martin, 1978). If an abnormal CL precedes a normal CL it gives a peak of oestrus behaviour approximately day 24 after the introduction of the rams. In the Sarda dairy breed, if the ram is introduced in May at the end of the anoestrous season (Casu and Manunta, 1968), more than 80% of the animals will respond to the ram effect and come on heat within 18–24 days of ram introduction (Dattena et al., 2010). However, if the animals are not prepared for the ram effect, because they are still deeply anoestrous, the results can be deleterious. In fact, it has been shown that if the ram is introduced to a flock in a deep anoestrous state, the ewes will return to the anoestrous state after one or two ovulations. So, for example, more than 50% of Merino ewes introduced to teaser rams in October in the southern hemisphere became anovular after 50 days (Rosa and Bryant, 2002), suggesting that photoperiodicity overrides the ram effect.

Good results can be obtained from ram effect in the following ways:

a) The females need to be at the end of the anoestrous season (start of the breeding season).
b) The females have to be isolated from males 1–2 months before the ram is introduced.
c) The male needs to be introduced in a flock with the apron.
d) The male needs to be introduced 15–17 days before the mating day.
e) The ratio of males to females needs to be between 1:16 and 1:25.
f) The females and the males need to be in a good physical condition.

2.3.2. Light treatment

To induce the oestrus cycle (heat, ovulations and return cycles) during the anoestrous season, it is necessary to manipulate the length of daylight with a lighting programme for the females and males in a barn. This technique, also called photoperiodic treatment, provides the only opportunity during the anoestrous period to induce a "mini" sexual season (2–3 cycles) for the breeds with a long and deep sexual rest (*e.g.* Alpine and Saanen dairy goat breeds). However, it is applicable only in an intensive farming system (light equipment in the barn) and must be planned well in advance: 3 months of "long days" with at least 16 h of daylight plus 2 months of "short days" with no more than 12 h of daylight is required. With these very seasonal breeds, which have 7 months of sexual rest from March to September, it is necessary to apply light treatment even in the Mediterranean area to have reproduction in the spring (April, May), kidding in autumn (September, October) and milk yield during winter. Thus, it is necessary to apply robust reproductive protocols for these goat breeds to have milk during winter, but it is quite simple to have milk in summer following their natural reproductive rhythms.

2.3.3. Breeding season

The breeding season in sheep and goats is conventionally considered to start in the late summer/early autumn in all the breeds and at all the latitudes. During this period, the female animals ovulate spontaneously and become pregnant easily. Thus, the main objective is to have a good concentration of lambing and new born lambs and kids in the same period (March–April). This is often a problem due to a reduced number of males in the flock (1–2%). It is well known that a good male can mate on average 6–8 animals per day (Hulet et al., 1962a, 1962b; Lightfoot and Smith, 1968), but with a high variability that depends on each male's attitude to mating and the number of females on heat each day. Thus, if a male is left alone with 100 animals most of the females will be pregnant in 30–60 days, due to many returns in heat, so the result is that the lambing season will last for at least as long as 2 months. If a higher male/female ratio (4%) is applied together with a good concentration of females on heat at the same time (ram effect), the lambing period will be more concentrated and better fertility will be obtained (Dattena et al., 2010, personal communication).

3. Heat stress management and animal welfare implications

Air change, space and volume allowance are considered to be the main factors responsible for air pollution in animal houses, in particular, during the hot season. Poor ventilatia, bedding and surface hygiene can be a serious limitation to the production performance and health of the farmed livestock. During summer, exposure to solar radiation and inadequate nutrition are also responsible for the accumulation of deleterious exogenous and endogenous heat load on the productivity and welfare of animals.

Experiments conducted on Comisana ewes showed a marked increase in rectal temperature and respiration rate, and an alteration in the metabolism and productive performance, after the exposure of ewes to temperatures of over 35 °C, even for short periods, or after a prolonged exposure to mean temperatures of 30 °C (Sevi et al., 2001; Caroprese et al., 2012). Under such conditions, an alteration in mineral metabolism (Mg, K, Ca, P), with a reduction in milk production and casein and fat content (mainly the reduction in long chain and unsaturated fatty acids), and a worsening of the, milk hygiene quality (with an increase in neutrophils, staphylococci, coliform and pseudomonas count) was observed. Moreover, a dramatic worsening of the cheese-making properties of milk were found, caused by the reduction in Ca and P content and by the increase in plasmin activity, the main endogenous proteolytic enzyme in milk (Sevi et al., 2004). In Sarda ewes, milk yield may be reduced by 15% if the maximum ambient temperatures are higher than 21–24 °C, and by 20% if minimum temperatures are changed from 9–12 to 18–21 °C (Peana et al., 2007). When the effects of the provision of shaded areas and the changing of feeding time to lactating ewes during summer on the fatty acid composition of milk were evaluated, both strategies were found to increase the unsaturated fatty acid levels (Sevi et al., 2002b). In particular, the provision of shade resulted in higher proportions of unsaturated chain and long chain FA in milk, primarily due to the increased content of oleic, linoleic and linolenic acids, and a decrease in caproic, capric, lauric, myristic and stearic acid. As a consequence, the long to short chain and unsaturated to saturated fatty acid ratios were significantly higher by 4 and 13%, respectively, in the milk of shaded ewes, compared to that of the unshaded animals.

Al-Tamimi (2007) observed an increase in respiratory and heart rates, and in rectal temperatures by 133, 12 and 1.5%, respectively, in goats exposed to solar radiation, compared to goats in shaded areas. When exposed to direct solar radiation, goats required 10–14 days to adapt to thermal stress through physiological adjustments (*i.e.* increased respiration rate and peripheral vasodilatation) and changes in feeding and water timing. When the ambient temperature changed from 20 to 40 °C, a reduction of feed intake by between 10 and 60% was recorded, depending on the goat breed (Lu, 1989). In such conditions, a marked alteration in the mineral balance and hormone production occurred. In pregnant goats, heat stress induces polydipsia (Olsson et al., 1995). When subjected to 4 days of water deprivation in a desert climate, goats can feed and yield milk by maintaining an adequate intestine and udder blood flow (Maltz et al., 1984).

Milk is also an important source of vaccenic acid (*trans*-11 $C_{18:1}$, VA), which is an intermediate of rumen biohydrogenation of linoleic and linolenic acid, and is converted to rumenic acid (*cis*-9 *trans*-11 $C_{18:2}$, RA) by Δ^9 desaturase in the mammary gland. RA is the major isomer of totally conjugated linoleic acid (CLA) of milk fat, and both VA and RA are considered to be health-promoting fatty acids (McGuire and McGuire, 2000). In ewes milk, Nudda et al. (2006) observed a reduction of VA and RA with the advancement of lactation, with the lowest values being recorded in summer. Flaxseed supplementation increased the content of milk VA by about 50% in the ewes exposed to solar radiation and by 18% in the ewes protected from solar radiation. Flaxseed supplementation increased the total CLA content of milk, regardless of direct exposition to solar radiation (Caroprese et al., 2011). The decrease in lauric, myristic and palmitic acid concentration led to a reduction of the atherogenic (AI) and trombogenic (TI) indexes in milk of ewes receiving flaxseed supplementation. Milk fat with high AI values has detrimental effects on human health. It is known that in the human diet, saturated fatty acid contributes to coronary diseases whereas unsaturated fatty acids, including CLA (rumenic acid), MUFA (in particular, oleic acid) and PUFA, have a protective effect against the risk of cardiovascular diseases (Williams, 2000).

The respiration rate of heat-stressed sheep can be reduced by the administration of whole flaxseed during summer. The nicotinic acid content of whole flaxseed has a peripheral vasodilator effect, thus improving heat dispersion by evaporation (Caroprese et al., 2012). Exposure to high ambient temperature also causes an increase in the water turnover and intake rate in sheep. Marai et al. (2007) reported a water intake increase of 50%, and a water loss decrease of 25% in the faeces and 40% in urine, during heat stress. Changes in water metabolism are also responsible for the alteration of nutrient digestibility in heat-stressed sheep. Furthermore, heat stress can induce an impairment of rumen functionality in sheep with a reduction in bacterial activity and a dilution of the rumen fluid (Bernabucci et al., 2009). It was found that in a pending high heat load situation, a ventilation regimen providing 70 m^3/h/ewe can sustain ewe milk production (Sevi et al., 2002a). The use of a ventilation rate of 35 m^3/h per ewe resulted in higher total milk coliform and an impairment of sheep udder health, with an increase in somatic cell count compared to milk from better ventilated animals (Sevi et al., 2003; Albenzio et al., 2005).

Diurnal thermal fluctuations can affect the sheep and goats' immune responses during summer. When Sevi et al. (2001) evaluated the cellular immune activity *in vivo* in sheep exposed to or protected from solar radiation and fed in the morning or in the afternoon, a reduced *in vivo* lymphocyte proliferation was found in ewes exposed to solar radiation and fed in the morning. The supplementation of whole flaxseed in ewes exposed to solar radiation can sustain their immune response. Most likely the administration of whole flaxseed can induce an increase in cortisol secretion, which in turn could influence the sheep humoral responses by stimulating IL-10 and inhibiting IL-12 production.

Ewes subjected to heat stress and a reduced ventilation rate display increased cortisol levels. The increase in cortisol secretion may be responsible for the impairment of their cellular immune response after the intradermal injection of mitogens and for the impairment their IgG production after antigen injection (Sevi et al., 2002a; Caroprese et al., 2012). The incidence of udder health problems in sheep increases during summer. A reduction in immune response as a result of heat stress and the increased microorganism proliferation as a consequence of the warm and humid environmental conditions occurring in the Mediterranean basin can explain the increased incidence of udder health problems. Heat stress, may in fact reduce the mammary defence capacity thus leading to enhanced bacterial colonization of the ewe udders, as suggested by the prevalence of environmental pathogens in the microbial species isolated from bacteriologically positive milk samples of ewes exposed to direct solar radiation (Sevi et al., 2001). As a result, there is a deterioration in the milk's hygienic and nutritional properties, as well as of its cheese-making ability (Sevi et al., 2001). When evaluating the effects of housing conditions on the welfare and production of lactating ewes in summer, Casamassima et al. (2001) found increased SCC in milk from ewes reared indoors, compared to outdoors. They attributed this result to the worsening of air and litter pollution conditions and to faecal contamination. In late lactation milk collected during summer months, Albenzio et al. (2004) found increased levels of SCC and macrophage cells, which were associated with enhanced plasminogen and plasmin activities. The increase in SCC commonly measured in late lactation milk during the hot season is responsible for the impairment of the coagulation properties of milk, promoting the conversion of plasminogen into plasmin.

The main nutritional strategies against high ambient temperatures are the use of a high-energy diet to balance reduced feed intake and an increased energy demand for thermoregulation. Also the use of protein with a low rumen degradability to balance the increased nitrogen catabolism and changed feeding times and the scheduling of feeding times so as to increase the number of feeding and shifting the feeding to late afternoon. Further, the use of supplements to improve the immune function and the physiological and production responses of sheep is suggested.

4. Conclusion

Out of season milk production in sheep and goats can be obtained by controlling their reproductive activity. In fact, with the rigorous application of specific protocols, it is possible to manage small ruminant reproduction throughout the year and maintain a continuous milk production. Especially in the Mediterranean area, the use of the "ram effect" at the end of the anoestrous season and light treatment can be effective and simple tools to help the farmer advance the breeding season. This together with a sufficient number of males (1 per 20–30 females) can ensure a good pregnancy rate for the females at the onset of and during the breeding season.

However, the summer production of milk requires particular control of the rearing environment in sheep subjected to heat stress even if both sheep and goats are considered to be among the most heat tolerant species. Exposure to high ambient temperatures has a detrimental impact on their production performance, immune function and udder health. Provision of shaded areas, careful litter management, adequate housing density and airspace, as well as proper indoor ventilation are critical for sustaining the production performance and the udder health of sheep during the hot season. Also, the improvement of nutrition management and the genetic development of heat-resistant breeds have been indicated as key strategies to improve the productivity, health and welfare of sheep and goats raised in hot climates.

Conflict of interest

None.

References

Acciaioli, A., Pugliese, C., Rapaccini, S., Lucifero, M., 1999. Influence of reproductive rhythm on productivity of Massese ewe. Proc. A.S.P.A. XIII Congr.: Rec. Prog. Anim. Prod. Sci. 1, 473–475.

Acciaioli, A., Giustini, L., Pianaccioli, L., Malvezzi, G., 2011. Indagine sulle tecniche di alimentazione nelle aziende ovine dell'Appennino pistoiese e qualità del latte (Survey of feeding techniques in the sheep farms of Pistoia Apennines and milk quality). Sci. Tecn. L.C. 62 (6), 407–412.

Albenzio, M., Caroprese, M., Santillo, A., Marino, R., Taibi, L., Sevi, A., 2004. Effects of somatic cell count and stage of lactation on the plasmin activity and cheese-making properties of ewe milk. J. Dairy Sci. 87, 533–542.

Albenzio, M., Santillo, A., Caroprese, M., Marino, R., Centoducati, P., Sevi, A., 2005. Effect of different ventilation regimes on ewe milk and Canestrato Pugliese cheese quality in summer. J. Dairy Res. 72, 447–455.

Al-Tamimi, H.J., 2007. Thermoregulatory response of goat kids subjected to heat stress. Small Rumin. Res. 71, 280–285.

Álvarez, L., Zarco, L.A., 2001. Los fenómenos de la bioestimulación sexual en ovejas y cabras (The phenomena of sexual biostimulation in sheep and goats). Vet. México 32, 117–129.

Bearden, H.J., Fuquay, J.W., Willard, S.T., 2004. Applied Animal Reproduction, 5th ed. Pearson Prentice-Hall, Upper Saddle River, NJ.

Bernabucci, U., Lacetera, N., Danieli, P.P., Bani, P., Nardone, A., Ronchi, B., 2009. Influence of different periods of exposure to hot environment on rumen function and diet digestibility in sheep. Int. J. Biometeorol. 53, 387–395.

Biagioli, O., Acciaioli, A., Franci, O., 1989. Le principali statistiche vitali della razza ovina Massese allevata nelle province di Lucca e Pistoia (The main vital statistics of Massese breed ewes reared in the provinces of Lucca and Pistoia). Agric. Ric. 11, 99–100.

Blache, D., Maloney, S.K., Revell, D.K., 2008. Use and limitations of alternative feed resources to sustain and improve reproductive performance in sheep and goats. Anim. Feed Sci. Technol. 147, 140–157.

Caja, G., Rancourt, M.D., 2002. Current situation and prospects of dairy sheep production in Spain. Opt. Médit. Série: Etud. Rec. 39, 57–66.

Caroprese, M., Albenzio, M., Bruno, A., Fedele, V., Santillo, A., Sevi, A., 2011. Effect of solar radiation and flaxseed supplementation on milk production and fatty acid profile of lactating ewes under high ambient temperature. J. Dairy Sci. 94, 3856–3867.

Caroprese, M., Albenzio, M., Bruno, A., Annicchiarico, G., Marino, R., Sevi, A., 2012. Effects of shade and flaxseed supplementation on the welfare of lactating ewes under high ambient temperatures. Small Rumin. Res. 102, 177–185.

Casamassima, D., Sevi, A., Palazzo, M., Ramacciato, R., Colella, G.E., Bellitti, A., 2001. Effects of two different housing systems on behavior, physiology and milk yield of Comisana ewes. Small Rumin. Res. 41, 151–161.

Casu, S., Manunta, G., 1968. Sulla attività sessuale della pecora di razza sarda nei diversi periodi dell' anno [Sexual activity of the sheep of Sarda breed in different periods of the year]. Zootec. Vet. 22, 249–256.

Chemineau, P., 1983. Effect on oestrus and ovulation of exposing creole goats to the male at three times of the year. J. Reprod. Fertil. 67, 65–72.

Chemineau, P., Levy, F., Thimonier, J., 1986. Effects of anosmia on the LH secretion, ovulation and oestrous behavior induced by males in the anovular creole goat. Anim. Reprod. Sci. 10, 125–132.

Chemineau, P., Martin, G.B., Saumande, J., Normant, E., 1988. Seasonal and hormonal control of pulsatile LH secretion in the dairy goat (*Capra hircus*). J. Reprod. Fertil. 83, 91–98.

Chemineau, P., Malpaux, B., Delgadillo, J.A., Guérin, Y., Ravault, J.P., Thimonier, J., Pelletier, J., 1992. Control of sheep and goat reproduction: use of light and melatonin. Anim. Reprod. Sci. 30, 157–184.

Chemineau, P., Pellicer-Rubio, M.T., Lassoued, N., Khaldi, G., Monniaux, D., 2006. Male-induced short oestrous and ovarian cycles in sheep and goats: a working hypothesis. Reprod. Nutr. Dev. 46, 417–429.

Cohen-Tannoudji, J., Einhorn, J., Signoret, J.P., 1994. Ram sexual pheromones: first approach of chemical identification. Physiol. Behav. 56, 955–961.

Costa, M.J.R.P., Siva, R., Souza, R.C., 1992. Effect of air temperature and humidity on ingestive behaviour of sheep. Int. J. Biometereol. 36, 218–222.

Cruz, J.F., Rondina, D., Freitas, V.J.F., 2005. Ovarian follicular dynamics during anoestrus in Anglo-Nubian and Saanen goats raised in tropical climate. Trop. Anim. Health Prod. 37, 395–402.

Curtis, S.E., 1983. Environmental Management in Animal Agriculture. Iowa State Press, Ames.

Dattena, M., Mayorga, I., Mara, L., Belloi, L., Gallus, M., Meloni, G., Cabiddu, A., Salaris, S., 2010. An example of reproduction management in organic sheep farming. In: XI International Mediterranean Symposium Symposium, 27–29 October, Zadar, Croazia.

Edgar, D.G., Bilkey, D.A., 1963. The influence of rams on the onset of the breeding seasons in the ewes. Proc. NZ Soc. Anim. Prod. 23, 78–87.

FAOSTAT, 2013. Available at: http://faostat3.fao.org/home/index.html#HOME (accessed 22 August 2013).

Franci, O., Pugliese, C., Acciaioli, A., Parisi, G., Lucifero, M., 1999. Application of two models to the lactation curve of Massese ewes. Small Rumin. Res. 31, 91–96.

Galal, S., Gürsoy, O., Shaat, I., 2008. Awassi sheep as a genetic resource and efforts for their genetic improvement: a review. Small Rumin. Res. 79, 99–108.

Giaccone, P., Todaro, M., Portolano, B., 2004. Analysis of milk production of Valle del Belice ewes reared in their area of origin and analysis of expansion of the breed. Agric. Med. 134, 246–250.

Gooding, J.R., Catt, K.J., Brawn, J.M., Katelbach, C.C., Cumming, I.A., Mole, B.J., 1969. Radioimmunassay for ovine luteinizing hormone: secretion of luteinizing hormone during estrus and following estrogen administration in the sheep. Endocrinology 85, 133–142.

Gootwine, E., Pollott, G.E., 2000. Factors affecting milk production in improved Awassi dairy ewes. Anim. Sci. 71, 607–616.

Gootwine, E., 2011. Mini review: breeding Awassi and Assaf sheep for diverse management conditions. Trop. Anim. Health Prod. 43, 1289–1296.

Gordon, I., 1997. Controlled Reproduction in Sheep and Goats. CAB International, Wallingford, UK.

Hulet, C.V., Ercanbrack, S.K., Price, D.A., Blackwell, R.L., Wilson, L.O., 1962a. Mating behavior of the ram in the one-sire pen. J. Anim. Sci. 21, 857–864.

Hulet, C.V., Ercanbrack, S.K., Price, D.A., Blackwell, R.L., Wilson, L.O., 1962b. Mating behavior of the ram in the multi-sire pen. J. Anim. Sci. 21, 865–869.

Karsch, F.J., Bittman, E.L., Foster, D.L., Goodman, R.L., Legan, S.J., Robinson, J.E., 1984. Neuroendocrine basis of seasonal reproduction. Recent. Prog. Horm. Res. 40, 185–232.

Knight, T.W., Lynch, P.R., 1980. Source of ram pheromones that stimulate ovulation in the ewe. Anim. Reprod. Sci. 3, 133–136.

Knight, T.W., 1983. 13th Seminar of Society of New Zealand Veterinary Association, vol. 13. Influencing the onset of ovarian activity: sheep and beef cattle, 16–20.

Knight, T.W., Tervit, H.R., Lynch, P.R., 1983. Effect of boar pheromones, ram's wool and presence of bucks on ovarian activity in anovular ewes early in the breeding season. Anim. Reprod. Sci. 6, 129–134.

Land, R.B., Pelletier, J., Thimonier, J., Mauleon, P., 1973. A quantitative study of genetic differences in the incidence of oestrus, ovulation and plasma luteinizing hormone concentration in sheep. J. Endocrinol. 58, 305–317.

L'Anson, H., Legan, S.J., 1988. Changes in LH pulse frequency and serum progesterone concentrations during the transition to breeding season in ewe. J. Reprod. Fertil. 82, 341–351.
Lightfoot, I., Smith, J.A.C., 1968. Studies on the number of ewes joined per ram for flock matings under paddock conditions. Aust. J. Agric. Res. 19, 1029–1042.
Lincoln, G.A., 1992. Photoperiod-pineal-hypothalamic relay in sheep. Anim. Reprod. Sci. 28, 203–217.
Lishman, A.W., Hunter, G.L., 1967. Oestrous activity in the ewe following isolation from the ram during anoestrus. Afr. J. Agric. Sci. 10, 747.
Lishman, A.W., 1969. The seasonal patterns of oestrous amongst ewes as affected by isolation from and joining with rams. Agroanimalia 1, 95.
Lu, C.D., 1989. Effects of heat stress on goat production. Small Rumin. Res. 2, 151–162.
Lyle, A.D., Hunter, G.L., 1965. Effect on occurrence of oestrus in the ewe during spring of six and 14 day teasing period prior to mating. Proc. South Africa Soc. Anim. Prod. 4, 140–142.
Malpaux, B., Viguié, C., Skinner, D.C., Thiéry, J.C., Pelletier, J., Chemineau, P., 1996. Seasonal breeding in sheep: mechanism of action of melatonin. Anim. Reprod. Sci. 42, 109–117.
Maltz, E., Olsson, K., Click, S.M., Fyhrquist, F., Silanikove, N., Choshniak, I., Shkolnik, A., 1984. Homeostatic responses to water deprivation or hemorrhage in lactating and non-lactating bedouin goats. Comp. Biochem. Physiol. Physiol. 77, 79–84.
Marai, I.F.M., El-Darawany, A.A., Fadiel, A., Abdel-Hafez, M.A.M., 2007. Physiological traits as affected by heat stress in sheep: a review. Small Rumin. Res. 71, 1–12.
Martin, G.M., Oldham, C.M., Cogniè, Y., Pearce, D.T., 1986. The physiological responses of anovulatory ewes to the introduction of rams: a review. Livest Prod. Sci. 15, 219–247.
Matton, P., Bhereur, J., Dufour, J.J., 1977. Morphology and responsiveness of the two largest ovarian follicles in anestrous ewe. Can. J. Anim. Sci. 57, 459–464.
McGuire, M.A., McGuire, M.K., 2000. Conjugated linoleic acid (CLA): a ruminant fatty acid with beneficial effects on human health. J. Anim. Sci. 77, 1–8.
Milán, M.J., Caja, G., González-González, R., Fernández-Pérez, A.M., Such, X., 2011. Structure and performance of Awassi and Assaf dairy sheep farms in northwestern Spain. J. Dairy Sci. 94, 771–784.
Morgan, P.D., Arnold, G.W., Lindsay, D.R., 1972. A note on the mating behavior of ewe with various senses impaired. J. Reprod. Fertil. 30, 151–152.
Mucchetti, G., Bonvini, B., Remagni, M.C., Ghiglietti, R., Locci, F., Barzaghi, S., Francolino, S., Perrone, A., Rubiloni, A., Campo, P., Gatti, M., Carminati, D., 2008. Influence of cheese-making technology on composition and microbiological characteristics of Vastedda cheese. Food Contr. 19, 119–125.
Nudda, A., Battacone, G., Usai, M.G., Fancellu, S., Pulina, G., 2006. Supplementation with extruded linseed cake affects concentrations of conjugated linoleic acid and vaccenic acid in goat milk. J. Dairy Sci. 89, 277–282.
Oldham, C.M., Martin, G.M., 1978. Stimulation of seasonally anovular merino ewes by rams: 2. Premature regression of ram-induced CL. Anim. Reprod. Sci. 1, 291–295.
Oldham, C.M., 1980. Stimulation of ovulation in seasonally or lactationally anovular ewe by rams. Proc. Aust. Soc. Anim. Prod. 13, 73–74.
Olsson, K., Josäter-hermelin, M., Hossaini-Hilali, J., Hydbring, E., Dahlborn, K., 1995. Heat stress causes excessive drinking in fed and food deprived pregnant goats. Comp. Biochem. Physiol. Physiol. 110, 309–317.
Ortvant, R., Bpcquier, F., Pelletier, J., Ravault, J.P., Thimonier, J., Volland-Nail, P., 1988. Seasonality of reproduction in sheep and its control by photoperiod. Aust. J. Biol. Sci. 41, 69–85.
Peana, I., Fois, G., Cannas, A., 2007. Effects of heat stress and diet on milk production and feed and energy intake of Sarda ewes. Ital. J. Anim. Sci. 6 (Suppl. 1), 577–579.
Pellicier, M.T., Leboeuf, B., Bodin, L., Baril, G., Caillat, H., Bouvier, F., Malpaux, B. 2009. Etude de la saisonnalité de chèvres de race Alpine et Créole maintenues hors-reproduction [Study of the seasonal Alpine breed goats and Creole kept out-breeding]. 18e Journées 3R, 2011.
Perkins, A., Fitzgerald, J.A., 1994. The behavioral component of the ram effect in the influence of ram sexual behavior on the induction of estrus in anovulatory ewes. J. Anim. Sci. 72, 51–55.
Pollott, G.E., Gootwine, E., 2004. Reproductive performance and milk production of Assaf sheep in an intensive management system. J. Dairy Sci. 87, 3690–3703.
Roche, J.F., Foster, D.L., Karch, F.J., Cook, B., Dziuk, P.J., 1970. Level of luteinizing hormone in sera and pituitaries of ewes during the estrus cycle and anestrus. Endocrinology 85, 568–572.
Rosa, H.J.D., Bryant, M.J., 2002. The 2ram effect as a way of modifying the reproductive activity in the ewe. Small Rumin. Res. 45, 1–16.
Secchiari, P., Trimarchi, G., Ferruzzi, G., Martini, A., Pistoia, A., Berni, P., Luisi, M., 1988. Effetti dell'apporto energetico della razione sull'inizio della carriera riproduttiva di agnelle Massesi [Effects of content of feed energy on the beginning of reproductive activity of Massese lambs]. Agric. Medit. 118, 381–388.
Sevi, A., Annicchiarico, G., Albenzio, M., Taibi, L., Muscio, A., Dell'Aquila, S., 2001. Effects of solar radiation and feeding time on behavior, immune response and production of lactating ewes under high ambient temperature. J. Dairy Sci. 84, 629–640.
Sevi, A., Albenzio, M., Annicchiarico, G., Caroprese, M., Marino, R., Taibi, L., 2002a. Effects of ventilation regimen on the welfare and performance of lactating ewes in summer. J. Anim. Sci. 80, 2349–2361.
Sevi, A., Rotunno, T., Di Caterina, R., Muscio, A., 2002b. Fatty acid composition of ewe milk as affected by solar radiation and high ambient temperature. J. Dairy Res. 69, 181–194.
Sevi, A., Taibi, L., Albenzio, M., Annicchiarico, G., Marino, R., Caroprese, M., 2003. Influence of ventilation regimen on micro-environment and on ewe welfare and milk yield in summer. Ital. J. Anim. Sci. 2, 197–212.
Sevi, A., Albenzio, M., Marino, R., Santillo, A., Muscio, A., 2004. Effects of lambing season and stage of lactation on ewe milk quality. Small Rumin. Res. 51, 251–259.
Silanikove, N., 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livest Prod. Sci. 67, 1–18.
Steri, R., Conte, G., Mele, M., Macciotta, N.P.P., Secchiari, P.L., 2007. Impiego di modelli matematici empirici nello studio della curva di lattazione della pecora Massese [Use of empirical mathematical models to study of the lactation curve of Massese ewe]. In: Proc. 6 Congress Biomet. Ital. Soc, pp. 191–194.
Thiéry, J.C., Chemineau, P., Hernández, X., Migaud, M., Malpaux, B., 2002. Neuroendocrine interactions and seasonality. Dom. Anim. Endocrinol. 23, 87–100.
Thiery, J.C., Martin, G.B., 1991. Neurophysilogical control of the secretion of gonadotrophin-releasing hormone and luteinizing hormone in the sheep: a review. Reprod. Nutr. Dev. 3, 137–173.
Underwood, E.J., Shier, F.L., Davemport, N., 1944. Studies in sheep husbandry in W.A.V. The breeding season in Merino crossbreed and in British breed ewes in the agricultural districts. J. Agric. (Western Australia) Ser. 2 11, 135–143.
Walton, J.S., McNeilly, J.R., McNeilly, A.S., Cunningham, F.J., 1977. Changes in concentration of follicle-stimulating hormones, luteinizing hormone, prolactin and progesterone in the plasma of ewes during the transition from anoestrus to breeding activity. J. Endocrinol. 75, 127–136.
Watson, R.H., Radford, H.M., 1960. The influence of rams on onset of oestrus in Merino ewes in the spring. Aust. J. Agric. Res. 11, 65–71.
Webb, R., Gauld, I.K., 1985. Genetic and physiology of follicle recruitment and maturation during seasonal anoestrus. In: Ellendorf, F., Elsaesser, F. (Eds.), Endocrine Causes of Seasonal and Lactational Anoestrus in Farm animal. Martinus Nijhoff, Lancaster, pp. 19–28.
Williams, C.M., 2000. Dietary fatty acids and human health. Ann. Zootechnol. 49, 165–180.
Zarazaga, L.A., Guzmán, J.L., Domínguez, C., Pérez, M.C., Prieto, R., 2005. Effect of plane of nutrition on seasonality of reproduction in Spanish Payoya goats. Anim. Reprod. Sci. 87, 253–267.