Review article

Factors of welfare reduction in dairy sheep and goats

Agostino Sevi[1], Donato Casamassima[2], Giuseppe Pulina[3], Antonio Pazzona[4]

[1]Dipartimento di Scienze delle Produzioni, dell'Ingegneria, della Meccanica e dell'Economia applicate. Università di Foggia, Italy

[2]Dipartimento di Scienze Animali, Vegetali e dell'Ambiente. Università del Molise, Campobasso, Italy

[3]Dipartimento di Scienze Zootecniche. Università di Sassari, Italy

[4]Dipartimento di Ingegneria del Territorio. Università di Sassari, Italy

Corresponding author: Prof. Agostino Sevi. Dipartimento Pr.I.M.E. Facoltà di Agraria, Università di Foggia. Via Napoli 25, 71100 Foggia, Italy - Tel. +39 0881 589328 - Fax: +39 0881 589331 - Email: a.sevi@unifg.it

Paper received June 8, 2007; accepted September 23, 2007

ABSTRACT

Scientific research on factors causing the reduction of well-being in sheep and goats is rather recent, as are studies of strategies to minimize the adverse effects of environmental challenges and improper management practices on flock welfare. Sheep and goats, considered very rustic animals, are reared prevalently under extensive production systems and are widespread mainly in marginal areas. For these reasons, only few studies on the welfare of these species have been carried out in the past. More recently, the scenario has changed, due to a gradual diffusion of intensive and semi-intensive production systems, especially in dairy sheep and goat breeds, to the growing concern of consumers about the life conditions of farmed animals, and to the issuing of a number of rules and laws on the safety of animal products and well-being of farmed livestock. As a consequence, several research groups have turned their attention to the welfare of sheep and goats. Nevertheless, information on this topic is still scarce. This paper reviews major critical points regarding the endangerment of welfare in farmed sheep and goats. Climatic extremes and seasonal fluctuations in herbage amount and quality are discussed as important causes of the reduction of well-being in extensive production systems, which can impair production efficiency of grazing animals and dramatically affect the welfare and health status of sheep and goats. Space allowance and structures of sheep and goat houses are described as the main potential sources of discomfort for housed flocks, together with inadequate control of micro-environment, and inappropriate milking procedures and human-animal interactions. Recent studies on the impact of high ambient temperature, different ventilation regimes, high stocking densities, reduced airspace and poor litter management on behaviour, immune and endocrine response, and on performance of sheep and goats are discussed. The effects of inadequate milking procedures and improper milking technical parameters on welfare and udder health of sheep and goats are also discussed. Finally, some practices aimed at minimizing emotional and nutritional stresses of lambs and kids after early separation from the mother, before the transition to artificial rearing, and at weaning time are described.

Key words: Sheep, Goats, Welfare, Extensive breeding, Housing.

RIASSUNTO

FATTORI DI RIDUZIONE DEL BENESSERE NEGLI OVINI E NEI CAPRINI DA LATTE

Lo studio dei fattori di riduzione del benessere negli ovini e nei caprini e la messa a punto di strategie finalizzate a minimizzarne l'impatto sono relativamente recenti. Gli ovini e i caprini sono da sempre accreditati di una proverbiale rusticità e in queste specie vi è una netta prevalenza dei sistemi estensivi di allevamento. Inoltre, gli ovini e i caprini sono prevalentemente diffusi nelle "aree difficili", caratterizzate da operatori zootecnici tradizionalmente poco propensi tanto all'innovazione quanto alla revisione delle tecniche di allevamento. Queste circostanze spiegano la carenza di studi sul benessere nelle specie ovina e caprina. In anni recenti, tuttavia, lo scenario ha subito una rapida evoluzione per effetto di diverse e concomitanti circostanze: la progressiva diffusione dei sistemi intensivi e semi-intensivi di allevamento, soprattutto nelle razze da latte, l'accresciuta sensibilità del consumatore verso il benessere animale, il necessario adeguamento alle normative comunitarie in materia di igiene degli alimenti di origine animale, che ha comportato l'adozione di tecniche di allevamento più rispettose del benessere e della sanità degli animali da reddito. Il bagaglio di conoscenze sull'argomento è quindi, per le specie ovina e caprina, più esiguo rispetto ad altre specie zootecniche da reddito. Obiettivo della presente rassegna è redigere un inventario dei punti critici di allevamento, catalogando, per i diversi sistemi di allevamento, i principali e più evidenti fattori di riduzione del benessere con le accertate o prevedibili conseguenze sullo stato di salute e sulle risposte fisiologiche, comportamentali e produttive degli ovi-caprini. Gli estremi climatici e le fluttuazioni nella disponibilità delle risorse pabulari vengono discussi come fattori principali di riduzione del benessere nell'allevamento estensivo con evidenti risvolti sull'efficienza biologica, sul benessere e sullo stato di salute degli ovini e dei caprini. La scelta dei parametri strutturali e dimensionali, il controllo del micro-clima, le interazioni animale-operatore e il management della mungitura, anche sotto il profilo della scelta e del controllo dei parametri di funzionamento dell'impianto, vengono discussi come le principali cause di potenziale discomfort per gli animali stabulati. Vengono inoltre presentate le evidenze scientifiche dell'impatto delle alte temperature ambientali, di inadeguati regimi di ventilazione, di elevate densità di allevamento, di una ridotta cubatura degli edifici e di uno scadente management della lettiera sulle riposte comportamentali, immunitarie, endocrine e produttive degli ovini e dei caprini. Infine vengono illustrate alcune tecniche in grado di ridurre lo stress emotivo e nutrizionale che grava sull'agnello e sul capretto allorché vengono separati dalla madre in occasione del passaggio all'allattamento artificiale e in concomitanza dello svezzamento.

Parole chiave: *Ovini, Caprini, Benessere, Allevamento estensivo, Allevamento stabulato.*

Introduction

Studies on the welfare of sheep and goats have developed slowly, due to some of their physiological peculiarities and their prevalent extensive production system. In fact, since sheep and goats are considered very rustic animals, their ability to cope with prohibitive environmental conditions and inadequate management practices, without harming their welfare and productive performance, has been often overrated. In addition, the diffusion of extensive breeding of these species has led to the belief that sheep and goats did not need any welfare assessment. This was based on the fact that generally the highest standard of livestock well-being, associated with minimal behavioural restriction and man's intervention in the biological cycle of the animal, is attributed to the extensive production system. Finally, sheep and goats are mostly spread throughout internal and marginal areas, where farmers are still anchored to traditional production systems and are not receptive to updated breeding techniques, especially to those without an immediate economic and tangible impact.

In the recent decades, this scenario has undergone a rapid change due to the following events: i) gradual diffusion of semi-intensive breeding systems, especially in highly productive dairy breeds, ii) greater consumer concern about the quality and sustainability, including ethical aspects, of the production cycle of animal products, iii) need for increasing flock profits and conforming to the quality standards requested by national and European regulations in terms of well-being and rearing practices that respect health.

The present review highlights the main causes that reduce well-being in dairy sheep and goats and their impact on animal health, behaviour, physiology and production in different production systems. Much more information is given on sheep than on goats. This is due to the fact that sheep are more abundant than goats; the latter are almost totally reared in developing countries, and, as a consequence, scientific research on small ruminants has concentrated almost exclusively on sheep (Rutter, 2002).

Factors of welfare reduction in grazing sheep and goats

Although the welfare of extensively managed animals has largely been ignored, the perception that welfare in these systems is good is not based on scientific assessment (Turner and Dwyer, 2007). Sheep and goats in extensive environments may face a range of compromises to their well-being, but principally those related to nutritional stress, inadequate water supply, climatic extremes, parasitical diseases and lameness.

Extensive rearing of sheep and goats in most of the Mediterranean areas is characterized by grazing during daytime and housing during night-time, with possible integration of concentrate feed, and of straw or hay. In extensive production systems, animals are free to move within a habitat that allows them to best perform their physiological and behavioural functions. However, grazing can also adversely affect animal well-being, due to seasonal fluctuations of herbage amount and quality; consequently, grazing animals are usually subjected to a temporary nutritional stress. If the nutritional stress occurs during mating season, it can reduce sheep fertility (Rassu *et al.*, 2004). In the areas where sheep and goat breeding is more diffused, late spring and summer are characterized not only by poor grass availability and palatability but also by a marked reduction of its protein content (Negrave, 1996). Therefore, grazing animals in extensive rearing can face nutritional unbalance during this period of the year, with the alteration of rumen fermentation and protein synthesis, which compromises their well-being and negatively influences milk fat and protein content as well. When goats graze in poor meadows with excessively fibrous vegetation, under bad weather conditions, and with limited time for herbage ingestion, they may show decreased milk production (Fedele *et al.*, 1993). Pulina *et al.* (2006) found that short-term feed restriction strongly reduced milk yield and increased milk fat content in Sarda dairy ewes. Undernutrition significantly affected the milk fatty acid profile, as a consequence of body fat mobilisation. Underfed ewes showed higher milk somatic cell count (SCC), indicating a metabolic stress of the animal and its mammary gland. The structure of the pasture (plant height, leaf to stem ratio, plant density, space distribution of the aerial biomass), which can modify grass prehension modalities by the animals (Hodgson, 1985), is another factor that can influence the welfare and performance of grazing sheep and goats. In particular, sward surface height and green leaf mass have been recognized as the factors playing a major role on ingestive behaviour, herbage intake and production performance of sheep and goats (Penning *et al.*, 1991). Field trials suggest that a sward surface height close to 60 mm and a green leaf mass of 1500 to 2000 kg/ha can improve intake, welfare and performance of sheep (Orr *et al.*, 1990; Penning *et al.*, 1994).

Inadequate water supply can also limit animal welfare in many pastures of the Mediterranean area. Water restriction causes stress to sheep, with a reduction in food intake (Ayoub and Saleh, 1998), an increase of rectal temperature and breath rate, a decrease of glycaemia and a rise of urea in blood and milk. In this species, water stress causes a more or less marked alteration of the metabolic profile (Lanen *et al.*, 1987; Casamassima *et al.*, 2006b; Hamadeh *et al.*, 2006), and often a reduction in live weight (Casamassima *et al.*, 2006b; Hamadeh *et al.*, 2006). In some cases, water scarcity leads to a decrease of up to 50% in milk production (Aganga, 2001) and, in pregnant ewes, to an increase in abortions and newborn death (Lynch *et al.*, 1972). The use of natural pastures favours the development of endoparasitism, whose etiologic agents are rarely mortal but provoke a considerable reduction in the feeding efficiency of sheep and goats, with a consequent reduction of weight growth, of milk yield and wool growth, an alteration in reproduction performance, and a shortening of productive career (Lia and Pantone, 2001). Parasitized sheep spend less time grazing, are less active than uninfected sheep and have reduced herbage intakes (Hutchings *et al.,* 2000). At early stages of endoparasitic infestations sheep displayed disturbed behavioural patterns: restlessness, disturbed lying behaviour, intense rubbing of area of the fleece, biting at the flanks. As the disease progresses, infected sheep become increasingly disturbed and agitated by the presence of the allergens (Dwyer and Bornett, 2004). Also lameness may represent a significant challenge to sheep and goat in extensive systems (Goddard, 2006). Sheep with mild or severe foot rot show elevated plasma adrenaline and noradrenaline levels (Ley *et al.*, 1992). Severe foot root is also associated with a significantly reduced threshold for nociceptive stimuli compared to healthy animals, indicating an increased sensitivity to acute pain (Ley *et al.*, 1995).

Among farmed livestock, sheep and goats are believed to be the most resistant to climatic extremes, especially to high ambient temperatures (Bettini, 1985). In sheep, the physiological drop in milk yield which occurs in summer, during late-lactation, often hides completely, or partially, the negative impact of high temperatures on milk production. Experiments conducted by Sevi *et al.* (2001a, 2002b) have shown a marked increase in rectal temperature, a metabolism alteration and a reduction of milk yield after ewe exposure, even for short periods, to average daily temperatures of 35°C or after prolonged ewe exposure to mean ambient temperatures of 30°C. In such conditions, a significant reduction of immune response has been observed together with a severe mineral unbalance (mainly magnesium, potassium, calcium and phosphorous), and a reduction of milk casein and fat contents (mainly long chain and unsaturated fatty acids). In addition, the milk hygienic quality, with an increase of neutrophil concentration, and of Staphylococci, coliform and *Pseudomonas* counts, and milk coagulating properties got worse. The latter could be attributed to the reduction of calcium and phosphorous content in milk and to a more intense plasmin activity under those stress conditions (Sevi *et al.*, 2004). Providing shade during the hottest hours of the day and changing feeding time to late afternoon helps to minimize the impact of high summer temperatures on lactating ewes.

Factors of welfare reduction in housed sheep and goats

Confined rearing is usually characterized by high stocking density and prolonged faeces accumulation in sheep and goat houses. Therefore, adequate space allowance, careful litter management and scrupulous monitoring of the micro-climatic factors (in terms of temperature, relative humidity and air quality) are crucial aspects in sheep and goat housing.

The minority of sheep and goat flocks are permanently housed, while most of them are housed only during the night and in periods in which grazing is not feasible (summer months in flat and costal lands, winter months in internal hill areas). In any case, it is fundamental to understand that maintenance of good hygiene conditions, associated with correct dimensioning of structural parameters and adoption of proper management practices, is important in either type of system. Unfortunately, sheep and goats often have shelters that are not appropriate, in terms of design, materials and size.

Stocking density and airspace allowance

Loynes (1983) suggests a minimum space allowance of 0.7 m^2/head, when animals are kept on straw litter, and of 1 m^2/head when sheep are on slatted floor, for sheep weighing no more than 60 kg. Space allowance should be increased by about 30% for sheep weighing from 60 to 90 kg and a further 30% during suckling of lambs. Space allowance can be reduced by 10% for recently sheared sheep and increased by 17% for horned ones (Dickson and Stephenson, 1979). Chiumenti (1987) suggests slightly higher values, i.e. 0.9-1.2 m^2/head on straw litter and 0.8–1 m^2/head on slatted floor. This author also suggests assigning a 2 m^2 paddock area per sheep.

The effects of stocking density on air quality and on health and production has been investigated in lactating ewes. Sevi *et al.* (1999a) found a significant decrease in air concentrations of total micro-organisms and coliforms in a room containing sheep kept in an area of 2 m^2/head compared to rooms where sheep had 1.5 or 1 m^2/head. In addition, the ewes housed in the least crowded room showed a significant increase in milk yield and milk protein, casein and fat yield, which determined an overall improvement of milk coagulating properties. The milk from the ewes stocked at 2 m^2/head had 3 to 4 times lower SCC and significantly lower concentrations of mesophilic, psychrotrophs, and coliform bacteria, compared to milk from ewes stocked at 1.5 and 1 m^2/head. Cases of sub-clinical mastitis were absent in the least crowded group, whereas they appeared earlier and in a growing number of animals as space allowance decreased to 1.5 and 1 m^2/head.

Space allowance reduction from 2 to 1 m^2/head showed interesting effects on feeding behaviour in goats. Loretz *et al.* (2004) found a relevant reduction of feeding activity (-5%) and of resting time (-13%) in horned goats and a slighter reduction of the same parameters (-8% and -6%, respectively) in goats without horns. Despite the presence of horns, feeding time was significantly reduced due to a reduction of feeding space from 20 to 10 cm/head.

Airspace is one of the most important factors that influence the concentration of airborne particulates in animal houses (Hartung, 1989). In housed calves, Wathes *et al.* (1983) found that doubling air space allowance caused a reduction of airborne micro-organisms which was equivalent to that achievable by quintupling air change rate. This could be of practical interest for sheep housing, in particular if sheep are raised in warm climates and do not benefit from efficient ventilation systems. When assessing the effects of different airspace allowances on dairy sheep, Sevi *et al.* (2001c) found that an airspace of less than 7 m^3/head led to a significant increase in relative humidity and airborne micro-organism concentration (mainly staphylococci count), a marked rise of somatic cell and of micro-organism count (mainly psychotropic bacteria) in milk, and a higher incidence of sub-clinical mastitis. In addition to such effects on the hygienic quality of air and milk, and on ewe udder health, a reduced milk yield (- 15%) and a lower casein content (-5%) were also observed.

When sheep are housed at a high stocking density, careful litter management is particularly important to mitigate drawbacks on animal welfare and production performance. Spreading of appropriate chemical products on litter, such as bentonite and paraformaldehyde, which can reduce bacteria proliferation and degrading processes of the nitrogen contained in urine and in faeces, is a suitable strategy to reduce airborne micro-organism levels and ammonia release from the manure (Sevi *et al.* 2001e; 2003a).

Ventilation

Ventilation plays a main role in maintaining the welfare and performance of housed sheep and goats, by affecting thermal exchanges between the animal's body surface and the environment, by avoiding an excessive increase in relative humidity, and by keeping levels of noxious gases and airborne particles under control (Sevi, 2005).

Ventilation rate is based on the length of ventilation cycles and on air speed. The first parameter is very important, because when air speed exceeds 1 m/s, the cooling efficiency of ventilation does not increase. On the contrary, turbulent air currents generated by very rapid ventilation rates may result in greater amounts of dust entering the animal house as well as in dust particles remaining suspended in the air for a longer time (Sevi *et al.*, 2003d).

Sevi *et al*. (2002a, 2003c) highlighted that, during summer, dairy sheep need an average ventilation rate of about 65 m^3/h per head, achieved by giving most ventilation cycles during the hottest hours of the day. However, results indicate also the importance of overnight air exchange. This aims mainly at removing dangerous gases (mostly ammonia) that easily develop from excreta decomposition and fermentation in hot weather.

Summer ventilation rate of less than 40 m^3/h per head causes altered behaviour, immune and endocrine responses, and about 10% lower milk yields in sheep. Poor ventilation also increases milk bacterial load and worsens milk cheese-making properties, leading to a high casein and lipid loss during curd formation and to an alteration of cheese ripening processes (Albenzio *et al.*, 2005).

The role of air exchange during the winter season is often underestimated. This can have important effects on welfare and production performance of dairy sheep and goats, by avoiding an excessive increase in relative humidity and by keeping levels of noxious gases and airborne particles under control. Some experiments (Sevi *et al.* 2003d; Albenzio *et al.*, 2004) have demonstrated that exposure of dairy sheep to low (about 25 m^3/h per ewe) and very high ventilation rates (about 75 m^3/h per ewe) results in increased noxious gases, dust and airborne microorganism concentrations compared to a moderate ventilation rate of about 45 m^3/h per ewe. In addition, exposure to inadequate ventilation regimes can reduce milk yield and deteriorate milk quality. Albenzio *et al.* (2004) found higher levels of somatic cell and mesophilic bacteria counts as well as a greater plasmin activity and a higher plasminogen to plasmin ratio in the milk collected from the ewes exposed to low (25 m^3/h) and very high (75 m^3/h) ventilation rates compared to the milk from ewes exposed to a moderate (45 m^3/h) ventilation rate.

In Table 1 recommended values of some spatial and micro-environment parameters in sheep and goat housing are reported.

Moving and handling

Frequent interaction between the animal and the stockman, with repeated animal manipulation, is another potential stress factor for housed sheep and goats. The commonly considered rusticity of sheep and goats often induces stockmen, especially those with

Table 1. Recommended values of some spatial and micro-environment parameters for housed sheep and goats.

Items	Recommended values
Space allowance:	
Young animals (15-25 kg body weight)	0.60 m^2/head
Young animals (25-40 kg body weight)	1 m^2/head
Adult animals (ewe and doe)	1.5-2 m^2/head
Adult animals (ram)	2.2-2.5 m^2/head
Feeder space	0.2 m/head
Airspace (adult animals)	7 m^3/head
Ventilation rate:	
Young animals (summer)	35 m^3/h/head
Young animals (winter)	20 m^3/h/head
Adult animals (summer)	70 m^3/h/head
Adult animals(winter)	45 m^3/h/head
Lighting:	
Glassed area	≥1/15 of total house area
Duration	≥8 hours a day
Intensity	≥100 lux
Air temperature:	
Maximum	25 °C
Minimum	5 °C
Relative humidity	≤70%
Dust	<1.6 mg/m^3 air
Airbone micro-organisms	<250 cfu/l air
Noxious gases;	
NH_3	<10 ppm
CO_2	<2500 ppm
H_2S	<2.5 ppm

less experience or aptitude, to handle them roughly. However, it has been widely demonstrated that goats and sheep are characterized by ancestral predatory fear, gregarious nature, and difficult adaptation to unfamiliar environments and integration with unknown groups. Therefore, sheep and goats can suffer as much as, if not more than, other farmed livestock species, when rearing practices change suddenly, in terms of time, place and stockmen involved in milking or when regrouping and relocation occur suddenly or frequently. They also suffer if handling is excessive or inappropriate. In lactating ewes, Sevi *et al.* (2001d) found that member exchange increased aggression and altered immune response. Cell mediated immunity was also affected by relocation. Mixing and moving also resulted in short-term but marked effects on production traits (up to 23% less milk yield, up to 19% less milk protein content and about 6% less milk fat content). A minor impact of regrouping and relocation was observed on ewe udder health. Thus, changes in environmental and social conditions should be occur as little as possible in sheep flocks, always taking care to minimize their impact on animal welfare.

Nutritional unbalance

Sheep are typically grazing animals in marginal and less popular areas so they can undergo nutritional stress rather frequently. High yielding dairy ewes farmed under semi-intensive conditions can experience nutritional unbalance as well. Undernutrition can occur in late spring and summer due to increased energy output for thermoregulation and concurrent reduction in energy intake, but also during pregnancy and the transition period, especially in twin-bearing ewes and in primiparous animals, which have to simultaneously synthesize milk, complete their growth, and acquire full immune competence. Sevi *et al.* (1998) demonstrated that ewe undernutrition during the last 6 weeks of pregnancy leads to a reduced yield of milk, protein and casein together with increased SCC, and altered amino acid composition of milk, probably due to extensive amino acid oxidation for energy supply. Caldeira *et al.* (2007), shifting the diet of non-lactating and non-pregnant Serra da Estrela ewes from very high to very low nutritional levels and vice-versa, found that both feed restriction and overnutrition must be avoided to prevent metabolic disturbances and to save the cost of excessive fattening and the maintenance of extra body weight. These authors observed that body condition score is a reliable indicator of sheep metabolic welfare and stated that it should never be below 1.5 or above 3.5.

Proper feeding strategies should be adopted also for primiparous ewes. Sevi *et al.* (2000) found that younger ewes gave milk with significantly less protein, casein and fat compared to older ewes, probably due to a more limited availability of body reserves, and that mastitis infection set in progressively earlier as the number of lactations decreased, probably due to less efficient natural defence mechanisms in younger ewes, as a consequence of less advanced development of the immune system.

Housing system can also affect the nutritional status of farmed animals. Indeed, the farmer has to adjust feeding rations taking into account the level of activity related to different housing systems in order to prevent transient conditions of nutritional stress in the ewe. When comparing behaviour, milk yield and physiology of ewes maintained in external paddock during daytime or confined indoors throughout the day, Casamassima *et al.* (2001) found that an outdoor enclosure was beneficial to the behavioural needs of lactating ewes, though it leads to transient energy deficit and drop of milk yield and quality.

Sometimes lactating ewes can experience energy and nutrient intake exceeding their own needs, especially with respect to dietary protein level. Excessive nitrogen intake can have a deleterious impact on animal welfare, due to an overloading of renal draining activity, and to high levels of ammonia release in sheep houses. This latter event can be magnified by poor air change in animal houses. Sevi *et al.* (2006), giving lactating ewes a low (13% CP of DM) and a moderate dietary protein level (16% CP of DM) under a low (23.5 m^3/h/ewe) and a moderate ventilation rate (47 m^3/h/ewe) in winter, found that animals fed the 16% CP level and exposed to the low ventilation rate displayed the lowest efficiency of dietary N utilization, excreted the greatest amounts of urine, total water and faecal N, and had the highest bacterial load and urea levels (more than 43 mg/dl) in their milk. Milk urea is considered a reliable indicator of animal nutritional status and biological efficiency. Bishonga *et al.* (1994) found that high urea concentrations in milk (34 to 50 mg/dl) were associated with negative effects on the initial development and survival rate of sheep embryos cultivated in vitro. Milk urea concentrations higher than 40 mg/dl are regarded as responsible for reduced reproductive efficiency (Cannas, 2002).

Impact of milking management on sheep and goat welfare

Milking routine

Milking management is a critical point in sheep and goat farms. The time animals need to adapt to machine milking, pre-parturition training to milking parlour, the number of lambs born by ewes, and type of milking (i.e. hand or machine milking), can markedly affect the welfare, health and production performance of dairy sheep and goats. The behaviour of animals in the milking parlour is probably influenced by both genetic factors and their previous handling experience. The stress caused by fear of humans has practical implications on dairy animal performance. Therefore, reducing the emotional or physical stress of dairy animals helps to increase their productivity and to maintain their health status.

Two main mechanisms may be involved in the response of lactating animals to stress: a local mechanism, proposed by Silanikove *et al.* (2000), which connects the plasmin-plasminogen system to the autocrine inhibition of lactation, and a systemic mechanism which takes into account the role of the hypothalamic-pituitary-adrenal (HPA) axis in determining the rate of milk secretion (Matteri *et al.*, 2000). Silanikove *et al.* (2000) showed that stress activates the HPA axis that liberates cortisol into blood plasma. This in turn induces the liberation of the plasmin activator from the mammary epithelial cells into the mammary cistern, where it activates the plasmin system that degrades β-casein and produces the residue 1-28 β-casein. This is also called proteoso-peptone channel blocking (PPCB). PPCB inhibits the ion channels in mammary epithelia apical membranes and thus also inhibits lactose and monovalent ion secretion. This results in a decrease in milk volume. When injecting the 1-28 ß-casein fraction into the udder lumen of goats, Pulina *et al.* (2005) observed a transient reduction in milk production, which was not associated with the disruption of the integrity of the mammary cell junctions.

In the systemic mechanism, stress activates the HPA axis and stimulates the secretion of adrenocorticotropic hormone (ACTH) by the pituitary gland. The ACTH stimulates the synthesis and release of glucocorticoids (cortisol and corticosterone) from the adrenal cortex. Cortisol causes a decrease in milk synthesis by blocking the uptake of glucose by the mammary gland

(Davis and Collier, 1985). A secondary effect of stress is the inhibition of prolactin (PRL) synthesis by the pituitary gland due to the hypothalamic release of dopamine. Both situations cause a transient metabolic energy surplus due to a reduction in the energy output by the milk and an increase in mobilization of stored energy. This is caused by a sharp increase in glucocorticoids, followed by an increase in insulin and adipose tissue uptake capacity. If the stress continues, it may have negative effects on lactation yield, especially in the second half of lactation, due to increased secretion of the leptin hormone by adipose tissue. This hormone inhibits the positive action of insulin-like growth factor-1 (IGF-1) on mammary parenchyma (Silva *et al.*, 2002).

Dimitrov-Ivanov and Djorbineva (2002) found that machine-milked calm ewes produced more milk than nervous ones. In cattle, animals with previous experience of quiet handling became calmer and easier to handle later on. The presence of a rough handler did not modify the total milk yield per milking but increased the residual milk by 70% (Rushen *et al.*, 1999), thus increasing milking duration, in dairy cows. This can be explained by the inhibition of oxytocin release by catecholamines, which are released from the adrenal gland in response to many types of stress, including fright (Bruckmaier and Blum, 1998).

In primiparous ewes that were machine milked 8 h after lambing, baseline levels of adrenalin and noradrenalin were slightly higher on day 1 than on day 15 of milking, and baseline levels of cortisol were significantly influenced by day of lactation (Negrão and Marnet, 2003). Higher levels of these hormones on day 1 were probably influenced by parturition. After the initial stress, oxytocin and milk ejection increased gradually suggesting that most ewes had adapted to machine milking by day 15.

In a study by Rassu *et al.* (2006), primiparous dairy ewes that started to enter the milking parlour 1 week before weaning the lambs showed a significantly lower milk SCC on the first 3 days than untrained ewes. The lowest content of milk fat was found on the first day of machine milking for both groups. Blood cortisol levels were not affected by the treatments during the study period (i.e. until 10 days in milking). The authors hypothesized that a week of training in the machine parlour was not long enough to allow a reduction of the stress caused by machine milking and weaning in primiparous ewes.

Machine milking does not have relevant effects on ewe milk yield or on milk protein and fat content in comparison to hand milking (Casamassima *et al.*, 2006a). Actually, if machine milking is properly performed, it can improve udder health and the hygienic quality of milk, as demonstrated by a reduction of somatic cell and bacteria counts (Casu *et al.*, 1978). However, over-milking, malfunction of the plant system and poor hygiene in milking operations can have negative effects, above all, on the hygienic characteristics of milk. In particular, transition from suckling to machine milking represents a critical point for dairy sheep and goats, because it is accompanied by a transitory immune depression and increased risk of mastitis (Albenzio *et al.*, 2003). Thus, control of sanitation of housing, milking procedures, and udder and milker hygiene is needed. Caroprese *et al.* (2006a) have demonstrated that ewes undergo marked fluctuations of cell-mediated and humoral immune response, and of plasma concentrations of Interleukine-6 (IL-6) during *peripartum*. Blood levels of immunoglobulin G (IgG) and of IL-6 are the most sensitive markers of physiological and nutritional stress related to the transition period and the number of lambs born to be delivered.

Sheep carrying out multiple gestations had a more marked reduction of immune function during *peri-partum* than single bearing sheep. Therefore, multiple bearing sheep need a more careful control of housing and milking hygiene, due to their decreased pathogen resistance. In fact, poor hygiene of milker, milking machine and milking room is an important cause of udder and milk contamination. The fact that some environmental mastitis related pathogens (*Escherichia coli, Pseudomonas Aeruginosa*) have prevailed in dairy sheep and goat flocks, especially in confined animals, indicates a widely diffused low level of hygiene in dairy sheep breeding, especially during milking operations (Albenzio *et al.*, 2002).

Milking system

Malfunction of the milking system, due to incorrect installation, lack of maintenance or improper use, can cause animal stress during milking and mammary gland diseases. Vacuum level, pulsation and milking unit are the main elements of the milking system. They are closely related to each other and influence milk ejection. These three factors must be well-balanced, in order to assure optimal functioning of the milking system.

Working vacuum

As working vacuum increases, milk flow rate increases; this can cause or favour diseases of the mammary gland. In dairy cows, vacuum increase can cause congestion and edema of the teat walls, due to dilation of capillary blood vessels (Hamann *et al.*, 1993), a greater number of opened sphincters after machine milking, a higher probability of hyperkeratosis (Rasmussen *et al.*, 1994; Mein *et al.*, 2003) and an increase in stripping milk (Reinemann *et al.*, 2001). Similarly, in dairy ewes and goats, vacuum increase and SCC are positively correlated (Le Du, 1989; Lu *et al.*, 1991; Pazzona and Murgia, 1993; Perrin and Baudry, 1993; Fernandez *et al.*, 1999; Sinapis *et al.*, 1999). In Italy, working vacuum levels normally used are on average still too high, being 42 kPa for ewes and 44 kPa for goats (Pazzona and Murgia, 1998; Billon *et al.*, 1999; Pazzona *et al.*, 2003).

Based on the above mentioned implications, working vacuum level should be as low as possible, on the condition that complete emptying of the mammary gland and no increase in milking duration are achieved. A vacuum of 36-38 kPa is generally recommended for low line systems in good operating condition. In fact, in Saaneen goats the opening of the teat sphincter, which is quite tonic in most animals of that breed, can be achieved only if a vacuum of at least 34.6 kPa is applied (Le Du and Benmederbel, 1984). This value is a lot higher than the physiologically necessary vacuum value of 26 kPa for Sarda ewes (Salaris *et al.*, 2004). For this reason, a milk line prototype for dairy ewes was designed and constructed within the project BEN.O.LAT ("Benessere Ovini da Latte", i.e. Welfare of dairy sheep) financially supported by the Italian Ministry of Agricultural and Forestal Policies (*Ministero delle Politiche Agricole e Forestali*). In 2006, such a milk line operated efficiently using a working vacuum of 28 kPa (Pazzona *et al.*, 2006).

Animal welfare is affected not only by working vacuum level but also by its stability. The mean vacuum drop between the receiver and the milkline during milking should not be higher than 2 kPa (UNI ISO 5707:2001; UNI 11008:2002). Vacuum instability is related to an inadequate milking system from a construction (e.g. insufficient vacuum reserve and wrong milkline dimension) and operational (e.g. anomalous pulsation and wrong milking routine) point of view. Quite often the working vacuum level is increased, in order to counterbalance some of the above listed problems. On the contrary, a stable vacuum is a clear indicator that the milking machine is functioning properly. Therefore, an objective way of evaluating technical and managerial choices of the farmer is to periodically control vacuum fluctuations in the milking unit and/or milkline during mechanical milking.

Pulsation

Pulsation has a fundamental role in animal welfare. Its use in machine milking aims to prevent teat edema and congestion and to reduce the incidence of mammary infections, animal pain and discomfort during milking (Mein *et al.*, 2003). Pulsation has no significant effects on milk yield and quality, but it improves animal welfare because an increase in pulsation rate and/or ratio corresponds to an increase in vacuum under the teat (Murgia and Pazzona, 2001).

The regulation UNI ISO 5707:2001 prescribes that phase "b" (milking) and phase "d" (massage) must last, respectively, at least 15% and 30% of the time required for each pulsation cycle of a dairy cow. The latter value is a threshold under which a considerable increase in teat thickness occurs, thus favouring new udder infections (Hamann and Mein, 1996). Guidelines on the recommended minimum duration of each phase of machine milking of sheep and goats have not been developed yet. However, since the tissues of such species are more sensitive than those of cows, the results obtained with the latter species are very likely to be valid for small ruminants as well (Eitam and Hamann, 1993).

The intermediate phases ("a" and "b") are certainly involved in the liner movements and the degree of teat compression by the liner walls. It is advisable to reduce these phases, to avoid shortening of the active phases of milking and massage. However, if the intermediate phases are too short, sudden vacuum drop inside the liner occurs, creating vacuum instability under the teat, which is one of the main causes of mastitis. To avoid lengthening milking duration and to prevent udder health problems, phase "a" should last between 15 and 20% of the entire pulsation cycle, and phase "c" between 12 and 15% (Gourreau, 1995; Billon and Gaudin, 2001).

Milking unit

Milking unit is the component of the milking system which influences milking efficiency the most, in terms of udder emptying and vacuum stability (Peris *et al.*, 1993; Pazzona and Murgia, 1996). The design of all elements that make part of the milking unit (liners, claw, milk tubes) is aimed at facilitating milk flow from the mammary gland to the milkline, and reducing to a minimum the vacuum fluctuations under the teat. Several studies have demonstrated that vacuum fluctuations are greatly associated with an increase of mastitis infection (Bramley, 1992).

The effect of the short milk tube on the proper functioning of the milking unit is often underestimated. When flow is high, the short milk tube fills with milk, thus impeding air extraction inside the liner. In these conditions, vacuum fluctuations under the teat are very high and, in addition, passive transport/movement of pathogenic microorganisms is favoured, because of milk reflow towards the teat. Current regulation UNI 11008:2002 prescribes that the minimum diameter of the short milk tube must be 8 mm. However, trials conducted on milking units for sheep milking have shown a reduction of 44% in vacuum fluctuations when a 10 mm diameter short milk tube was used instead of an 8 mm diameter one (Murgia and Pazzona, 2001). For goats, it necessary to use a short milk tube with at least 10 mm of diameter, in order to assure a regular milk flow towards the claw. Similarly, an internal diameter of 14 mm for the long milk tube, higher than the 12 mm prescribed by current regulation, are also recommended for sheep.

Most diseases of the mammary gland are caused by the use of improper liners, i.e. insufficient elasticity and inadequate diameter of the mouthpiece lip in relation to teat dimensions. If the diameter of the mouthpiece lip is too low, the base of the teat shows a purple ring due to its irritation. On the contrary, if such diameter is too high, the liner climbs the mammary gland, thus slowing down or stopping the milk flow and exposing a larger surface of the teat to vacuum. As a rule, soft liners are recommended so that their shape can adjust to the teat shape, thus avoiding teat compression. During massage, the teat is submitted to a progressive, gentle and efficient pressure increase, especially at the teat apex, where blood tends to accumulate due to higher exposition to vacuum. By using soft liners in a light milking unit, made of plastic shell and claw, it is possible to use milk vacuum levels as low as 36-38 kPa. Conversely, if liners are not flexible, made of dry rubber, higher vacuum levels should be used (42-44 kPa). If the latter values are not adopted, the stimulatory effect of the liner on the teat is compromised, due to insufficient closure of the hard line. Under this condition, machine milking can be stressful (i.e. painful, to the animal) because not massaging the teat causes blood and lymph stasis at the teat apex. In general, even though the use of a rigid liner increases milk flow, it also causes an incomplete emptying of the mammary gland. In order to avoid the risk of constant vacuum under the teat, the minimum length of the liner barrel should be about 90 mm for sheep and 110 mm for goats.

The adoption of systems for automatic removal of milking units eliminates the risk of exposing animals to overmilking and, thus, reduces mammary gland stress, with consequent reduction of milk SCC. Although this technology has been widely used in dairy cows for years, only recently has it been more widely adopted in sheep. In fact, only 2-3% of the milking systems used in sheep farms have adopted this type of automatism (Pazzona and Murgia, 2004).

Another important accessory of the milking unit is a device for early diagnosis of mastitis. Electrolyte concentration in milk infected by mastitis is altered due to the damage of the secreting cells. This causes a variation in electrical conductivity which is highly correlated with SCC. The installation of conductometry cells in the claw, in a way that the milk of each udder half fills in the cell before mixing with the milk of the other half, makes it possible to monitor udder health status during milking. Some studies have demonstrated that this technology, already successfully adopted in dairy cows (Lansbergen *et al.*, 1994; Nielen *et al.*, 1995; Milner *et al.*, 1997), could be transferred to small ruminants, with the aim of quickly detecting the onset of subclinical infections (Le Du, 1985; Peris *et al.*, 1991; Pazzona and Murgia, 1993; Sanchez *et al.*, 1999).

Impact of breakdown of the maternal/filial bond on lamb and kid welfare

Artificial rearing

Artificial rearing has not had great diffusion in sheep and goat breeding. Apart from technical and management factors, the outcome of artificial rearing of lambs and kids depends largely on the ability of the newborn to readily adapt to the artificial teat (Sevi *et al.,* 1996). During the transition from maternal milk to artificial rearing, emotional and nutritional stresses of young animals have deleterious effects on their growth, health and vitality. Such stresses are caused by the breakdown of the mother/young bond and by inadequate substitution of sheep milk, which is nutritionally much richer than commercial milk replacer. The recent introduction of the so-called acid milk replacers on the market solves a number of technical problems, but tends to sharpen the nutritional stress of the lamb due to their lower fat and protein contents compared to traditional milk replacers.

When the transition to artificial rearing is abrupt, it is necessary to use strategies which help lambs and kids to have a fast and positive approach to the artificial teat. This is important because of at least three reasons: firstly, lack of adaptation to artificial rearing can have deleterious effects on growth and survival of new-born animals; secondly, the presence of long-lasting stress conditions can lead to a reduction of immune function; and thirdly, the more difficult the approach to artificial rearing is, the more compromised is the ability of young animals to face other stressful situations, even transitory ones. Previous studies have highlighted that, even after an early separation of lambs from their mothers, a gradual transition over a 10-day period, from maternal milk to milk replacer can improve the welfare of the artificially reared lamb, even if it does not allow it to reach the same growth rate of the dam suckled lamb (Sevi *et al.*, 1999b, 2001b). On the contrary, keeping the lamb with the mother, thus giving it all maternal stimuli (touch, vocal, smell and sight), but hindering its access to the mother udder, does not improve the well-being of the lamb. Instead, such deprivation from natural suckling frustrates the lamb, probably because of non satisfaction of its social and nutritional expectations (Napolitano *et al.*, 2003). Similarly, a gradual separation of the lamb from the mother, obtained by reducing progressively the time the lamb can spend with the dam during a 10-day period, does not have beneficial effects on the growth and welfare of the lamb, because it does not stimulate the approach to the artificial teat and does not minimize the stress related to the breakdown of the already consolidated maternal/filial bond (Sevi *et al.*, 2003b). A useful tool to minimize the stress related to artificial rearing is gentling (i.e. a friendly and lovely approach of the stockman towards the new-born animal). In fact, several studies (Boivin and Braastad, 1996; Boivin *et al.*, 2001; Caroprese *et al.*, 2006b) have highlighted that gentling strongly encourages the lamb and the kid reared without their mothers to positively interact with the stockman, whereas gentling has no beneficial effects on dam-reared animals. In artificially reared lambs, gentling improves their immune reactivity, making it comparable to that of dam-suckled lambs, and reduces their plasma cortisol responses to handling. The latter event seems to have positive effects on slaughter stress as well and, consequently, on some lamb meat characteristics (Napolitano *et al.*, 2006). Peer rearing, mainly in the presence of older and more expert lambs, can also be greatly beneficial, by minimizing the stress related to lamb separation from the mother and by stimulating an adequate behaviour of the artificially reared lamb (Casamassima and Sevi, 1993).

Given that one of the main objectives of artificial rearing is to increase milk availability for dairy products (i.e. artificial rearing is rarely adopted to reduce the lambing and kidding interval), some authors (Papachristoforou, 1990; Gargouri *et al.*, 1993; Eik *et al.*, 1999; McKusick *et al.*, 2001) have achieved satisfying results by the adoption of a mixed regime in which lamb and kid suckling is alternated with milking during the first month *post-partum*. Such mixed system takes advantage of the facts that the first month following delivery is the most productive (i.e. higher milk volume), and that sheep and goats, due to genetic merit and to good flock management, produce more milk than needed for the normal growth of a lamb or a kid (Boucquier *et al.*, 1999). When the mixed system is adopted, it is important to consider delaying the separation of the young animal from its mother, with the advantage of better lamb welfare (Napolitano *et al.*, 1995), and using the fastest way of adapting the young animal to solid food, thus counterbalancing lower milk availability with higher hay and concentrate intake (Palazzo *et al.*, 2005).

Weaning

Weaning imposes the transition from maternal milk to solid food and the breakdown of the maternal/filial bond at an older age than that of artificially reared animals. In sheep and goats, the rupture of the strong mother/young bond occurs naturally at different ages, depending on the gradual changes of the nutritional needs of lambs or kids (Pryce, 1992) and on the progressive reluctance of the dam to be suckled by them (Gordon and Siegmann, 1991; Bungo *et al.*, 1998). In goats, such changes occur around the seventh week after kid birth; therefore, weaning should not begin before that period to avoid stress to kids (Bungo *et al.*, 1998).

The farmer may prefer to anticipate the separation between mother and offspring at weaning, similarly to what may happen at artificial rearing. This can cause stress to the lamb, even if at a lower level than that caused by the transition to artificial rearing (Orgeur *et al.*, 1998). Field trials have shown that the impact of sudden weaning is less intense than that of gradual weaning, with repeated and progressively longer separations of the lambs from their mothers (Orgeur *et al.*, 1998). Sudden weaning, at three months of age, seems to be less stressful to lambs than partial separation from the mothers; the latter consisting of separating the lambs from the mothers but allowing them to receive visual and auditory stimuli from them (Orgeur *et al.,* 1999). The introduction of just weaned lambs in groups of sheep, even if non-familiar to them, seems to induce a faster adaptation of the lamb to the new feeding regime. This confirms the importance of the presence of older and more expert animals to help just-weaned lambs to overcome the impact of mother separation (Youssef *et al.*, 1995).

Conclusions

Field trials have clearly demonstrated that even if sheep and goats are considered to be very rustic, they can greatly benefit from careful flock management, which can markedly improve their well-being and biological efficiency. Extensive farming has proved to be beneficial to the welfare needs of lactating ewes, but exposure to climatic extremes, seasonal fluctuations of herbage quality and quantity, and parasitism can threaten the welfare of extensively reared flocks. Under semi-intensive farming conditions, instead, sheep and goats are generally preserved from hunger and thirst, and are sheltered from climatic extremes, but they live in a very predictable and less motivating environment. In semi-intensive rearing much attention must be given to micro-environment control, and to choice of proper house structures, material and design, in order to avoid crowding, aggressive behaviour, increased ambient pollution, and poor udder health. Irrespective of rearing system, proper timing, careful control of sanitation of milking operations and adoption of correct technical parameters of milking machines are also important for sheep and goat welfare. For all these reasons the farmer and the stockmen play a major role in semi-intensive and extensive rearing. More recent studies have focused on the human-animal relationship, which has been often overlooked in common rearing practices but can have a relevant impact on sheep and goat welfare and production performance.

Part of this paper was previously published in Il benessere degli animali da reddito, quale e come valutarlo *(G. Bertoni ed.), Fondaz. Iniziative Zooprof. Zoot. Publ., Brescia, Italy, vol. 67, 2007.*

The authors are grateful to Dr. Ana Helena Dias Francesconi from the University of Sassari for her assistance.

REFERENCES

Aganga, A.A., 2001. Water utilization by sheep and goats in Northern Nigeria. World Animal Review (FAO) 73:9-14.

Albenzio, M., Marino, R., Caroprese, M., Santillo, A., Annicchiarico, G., Sevi, A., 2004. Quality of milk and of Canestrato pugliese cheese from ewes exposed to different ventilation regimens. J. Dairy Res. 71:434-443.

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

Albenzio, M., Taibi, L., Caroprese, M., De Rosa, G., Muscio, A., Sevi, A., 2003. Immune response, udder health and productive traits of machine milked and suckling ewes. Small Ruminant Res. 48:189-200.

Albenzio, M., Taibi, L., Muscio, A., Sevi, A., 2002. Prevalence and etiology of subclinical mastitis in intensively managed flocks and related changes in the yield and quality of ewe milk. Small Ruminant Res. 43:219-226.

Ayoub, M.A., Saleh, A.A., 1998. A comparative physiological study between camels and goats during water deprivation. Emirates J. Agric. Sci. 10 (2): 44-60.

Bettini, T.M., 1985. Elementi di scienze delle produzioni animali. Edagricole, Bologna, Italy.

Billon, P., Gaudin, V., 2001. Influence of the duration of a and c phase of pulsation on the milking characteristics and on udder health of dairy cows. ICAR Technical Series 7:105-111.

Billon, P., Ronningen, O., Sangiorgi, E., Schuiling, E., 1999. Quantitative requirements of milking installations for small ruminants. A survey in different countries. Milking and milk production of dairy sheep and goats. Proc. 6th Int. Symp. on Milking of Small Ruminants, Athens, Greece, 95:209-215.

Bishonga, C., Robinson, J.J., McEvoy, T.G., Aitken, R.P., Findlay, P.A., Robertson, I., 1994. The effects of excess rumen degradable protein in ewes on ovulation rate, fertilization and embryo survival in vivo and during in vitro culture. Anim. Prod. 58:447(abstr.)

Boivin, X., Braastad, B.O., 1996. Effects of handling during temporary isolation after early weaning on goat kids' later response to humans. Appl. Anim. Behav. Sci. 48:61-71.

Boivin, X., Nowak, R., Terrazas Garcia, A., 2001. The presence of the dam affects the efficiency of gentling and feeding on the early establishment of the stockperson-lamb relationship. Appl. Anim. Behav. Sci. 72:89-103.

Boucquier, F.M., Aurel, M.R., Barillet, F., Jacquin, M., Lagriffoul, G., Marie, C., 1999. Effect of partial-milking during the suckling period on milk production of Lacaune dairy ewes. In: Milking and Milk Production of Dairy Sheep and Goats. EAAP Publ. No. 95, Wageningen, The Netherlands, pp 257-262.

Bramley, A.J., 1992. Mastitis and machine milking. In: A.J. Bramley, F.H. Dodd, G.A. Mein and J.A. Bramley (eds.) Machine milking and lactation. Insight Books, Berkshire, UK, pp 343-372.

Bruckmaier, R.M., Blum, J.W., 1998. Oxytocin release and milk removal in ruminants. J. Dairy

Sci. 81:939-949.

Bungo, T., Shimojo, M., Nakano, Y., Okano, K., Masuda, Y., Goto, I., 1998. Relationship between nursing and suckling behaviour in Tokara native goats. Appl. Anim. Behav. Sci. 59:357-362.

Cannas, A., 2002. Feeding of lactating ewes. In: G. Pulina (ed.) Dairy Sheep Feeding and Nutrition. Avenue Media, Bologna, Italy, pp. 123-166.

Caroprese, M., Albenzio, M., Annicchiarico, G., Sevi, A., 2006a. Changes occurring in immune responsiveness of single and twin bearing Comisana ewes during the transition period. J. Dairy Sci. 89:562-568.

Caroprese, M., Napolitano, F., Albenzio, M., Annicchiarico, G., Musto, M., Sevi, A., 2006b. Influence of gentling on lamb immune response and human-lamb interactions. Appl. Anim. Behav. Sci. 99:118-131.

Casamassima, D., Palazzo, M., Pizzo, R., D'Alessandro, A.G., Martemucci, G., 2006a. Risposta fisiologica e produttiva in pecore sottoposte a mungitura manuale e meccanica. Proc. 60th Nat. Congr. SISVet, Terrasini (PA), Italy, 60:477-478.

Casamassima, D., Pizzo, R., Palazzo, M., Quaranta, A., D'Alessandro, A.G., Martemucci, G., 2006b. Effetto della restrizione idrica sulle prestazioni produttive e su alcuni parametri ematici in ovini di razza Comisana allevati intensivamente. pp 477-478 in Proc. 14th Int. Congr. FeMeSPRum, Santiago de Compostela, Spain.

Casamassima, D., Sevi, A., 1993. Comportamento post-natale e capacità di adattamento alla tettarella artificiale di agnelli sottoposti a stimoli diversi. Nota II. Osservazioni sulle razze Leccese e Comisana. Agricoltura Ricerca 15:67-72.

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 Ruminant Res. 41:151-161.

Casu, S., Boyazoglou, J.G., Ruda, G., 1978. Essais sur la traite mechanique semplifiee des brebis Frisonne x Sarde. pp 235-243 in Proc. 4th Int. Symp. sur la traite mechanique des petites ruminants, Alghero, Italy.

Chiumenti, R., 1987. Costruzioni rurali. Edagricole, Bologna, Italy.

Davis, S.R., Collier, R.J., 1985. Mammary blood flow and regulation of substrate supply or milk synthesis. J. Dairy Sci. 68:1041-1058.

Dickson, I.A., Stephenson, D.E., 1979. The housing of ewes. West of Scotland Agricultural College, Auchincruive, Scotland, Technical Note no. 63.

Dimitrov-Ivanov, I., Djorbineva, M., 2002. Assessment of welfare, functional parameters of the udder, milk productive and reproductive traits in dairy ewes of different temperament. Page192 (abstr.) in Proc. 53rd Ann.Meet. AAP, Cairo, Egypt.

Dwyer, C.M., Bornett, H.L., 2004. Chronic stress in sheep: assessment tools and their use in different management conditions. Anim.Welfare 13:293-304.

Eik, L.O., Eknœs, M., Havrevoll, Ø., Garmot, T., Raats, J., Adnoy, T., 1999. Partial suckling during the grazing period as a management tool for improving the annual production patterns of goat milk in Norway. In: Milking and Milk Production of Dairy Sheep and Goats. EAAP Publ. no. 95, Wageningen, The Netherlands, pp 263-266.

Eitam, M., Hamann, J., 1993. Relevance of machine-induced teat tissue reactions in cows for improvement of machine milking in small ruminants. pp 401-408 in Proc. 5th Int. Symp. on Machine Milking of Small Ruminants, Budapest, Hungary.

Fedele, D., Pizzillo, M., Claps, S., Morand-Fehr, P., Rubino, R., 1993. Grazing behaviour and diet selection of goats on native pasture in Southern Italy. Small Ruminant Res. 11:305-322.

Fernandez, N., Diaz, J.R., Peris, C., Rodriguez, M., Molina, M.P., Torres, A., 1999. Machine milking parameters for the Manchega sheep breed. Proc. 6th Int. Symp. EAAP on Milking of Small Ruminants, Athens, Greece, 95:233-238.

Gargouri, A., Caja, G., Such, X., Ferret, A., Casals, R., Peris, S., 1993. Evaluation of a mixed system of milking and suckling in Manchega dairy ewes. Proc. 5th Int. Symp. on Machine Milking of Small Ruminants. Hung. J. Anim. Prod. (Suppl. 1): 484-499.

Goddard, P., Waterhouse T., Dwyer, C., Stott, A., 2006. The perception of the welfare of sheep in extensive systems. Small Ruminant Res. 62:215-225.

Gordon, K., Siegmann, M., 1991. Suckling behavior of ewes in early lactation. Phisiol. Behav. 50:1079-1081.

Gourreau, J.M., 1995. Accidents et maladies du trayon. Ed. France Agricole, Paris, France.

Hamadeh, S.K., Rawda, N., Jaber, L.S., Habre, A., Abi Said, M., Barbour, E.K., 2006. Physiological response to water restriction in dry and lactating Awassi ewes. Livest. Prod. Sci. 101:101-109.

Hamann, J., Mein, G.A., 1996. Teat thickness changes may provide biological test for effective pulsation. J. Dairy Res. 63:179-189.

Hamann, J., Mein, G.A., Wetzel, S., 1993. Teat tissue reactions to milking: effects of vacuum level. J. Dairy Sci. 76:1040-1046.

Hartung, J., 1989. Practical aspects of aerosol sampling in animal houses. In: C.M. Wathes and R.M. Randall (eds.) Aerosol Sampling in Animal Houses. European Community Commission Publications, Luxembourg, pp 14-23.

Hodgson, J., 1985. The control of herbage intake in grazing ruminant. P. Nutr. Soc. 44:339-346.

Hutchings, M.R., Gordon, I.J., Robertson, E., Kyriazakis, I., Jackson, F., 2000. Effects of parasitic status and level of feeding motivation on the diet selected by sheep grazing grass/clover swards. J. Agr.Sci. 135:65-75.

Lanen, S., Nehmadi, L., Yagil, R., 1987. Dehydration tolerance in Awassi fat-tailed sheep. Can. J. Zool. 65:363-367.

Lansbergen, L.M.T.E., Nielen, M., Lam, T.J.G.M., Pengov, A., Schukken, Y.H., Maatje, K., 1994. Evaluation of a prototype on-line electrical conductivity system for detection of subclinical mastitis. J. Dairy Sci. 77:1132-1140.

Le Du, J., 1985. Paramètres de fonctionnement affectant l'efficacité des machines a traire pour brebis et chèvres. pp 11-12 in Proc. 36th Ann.Meet. EAAP, Kallithea, Greece.

Le Du, J., 1989. La traite mècanique des chèvres. Prod. Anim. 2:31-38.

Le Du, J., Benmederbel, B., 1984. Aptitude des chèvres de race Saanen à la traite mécanique. Relations avec les caractéristiques physiques du trayon. Ann. Zootech.. 33:375-384.

Ley, S.J., Livingston, A., Waterhouse, A.E., 1992. Effects of clinically occurring chronic lameness in sheep on the concentrations of plasma noradrenaline and adrenaline. Res. Vet. Sci. 53:122-125.

Ley, S.J., Waterhouse, A.E., Livingston, A., 1995. A field study on the effect of lameness on mechanical nociceptive thresholds in sheep. Vet. Rec. 137: 85-87.

Lia, R., Pantone, N., 2001. Influenza delle infestazioni da strongilidi-gastrointestinali sulla produzione quanti qualitativa del latte negli allevamenti degli ovini condotti con sistemi tradizionali. pp 81-91 in Proc. Standing Seminar on Sheep milk quality, Foggia, Italy.

Loretz, C., Wechsler, B., Hauser, R., Rusch, P., 2004. A comparison of space requirements of horned and hornless goats at the feed barrier and in the lying area. Appl. Anim. Behav. Sci. 87:275-283.

Loynes, I.J., 1983. Sheep house design. Housing Sheep. Farm Buildings Information Centre. Kenilworth, Stoneleigh, UK.

Lu, C.D., Potchoiba, M.J., Loetz, E.R., 1991. Influence of vacuum level, pulsation ratio and rate on milking performance and udder health in dairy goats. Small Ruminant Res. 5:1-8.

Lynch, J.J., Brown, G.D., May, P.F., Donnelly, J.B., 1972. The effect of withholding drinking water on wool growth and lamb production in Merino sheep in a temperate climate. Aust. J. Agr. Res. 23:659-668.

Matteri, R.L., Carroll, J.A., Dyer, C.J., 2000. Neuroendocrine responses to stress. In: G.P. Moberg and J.A. Mench (eds.) The biology of stress: Basic principles and implications for animal welfare. CAB International, Wallingford, Oxon, UK, pp 43-76.

McKusick, B.C., Thomas, D.L., Berger, Y.M., 2001. Effect of weaning system on commercial milk production and lamb growth of East Friesian dairy sheep. J. Dairy Sci. 84:1660-1668.

Mein, G.A., Williams, D.M.D., Reinemann, D.J., 2003. Effects of milking on teat-end hyperkeratosis:1, Mechanical forces applied by the teatcup liner and responses of the teat. pp 114-123 in Proc. 42nd Ann. Meet. Nat. Mastitis Council, Fort Texas, USA.

Milner, P., Page, K.L., Hillerton, J.E., 1997. The effects of early antibiotic treatment following diagnosis of mastitis detected by a change in the electrical conductivity of milk. J. Dairy Sci. 80:859-863.

Murgia, L., Pazzona, A., 2001. Valutazione delle prestazioni dei gruppi di mungitura per gli ovini, pp 1-12 in 7th Nat. Congr. AIIA (Italian Society of Agricultural Engineers) on Agricultural engineering for developing the Mediterranean Countries, Vieste (FG), Italy.

Napolitano, F., Annicchiarico, G., Caroprese, M., De Rosa, G., Taibi, L., Sevi, A., 2003. Lambs prevented from suckling their mothers display behavioral, immune and endocrine disturbances. Physiol. Behav. 78:81-89.

Napolitano, F., Caroprese, M., Girolami, A., Marino, R., Muscio, A., Sevi, A., 2006. Effects of early maternal separation of lambs and rearing with minimal and maximal human contact on meat quality. Meat Sci. 72:635-640.

Napolitano, F., Marino, V., De Rosa, G., Capparelli, R., Bordi, A., 1995. Influence of artificial rearing on behavioural and immune response of lambs. Appl. Anim. Behav. Sci. 45:245-253.

Negrão, J.A., Marnet, P.G., 2003. Cortisol, adrenalin, noradrenalin and oxytocin release and milk yield during first milkings in primiparous ewes. Small Ruminant Res. 47:69-75.

Negrave, R., 1996. Sheep grazing controls Calamagrostis Canadensis-dominated vegetation in the Boreal Forest Integrated Forest Vegetation Management. Page 2 in Options and Application, FRDA Report 251.

Nielen, M., Schukken, Y.H., Brand, A., Haring, S., Ferwerda-van Zonneveld, R.T., 1995. Comparison of some analysis techniques for on-line clinical mastitis detection. J. Dairy Sci. 78:1050-1061.

Orgeur, P., Bernard, S., Naciri, M., Nowak, R., Schaal, B., Lévy, F., 1999. Psychobiological consequences of two different weaning methods in sheep. Reprod. Nutr. Dev. 39:231-244.

Orgeur, P., Mavric, N., Yvore, P., Bernard, S., Nowak, R., Schaal, B., Levy F., 1998. Artificial weaning in sheep: consequences on behavioural, hormonal and immuno-pathological indicators of welfare. Appl. Anim. Behav. Sci. 58:87-103.

Orr, R.J., Parsons, A.J., Penning, P.D., Treacher, T.T., 1990. Sward composition, animal performance and the potential production of grass/white clover swards continuously stocked with sheep. Grass Forage Sci. 45:325-336.

Palazzo, M., Pizzo, R., D'Alessandro, A.G., Casamassima, D., 2005. Effetto della durata di permanenza degli agnelli con le madri e della mungitura sulle performance produttive dell'agnello da latte. Proc. 13th Nat. Congr. Femesprum, Bari, Italy, http://www2.vet.unibo.it/staff/Gentile/Femesprum/Pdf%20Congressi/XIII%20congresso%20Bari/Palazzo.pdf

Papachristoforou, C., 1990. The effects of milking method and post-milking suckling on ewe milk production and lamb growth. Ann. Zootech. 39:1-8.

Pazzona, A., Caria, M., Murgia, L., 2006. Sistemi di mungitura e benessere animale nell'allevamento caprino. pp 29-36 in Proc.17th Nat. Meet. SIPAOC, Lamezia Terme, Italy.

Pazzona, A., Murgia, L., 1993. Effetto del vuoto di mungitura e delle frequenze di pulsazione sulla carica leucocitaria del latte di pecora. Inform. Agr. 42:43-46.

Pazzona, A., Murgia, L., 1996. Mungitrici per ovini: la conduttura del latte. Inform. Agr. 19:45-46.

Pazzona, A., Murgia, L., 1998. Caractéristiques constructives et du fonctionnement des installations de traite des ovins installies en Sardaigne. pp 170-175 in Proc. 6th Int. Symp. EAAP on Milking of Small Ruminants, Athens, Greece.

Pazzona, A., Murgia, L., 2004. Qualità del latte e benessere animale nella mungitura degli ovini e dei caprini. pp 37-65 in *Quaderni I Georgofili* on Innovative technologies for the production of high quality milk in small ruminants, Firenze, Italy.

Pazzona, A., Murgia, L., Caria, M., 2003. Una mungitura ad hoc anche per la capra. Inform. Zootec.18:196-202.

Penning, P.D., Parsons, A.J., Orr, R.J., Hooper, G.E., 1994. Intake and behavior response by sheep to changes in sward characteristics under rotational grazing. Grass Forage Sci. 49:476-486.

Penning, P.D., Parsons, A.J., Orr, R.J., Treacher, T.T., 1991. Intake and behavior response by sheep to changes in sward characteristics under continuous stocking. Grass Forage Sci. 46:15-28.

Peris, C., Diaz, J.R., Torres, A., Fernandez, N., Rodriguez, M., 1993. Effect of variable traction on the teat-cup during machine milking of ewes. pp 385-400 in Proc. 5th Int. Symp. on Machine Milking of Small Ruminants, Budapest, Hungary.

Peris, C., Molina, P., Fernandez, N., Rodriguez, M., Torres, A., 1991. Variation in somatic cell count, California mastitis test and electrical conductivity among various fractions of ewe's milk. J. Dairy Sci. 74:1553-1560.

Perrin, G.G., Baudry, C., 1993. Numèration cellulares du lait de chèvre. Lait 73:489-497.

Pryce, C.R., 1992. A comparative systems model of the regulation of maternal motivation in mammals. Anim. Behav. 43:417-441.

Pulina, G., Mazzette, A., Battacone, G., Nudda, A., 2006. Feed restriction alters milk production traits in Sarda dairy ewes. J. Dairy Sci. 89(Suppl. 1):59 (abstr.).

Pulina, G., Nudda, A., Fancellu S., Barbato, A.M., Rubattu, R., 2005. Infusion of casein hydrolizates into the mammary gland simulates the omission of one daily milking in goats. Ital. J. Anim. Sci. 4:389-391.

Rasmussen, M.D., Frimer, E.S., Decker, E.L., 1994. Reverse pressure gradients across the teat canal related to the machine milking. J. Dairy. Sci. 77:984-993.

Rassu, S.P.G., Cannas, E.A., Nicolussi, P., Bonelli, P., Pulina, G., 2006. The impact of machine milking on milk production traits and cortisol in primiparous dairy ewes. J. Dairy. Sci. 89(Suppl. 1):303 (abstr.).

Rassu, S.P.G., Enne, G., Ligios, S., Molle, G., 2004. Nutrition and Reproduction In: G. Pulina (ed.) Dairy Sheep Nutrition. CABI Publishing, Wallingford, UK, pp. 109-128.

Reinemann, D.J., Davis, M.A., Costa, D., Rodriguez, A.C., 2001. Effects of milking vacuum on milking performance and teat condition. Home page address: http://www.uwex.edu

Rushen, J., De Passille, A.M., Munksgaard, L., 1999. Fear of people by cows and effects on milk yield, behavior, and heart rate at milking. J. Dairy Sci. 82:720-727.

Rutter, S.M., 2002. Behaviour of sheep and goats. In: P. Jensen (ed.) The ethology of domestic animals. An Introductory Text. CABI Publishing, Wallingford, UK, pp. 145-158.

Salaris, S., Goddi, G., Piras, M., 2004. Effetto di differenti fattori sull'efficienza della mungitura meccanica e lo stato sanitario della mammella. In: G. Goddi, M. Sanna, S. Casu, M. Piras and S. Salaris (eds.) Approfondimenti sulla mungitura meccanica degli ovini da latte. La Celere Editrice, Alghero (SS), Italy, pp 37-54.

Sanchez, A., Contreras, A., Corrales, J.C., 1999. Parity as risk factor for caprine subclinical intramammary infection. Small Ruminant Res. 31:197-201.

Sevi, A., 2005. Influence of sunlight, temperature and environment on the fatty acid composition and coagulatine properties of sheep milk. In: D. Gabina, J.C. Le Jaouen, A. Pirisi, A. Ayerbe and Y. Soustre (eds.) The Future of the Sheep and Goat Dairy Sectors. Special Issue No. 200501/2005, International Dairy Federation, pp. 305-311.

Sevi, A., Albenzio, M., Annicchiarico, G., Caroprese, M., Marino, R., Santillo, A., 2006. Effects of dietary protein level on ewe milk yield and nitrogen utilization, and on air quality under different ventilation rates. J. Dairy Res. 73:197-206.

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., Albenzio, M., Marino, R., Santillo, A., Muscio, A., 2004. Effects of lambing season and stage of lactation on ewe milk quality. Small Ruminant Res. 51:251-259.

Sevi, A., Albenzio, M., Muscio, A., Casamassima, D., Centoducati, P., 2003a. Effects of litter management on airborne particulate in sheep houses and on the yield and quality of ewe milk. Livest. Prod. Sci. 81:1-9.

Sevi, A., Annicchiarico, G., Albenzio, M., Taibi, L., Muscio, A., Dell'Aquila, S., 2001a. 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., Caroprese, M., Annicchiarico, G., Albenzio, M., Taibi, L., Muscio, A., 2003b. The effect of a gradual separation from the mother on later behavioral, immune and endocrine alterations in artificially reared lambs. Appl. Anim. Behav. Sci. 83:41-53.

Sevi, A., Massa, S., Annicchiarico, G., Dell'Aquila, S., Muscio, A., 1999a. Effect of stocking density on ewes milk yield and incidence of subclinical mastitis. J. Dairy Res. 66: 489-499.

Sevi, A., Muscio, A., Casamassima, D., 1996. Recenti acquisizioni sull'allattamento artificiale dell'agnello. Agricoltura Ricerca 15:31-40.

Sevi, A., Napolitano, F., Casamassima, D., Annicchiarico, G., Quarantelli, T., De Paola, R., 1999b. Effect of a gradual transition from maternal to reconstituted milk on behavioural, immune and endocrine responses of lambs. Appl. Anim. Behav. Sci. 64:249-259.

Sevi, A., Napolitano, F., Casamassima, D., Dell'Aquila, S., 2001b. Effect of milk source on welfare and weight gain of lambs. Anim. Welfare 10:163-172.

Sevi, A., Rotunno, T., Di Caterina, R., Muscio, A., 2002b. The fatty acid composition of ewe milk, as affected by solar radiation under high ambient temperature. J. Dairy Res. 69:181-194.

Sevi, A., Taibi, L., Albenzio, M., Annicchiarico, G., Marino, R., Caroprese, M., 2003c. Influence of ventilation regimen on micro-environment and on ewe welfare and milk yield in summer. Ital. J. Anim. Sci. 3:197-212.

Sevi, A., Taibi, L., Albenzio, M., Annicchiarico, G., Muscio, A., 2001c. Airspace effects on the yield and quality of ewe milk. J. Dairy Sci. 84:2632-2640.

Sevi, A., Taibi, L., Albenzio, M., Caroprese, M., Marino, R., Muscio, A., 2003d. Ventilation effects on air quality and on the yield and quality of ewe milk in winter. J. Dairy Sci. 86:3881-3890.

Sevi, A., Taibi, L., Albenzio, M., Muscio, A., Dell'Aquila, S., 2000. Effect of parity on milk yield, composition, somatic cell count, renneting parameters and bacteria counts of Comisana ewes. Small Ruminant Res. 37:99-107.

Sevi, A., Taibi, L., Albenzio, M., Muscio, A., Dell'Aquila, S., Napolitano, F., 2001d. Behavioral, adrenal, immune, and productive responses of lactating ewes to regrouping and relocation. J. Anim. Sci. 79:1457-1465.

Sevi, A., Taibi, L., Muscio, A., Albenzio, M., Dantone, D., Dell'Aquila, S., 2001e. Quality of ewe milk as affected by stocking density and litter treatment with bentonite. Ital. J. Food Sci. 13:77-86.

Sevi, A., Taibi, L., Muscio, A., Dell'Aquila, S., Casamassima, D., 1998. Quality of ewe milk as affected by number of lambs and length of suckling. Ital. J. Food Sci. 10:229-242.

Silanikove, N., Shamay A., Shinder D., Moran A., 2000. Stress down regulates milk yield in cows by plasmin induced β-casein product that blocks K^+ channels on the apical membranes. Life Sci. 67:2201-2212.

Silva, L.P.T., VanderHarr, M.S., Weber Nielsen, M.S., Etchebarne, B.E., 2002. Leptin reduces proliferation of a bovine mammary epithelial cell line. J. Dairy Sci. 85(Suppl. 1): 3277-3286.

Sinapis, E., Vlachos, I., Barillet, F., Zervas, N.P., 1999. Influence of the vacuum level of the milking machine and zootechnical factors on the somatic cell counts of local Greek goats. Milking and Milk Production of Dairy Sheep and Goats. Proc. 6th Int. Symp. EAAP on Milking of Small Ruminants, Athens, Greece, 95:513-518.

Standard UNI ISO 5707, 2001. Milking machine installations – Construction and performance.

Standard UNI 11008, 2002. Impianti per la mungitura meccanica della specie ovina e caprina – Terminologia, requisiti costruttivi e prestazionali.

Turner, S.P., Dwyer, C.M., 2007. Welfare assessment in extensive animal production systems: challenges and opportunities. Anim. Welfare 16:189-192.

Wathes, C.M., Jones, C.D.R., Webster, A.J.F., 1983. Ventilation, air hygiene and animal health. Vet. Rec. 113:554-559.

Youssef, M.Y.I., Philips, C.J.C., Metwally, M., 1995. The effect of pre-weaning grazing experience and presence of adult ewes on grazing behaviour of weaned lambs. Appl. Anim. Behav. Sci. 44:257-281.