Milk yield and composition in Swedish landrace goats *(Capra hircus)* kept together with their kids in two different systems

Mjölkmängd och sammansättning hos svenska lantrasgetter (*Capra hircus*) som hålls tillsammans med sina killingar i två olika system

Madeleine Högberg

Department of Anatomy, Physiology and Biochemistry

Master Thesis
30 HEC

Swedish University of Agricultural Sciences

Uppsala 2011

Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
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Madeleine Högberg

Supervisor:
Kristina Dahlborn Dept. of Anatomy, Physiology and Biochemistry

Examiner:
Eva Sandberg, Dept. of Anatomy,Physiology and Biochemistry

Credits: 30 HEC
Level: Advanced, A2E
Course title: Degree project in Animal Science
Course code: EX0562
Programme: Animal Science MSc Programme/Agriculture Programme Open Entrance

Place of publication: Uppsala
Year of publication: 2011
On-line publication: http://epsilon.slu.se

Keywords: Goats, milk yield, milk composition, casein, rearing system, kids

Table of contents

Abstract

Swedish goats are mainly held for cheese production and therefore, both milk quality and composition are of great importance for dairymen. Today, only few data exists on milk composition from Swedish dairy goats and the casein content is still unknown. One way to reduce the work load for goat farmers and increase animal welfare can be to keep goats and kids together for longer periods. The aims of this study were to investigate how milk yield and composition were affected when kids suckled their dams during 8 weeks, and to measure the casein content on farm level by a mid-infrared spectroscopy method, previously calibrated for goat milk. Lactating goats were kept in two different MIX- systems where the dams are both suckled and milked. All goats were machine milked twice daily. Group 1 (n=5) was kept together with one kid for 16 hours a day (T-16h), kids and dams were separated daytime between 7:30 and 15:00, kids were allowed to suckle before each milking. In group 2 (n=6) the dam and kid were kept together for 24 hours but the kid was only allowed to suckle one teat as the other teat was covered with a bra. The daily milk yield was higher in T-16h goats ($P<0.05$) compared with T-24h goats; 2.5 ± 0.8 and 2.1 ± 0.6 kg, respectively. The fat content was higher in T-16h 4.9 ± 0.9% than in T-24h goats; 4.4 ± 0.7% ($P< 0.001$). The protein and lactose content were 3.2 ± 0.4% and 4.8 ± 0.4% in T-16h goats and 3.1 ± 0.3 and 4.7 ± 0.3% in T-24 goats. The daily casein number (% of total protein) was 72 ± 5% in both groups. The results indicate that it is possible to maintain milk yield with one kid present. Suckling also increases the fat content if the kid is allowed to suckle before each milking. This study shows that the milk composition is positively affected by keeping goats and kids together, and that it is possible to measure the casein content in goat milk by a mid-infrared spectroscopy method on-farm.

Keywords: Goats; Milk yield; Milk composition; Casein; Rearing system; Kids

Sammanfattning

Svenska mjölkgetter hålls vanligen för ostproduktion och därför är mjölkens kvalité och sammansättning extra viktig. För svenska lantrasgetter är information om mjölkens sammansättning bristfällig och mjölkens kaseinhalt är fortfarande okänd. Syftet med denna studie var att undersöka hur mjölkmängd och sammansättning påverkas när geten dias av sin ena killing under 8 veckor, och för att mäta kaseinhalten i mjölken med hjälp en infraröd spektrometrisk metod, nyligen kalibrerad för getmjölk. Lakterande getter hölls i två olika MIX-system (de både diades och mjölkades). Grupp 1 (n=5) diades fritt av en killing i 16 timmar per dygn (T-16h) och separerades från killingen dagtid under 8 timmar mellan klockan 7:00-15:00. Grupp 2 (n=6) var tillsammans med killingen hela dygnet (T-24h) och killingen diade en spene fritt medan den andra spenen endast maskinmjölkades. Den maskinmjölkade spenen var täckt med en BH för att förhindra killingen att dia. Båda grupperna maskinmjölkades två gånger per dag. Den dagliga mjölkmängden var högre ($P<0.05$) hos T-16h getterna (2.5 ± 0.8 L) jämfört med T-24h gruppen (2.1 ± 0.6L), även fetthalten var högre hos T-16h (4.9 ± 0.9%) än hos T-24h getterna (4.4 ± 0.7%). Protein och laktos halterna var 3.2 ± 0.4 och 4.8 ± 0.4% för T-16h och 3.1 ± 0.3% och 4.7 ± 0.3% för T-24h gruppen. Kaseintalet (% av totalt protein) var 72 ± 5% för båda grupperna. Resultaten visar att det är möjligt att bibehålla mjölkmängden även om geten hålls tillsammans med en killing. Digivning ökar också mjölkens fetthalt om killingen får dia innan varje mjölkning. Studien visar att mjölkens sammansättning påverkas positivt när get och killing går tillsammans, och att det är möjligt att mäta kaseinhalt i mjölk på individnivå i besättningen med hjälp av en infraröd spektrometrisk metod.

Nyckelord: Getter, mjölkmängd, mjölksammansättning, kasein, uppfödnings system, killingar

Introduction

Goat milk production is a dynamic and growing industry that is fundamental for both wellbeing and economical incomes for hundreds of millions of people worldwide (Silanikove *et al*., 2010). In developing countries, goat milk is a primary product for human consumption while in the industrial world large scale dairy farms produce high quality cheeses (Haenlein, 2007).

The main role of dairy goat farming is to produce marketable milk; therefore early weaning of kids believes to be the most profitable way of saving milk for human consumption (Delgado-Pertínez *et al*., 2009). Dairy goats in the industrial world are usually separated from their kids hours or days after parturition since all milk is needed for the dairy. In contrast, farmers in developing countries often keep the kids with the dams for weeks or months (Ahuya *et al.*, 2009), and this is also often the case for dairy ewes in Europe (Napolitano *et al*., 2008). Since goat and kid holding systems differ between countries, farmers and breeds, there are contradicting opinions regarding the best practice on how dairy goats should be kept. The debate is focused on whether early separation or slaughter of the offspring would enhance or reduce milk availability for human consumption (Balasse, 2003).

During cheese production both milk yield and composition are of great importance, since casein (protein) and fat content affects both quality and yield of the curd (Soryal *et al.,* 2005; Diaz *et al*., 1999: Clark and Sherbon, 2000). How milk composition is affected by natural rearing systems (MIX-systems = both suckling and milking) compared to artificial rearing systems (AR-systems = kids are fed on replacer and goats are machine milked only) is not fully understood since the results are contradictory (Marnet and Komara, 2008). Dairy farmers, especially cheese producers, have often a heavy workload and one way to reduce the working hours is to keep the goats in naturally reared systems (both suckling and milking). If kids are allowed to suckle instead of being fed with bottles, the workload can be reduced by 27% (Marnet and Komara, 2007).

In Sweden, the market for goat cheese has increased and there are about 1436 registered goat holdings (SJV, 2010), and the number of dairies are today about 100 (Cornell *et al.*, 2010). The management systems of how long kids are kept with their dams differ greatly between farmers (1 day up to 5 months). According to a survey performed by Brandt (2009) kids are usually separated 2 weeks or 2 months after birth and the average daily milk yield in Swedish dairy goats are approximately 2.8L per day and goat. Information about the milk composition in Swedish dairy goats is partly lacking since regularly milk analyses on milk composition today are missing. Due to Norman, (personal communication, 2010) have the Swedish goats a fat content on 2.6-3.4% and a protein content on 2.5-3.0%. The casein content is still unknown but is assumed to be lower than the content of dairy cows ≤ 75% (personal communication, Sjaunja, 2009). When producing cheese, milk composition (fat, protein and casein) is of great importance, since milk with low levels of these components results in lower cheese yields, poorer coagulation properties and irregular curds (Storry *et al.*, 1983; Damian *et al.,* 2008).

Several factors affects milk yield and composition in dairy animals, for example breed (Soryal *et al.,* 2005; Damian *et al*., 2008), udder morphology (Marnet and McKusick, 2001), genetics (Moatsou *et al*., 2004), parity (Peris *et al*., 1997; Salama *et al.*, 2004; Carnicella *et al*., 2008; Ahuya *et al*., 2009; Crepaldi *et al*., 1999) feed and pasture (Dønnem *et al*, 2011), light (Flores *et al*., 2010), number of kids (Carnicella *et al*., 2008; Ahuya *et al*., 2009; Crepaldi *et al*., 1999), kidding time (Crepaldi *et al.*,1999) kid holding systems (Marnet *et al*., 2002) and milking interval (Salama *et al*., 2003; Salama *et al*., 2004;). Swedish goats have lower milk dry matter content compared to breeds in other countries (Lepiage, 2010). The examples above do certainly have a major impact, but it may also be a consequence of deficient milk ejection, since milk rich in fat stays in the upper part of the alveoli and needs a contraction of the myoepithelial cells to be available for the milker.

The aims of the present study were to investigate how milk yield and composition were affected in goats kept in two different rearing systems, suckled by one kid during 8 weeks. We also wanted to measure the casein content on farm by a mid-infrared spectroscopy method, previously calibrated for goat milk.

Background

Milk storage in the mammary gland

Milk is produced in the secretory tissue, in the alveoli and is stored both in the gland cistern and in the alveoli between milkings (Bruckmaier, 2005). The proportion of milk stored in the cisternal and the alveolar compartment varies according to species, breed, milking interval, and stage of lactation (Salama *et al*., 2004). Goats have large cisterns and store between 50-80% in the gland cistern compared to dairy cows that store about 20% in the cistern (Salama *et al*., 2004; Marnet and McKusick, 2001; Bruckmaier, 2005*)*. The cisternal milk can easily be emptied without milk ejection and milk stored in the alveolar compartment can only be expressed into the cistern after a contraction of the myoepithelial cells (Andersson, 1951; Soloff *et al*., 1980; Bruckmeier *et al*., 1994; Marnet and McKusick, 2001).

Animals with large cisterns are able to store the milk more effectively between milkings (Marnet and McKusick, 2001) and therefore goats, in contrast to dairy cows, are less dependent on milk ejection (Peris *et al*., 1997). In small ruminants, this is evident, since the milk flow has no correlation with oxytocin in plasma during milking (Marnet and McKusick, 2001). Therefore, pre-stimulation longer than 30 s is not necessary during machine milking of goats (Basic *et al.*, 2009). Moreover, greater storage capacity also leads to higher milk yields in goats and reduces the milk losses in once daily milking practices (Marnet and Komara, 2007). Even if goats are less dependent of milk ejection, the neuroendocrine reflex is of big importance both for obtaining higher milk yields and higher fat contents. Fat globules (especially the largest ones) do not pass freely from the alveoli to cistern between milkings, a contraction of the myoepithelial cells is needed to release the fat to the cistern (Ayadi *et al*., 2004; Salama *et al.*, 2005). This explains why milk stored in the cistern has a low fat content and milk from the alveoli is rich in fat (Linzell and Peaker, 1971; Marnet *et al*., 2001; Salama *et al*., 2005; Sarikaya *et al*., 2005;). There have been several suggestions regarding why the fat globules stay in the upper part of the alveoli. Sarikaya *et al*. (2005) and Andersson (1951) suggest that fat has lower density than water and Andersson (1951) further describes that this is due to changes of pressure within the gland. The pressure increases when new milk is secreted and this prevents big particles like fat globules to pass freely from the alveoli. The pressure in the alveoli declines during milking (milk ejection is needed) which results in higher fat content in the end of milking. Other milk components, like protein and lactose concentrations do not differ much between cisternal and alveolar milk since they are small and can pass freely between the two compartments (McKusick *et al*., 2002; Salama *et al*., 2005; Castilllo *et al*., 2008) and therefore remains quite constant during milking. Anyway, deficient milk ejection leads to both lower milk yields and a lower fat content. Therefore, this is important knowledge for dairy farmers, especially cheese producers who needs milk rich in fat.

Frequent milkings increases milk yield

Maintained milk synthesis depends on frequent milk removal and milk production eventually stops if milk removal ceases. This effect has been explained as a combination of inhibitory effects by the presence of milk in the secretory tissue and an effect of the high intra-mammary pressure. The effects of the pressure that milk fill exerts on the secretory cells and blood perfusion in the capillary net has been discussed since Fleet and Peaker (1978) found that the rate of milk secretion declined when the calculated pressure within the alveoli increased.

Several studies have shown that more frequent milking increases milk yield in goats (Wilde *et al*., 1987; Henderson *et al*., 1985; Koyuncu and Pala, 2008) which leads to mammary growth and increased activity per cell. In reverse, less frequent removal of milk inhibits further milk synthesis (Wilde *et al*., 1987; Li *et al*., 1999; Fitzgerald *et al*., 2007). When milk is present in the secretory tissue the number of cells in the alveoli decreases which is an effect of apoptosis (Li *et al*., 1999; Knight *et al*., 2001). Less removal of milk results in reduced blood flow to the udder which can initiate apoptosis (Capuco *et al*., 2003; Koyuncu and Pala, 2008). Local mammary factors regulate the milk synthesis in each gland (left or right in goats) and they are independent of each other. If milking frequency increases in one gland only, milk yield will increase in that gland but not in the other (Stelwagen, 2001).

Furthermore, Wilde *et al.* (1996) suggest that the autocrine peptide “feed-back inhibitor of lactation (FIL) is a factor that is responsible for the inhibitory effect during incomplete milking. FIL is only present in the alveolar compartment and is proposed to inhibit milk secretion without influencing gross milk composition (Wilde *et al.*, 1996). When milk is accumulated in the alveolar fraction, an inhibition of further milk synthesis appears (Marnet and Komara, 2007). Frequent milkings in goats has been shown to reduce the effect of FIL (Peaker and Wilde, 1996) and milk must be removed from the alveoli to avoid the inhibition of milk synthesis (Henderson and Peaker, 1985).

Management regimes in dairy goats

The main role of dairy goat farming is to produce marketable milk. To achieve high quality milk, different kid rearing methods are practiced in intensive-, semi-intensive and extensive systems. Early weaning of kids, as practiced in most of the intensive systems, is believed to be the most profitable way of saving milk for human consumption (Delgado-Pertínez *et al*., 2009; Miranda de la Lama and Mattiello, 2010). In reverse, dairy animals in semi-intensive and extensive systems are often kept in MIX-systems (both milked and suckled) as they are kept together with their kid for longer periods. Animals reared in MIX- systems are often separated from their offspring’s for some hours daily (e.g. when the goats are browsing) to save milk for human consumption.

The milking management systems in the intensive dairy industry have been discussed since consumers do not agree that early separations between dam and kid are defensible when it comes to animal physiology, animal welfare and milk quality aspects (Marnet and Komara, 2008). Bungo *et al*. (1998) have found that kids become more independent as they grow older: the number of sucklings declines and the kid starts to eat forage as a supplement to the milk after 5 weeks of age. Therefore, it has been suggested by Miranda-de la lama and Mattiello (2010) that weaning not should occur before 6–7 weeks of age with respect to behavioural development and good animal welfare.

Breeders of dairy ewes do often practice MIX-systems (both suckling and milking) or only suckling in the beginning of the lactation. In the latter system the ewes are machine milked after separation from their lambs, but not always during the suckling period. This is positive from an animal welfare perspective and also reduces the working time by 27% (Marnet and Komara, 2007). MIX-systems are particularly advantageous for the dairy cheese producers that often have a heavy workload. A reduced workload enables farmers to produce cheese and take care of selling with reduced number of employees involved. MIX- systems are especially appropriate for high yielding animals as the offspring normally cannot empty the dam's udder (Marnet and Komara, 2007). Moreover, Delgado-Pertinez *et al*. (2009) demonstrated that it is more profitable to rear goats in MIX-systems compared to artificial rearing systems (AR = kids are reared artificially and are fed on replacers, and dams are milked only).

However, when comparing management systems between goats and sheep it is important to have in mind that these species differ in both behavior and physiology. For example goats, in contrast to sheep hide their offspring in the beginning of lactation whereas lambs follow their dams (Lickliter, 1987). Furthermore, goats store a higher proportion of milk in the cistern than sheep (Marnet and Komara, 2008), which results in higher milk secretion rates between milkings compared to animals that store higher amounts of milk in the alveoli (Peaker and Blatchford, 1988). Moreover, ewes have higher dry matter content in milk than goats.

How is milk yield and composition affected in dairy animals during suckling?
How the milk yield and composition are affected in dairy animals kept in MIX-systems compared to AR reared animals has been extensively discussed. Both suggestions and results from earlier studies are contradictory, which partly depend on comparisons between different breeds, species and different milking regimes. For example Lyons *et al.* (1989) and McKusick *et al*. (2002) suggest that animals kept in MIX–systems have an impaired milk ejection during machine milking, since the milk only is ejected when offspring's are present. Deficient milk ejections lead to lower milk yields and lower fat contents, since milk fat synthesis may be inhibited and milk fat transfer from the alveoli to the cistern between milkings does not occur (Marnet and McKusick, 2002). Impairments of milk ejection in suckled animals can though be recovered two weeks after separation from the offspring when both milk yield and fat content are at similar levels as from artificially reared animals milked twice daily (McKusick *et al*., 2001; Mendoza *et al*., 2010).

On the contrary, others have suggested that suckling plus frequent milking during early lactation improves mammary development by increasing both mammary proliferation and differentiation of mammary cells of goats (Wilde *et al*., 1987). The mother-young-bound has very strong effect on regulation of hormones involved in lactation, and interruption of the maternal-young-bound immediately after birth has resulted in negative effects of lactation persistency, and less effective oxytocin release during milkings (Marnet and McKusick, 2001). Oxytocin-mediated milk ejections are therefore necessary for a complete emptying of the udder, which also further stimulates milk secretion positively (Bruckmeier, 2005). Studies in goats (Olsson and Högberg, 2008) and ewes (Marnet and Negrao, 2003) confirm that oxytocin levels in plasma only increase during suckling and not during milking. The latter demonstrates that higher milk yields were obtained in ewes during suckling compared to machine milking, which also has been demonstrated by Delgado-Pertinez *et al.* (2009).

Milk and cheese production

Cheese properties, quality and yield depend on milk composition, especially protein, casein and fat content (Storry *et al*., 1983; Damian *et al*., 2008). For farmers it is therefore desirable with milk rich in these components. Proteins consist of 75% caseins (α_{S1}, α_{S2}, ß and K-caseins) and 25% wheyproteins (β-lactoglobulin, α-lactalbumin, immunoglobulines and serum-albumines). Both amount and proportion of the caseins later affect the cheese making properties (Walstra *et al*., 1999). During coagulation, casein and calcium phosphate bridge micelles together to form a network which entraps fat and other solids. Goat milk that contains high amounts of total solids, protein and fat coagulates more quickly and forms firmer curds than milk containing low levels of these components (Clark and Sherbon, 2000). Soryal *et al*. (2005) showed that Nubian goats has higher fat, protein and casein content compared to Alpine goats which resulted in 2.7 and 1.7 kg of curd from 10 liters of milk, respectively. As the Swedish goat milk has poorer coagulation properties, it takes about 12 L of milk to produce 1 kg of cheese (personal communication, Norman 2010). This may depend on several factors but it could be a result of low dry-matter content in the milk. Goats with high solids in milk, particularly Nubians is therefore recommended if cheese-making is the objective, since coagulation rate and curd firmness are important economical factors (Clark and Sherbon, 2000).

Kids

An early separation between kids and their mothers is a stressful event, which often leads to reduced growth rates and weight losses (Miranda de la Lama and Mattiello, 2010). With regard to rearing systems, Perez *et al*. (2001) demonstrated that kids reared on goat milk had higher average daily weight gain (ADG) than kids fed with both goat and cow milk–replacers. Kids fed on goat milk consumed less milk than the replace fed kids, which could be explained by a more efficient utilization of the diet. In contrast, two studies by Delgado-Pertinez *et al.* (2009) show that naturally reared kids of the Florida breed and Payoya breed had similar ADG as AR kids.

Material and methods

Animals

Eleven lactating goats of the Swedish domestic landrace (*Capra Hircus*) were kept together with their kids in a loose housing pen with straw and sawdust bedding (home pen). Hay was available *ad. libitum* in baskets at 7.00, 12:00 and 16:00 and the animals had free access to water and mineral licks. Room temperature was kept at 17±1º C. The Local Animal Ethical Committee in Uppsala, Sweden approved the care of the animals and the experimental design.

Housing during experimental period

All goats were kept together with their kids for four days. On day five, one of their kids was randomly separated and raised artificially (AR; if the goat had more than one kid). The other kid was still kept together with their dam. The goats were blocked by parity and randomly assigned into the two different systems/treatments (Table 1).

In group 1 (n=5) goats and kids were kept together in the home pen for 16 hours a day (T-16h). They were separated daytime between 7:00-15:00 (like going on pasture) and moved to a trial room next door. There, they were kept in a loose housing pen and had free access to hay, water and mineral licks. The kids were also moved to the trial room at 15:00 and were allowed to suckle their dams during 30 minutes before each afternoon milking (AM). Both goats and kids went back to their home pen after each AM. Kids and dams stayed together during the nights and the kids had free access to both teats.

In group 2 (n=6) goats and kids were kept together for 24 hours a day (T-24h). The kids were only allowed to suckle one teat, as the other was covered with a bra to prevent the kids from suckling. Both dams and kids stayed in their home pens all day except during milking when the goats were moved to the milking parlor.

Table 1. Lactating goats were kept in two different rearing systems during 8 weeks. Five goats were kept together with one kid for 16h a day (T-16h). During daytime (between 7:00-15:00) dams were removed to a trial room next door while kids stayed in their home pen. The other goats (n=6) were kept with one kid for 24 hours in their home pen. Their kids were only allowed to suckle one teat and the other teat was covered with a bra. Both groups were loose held and had free access to hay, water and mineral licks.

Goat	System	Lactation	Kidding date	Kids	M.Y(g/d)	Fat (%)	Prot (%)
Käck	T-16h	3	2009-03-05	♂♂	3289	4.3	2.7
Polly	T-16h	3	2009-03-14	♂♂	1854	4.7	2.9
Jet	T-16h	2	2009-03-08	♀	2488	3.4	2.7
Svea	T-16h	1	2009-03-07	♂♂♂	1896	4.6	2.9
*Fruxo	T-16h	3	2009-03-31	♀♀	397	6.1	3.3
Pim Pim	T-24h	3	2009-03-08	♀♂	2472	3.8	2.8
Zoo	T-24h	3	2009-03-13	♀♂	1982	4.2	3.0
Topas	T-24h	2	2009-03-17	♀	2444	3.9	2.9
Turmalin	T-24h	2	2009-03-09	♀♀	2887	4.2	2.7
Citrin	T-24h	2	2009-04-03	♂	1188	4.6	3.4
Puma	T-24h	1	2009-03-06	♀♂	1887	3.8	2.8

* Stayed together with two kids and were therefore not included in statistics for milk yield and composition.

Milking

The goats were machine milked twice daily at 7:30 in the morning (MM) and 15:30 in the afternoon (AM) for 8 weeks. One goat at a time was milked in a milking parlor between the home pen and the trial room. The goats were given concentrate (0.2 kg) and carrots (0.1 kg) in connection with each milking. Milking equipment (De Laval international AB, Tumba, Sweden) with a pulsation rate 90 cycles /minute and system vacuum 42 kPa was used. Milk samples were taken once or twice a week during different days of lactation (day 8 of lactation = D8, D12, D14, D19, D22, D29, D33, D36, D40, D50 and D70). Missing values from day 50 was due to problems with the milk analyzer equipment. One goat in the T-24h group kidded later than the other goats and milk samples were collected on other lactation days due to that the milk analyzer was out of function (D8=D6, D12 =D10, D14=D20, D19 =D41, D22=D43, D290D44, D33=D50, D36=D52, D40=D57, D50= D59 and D70=D62).

Both udder halves were separated with a special "separation-milker 8L"bucket milking machine (provided by DeLaval international AB, Tumba, Sweden). Missing values from week 8-10 was depending of problems with the milk analyzer equipment.

Milk analyses
Milk from each udder half was weighed and measured in grams (g; Mettler Toledo, Stockholm, Sweden). Samples of fresh milk were collected in 10 ml plastic tubes and heated in a water-bath to 40ºC before analyses of fat, lactose and total protein. The samples were later measured by a mid-infrared spectroscopy method (Miris farm milk analyser, 2001), previously calibrated for goat milk (by Miris AB, Uppsala, Sweden). Milk samples for sodium and potassium were stored at -20˚C until assayed.

Casein
The casein content was determined stepwise and was separated from the whey proteins by a rennet coagulation method. The infrared spectrometry method was calibrated for goat milk and determined by Kjelldahl method (N x 6.38).

The rennet coagulation method was performed as followed:
1. 60 µl of $CaCl_2$ ($CaCl_2$ 48% = 80g $CaCl_2$ + 100 ml H_2O) was added to 40 ml plastic tubes (to increase the syneresis).
2. 20 ml of fresh milk was added to the tubes and pre-heated to 40^{o}C in a water bath.
3. Addition of 200 µl standard rennet (Kemikalia AB, Skurup, Sweden) with 180 IMCU (international milk clotting units) containing 75% chymosin and 25% pepsin was added to the tubes during gently stirring.
4. The samples were set to coagulate for 5 minutes
5. The curd (caseins) was cut into pieces and post-heated for another 5 minutes in the water bath.
6. The curd was filtrated from the whey proteins and the whey yield was measured (ml).
7. The whey was collected in 10 ml plastic tubes and one drop of a special detergent (Triton X®-100, Merck KGaA, Darmstadt, Germany) was added to the whey samples. They were heated to 40^{o}C in a water bath before the mid-infrared spectroscopy analysis.
8. The proportion of casein was finally calculated from the proportion of whey protein and the total protein content due to a formula (Miris AB, Uppsala, Sweden):

Fat (%) / Fat density (0.93) + protein x casein- fatcor (0.7) /protein density (1.11) = X

100 – X / 100 = Y

Y =correlation factor for fat content in milk
100 = correlation factor
Casein = protein – (whey-protein x Y)
Casein number = casein / protein

Sodium and potassium
Sodium (Na^+) and potassium (K^+) in milk were analysed by "flame photometry" (FF-IL 943, Instrumentation Laboratory, Milan, Italy). Before analysis, 1 ml of Trichloroacetic acid (Trichloroacetic acid m.v 163, 39, Merck, Darmstadt, Tyskland) was admixed to the samples. The samples were then spun at 20^{o}C in 20 minutes at 1500 x g. Finally, 0.5 ml of the supernatant was analyzed by flame photometry.

K**ids**
The kids were randomly divided into three groups. Group 1 was separated from their dam daytime between 7:00-15:00; they were allowed to suckle both teats 16 hours during night (T-16h). The kids in the T-24h group stayed with their dam for 24 hours a day except during milkings. They were only allowed to suckle one teat as the other was covered with a bra. Group 3 were raised artificially (AR) and had free access to heated (37^{o}C) raw goat milk from

the herd. All kids were weighed once a week (Mettler Toledo, Stockholm, Sweden and Stathmos AB, Jönköping, Sweden) and the weights were measured in gram. All groups had free access to hay, straw, mineral licks and water and were given concentrates one a day.

Statistics
Data were analyzed using Microsoft Excel (2007) and SAS® (SAS Institute, 2004). Values are presented as mean values ± standard deviation (SD). A mixed procedure approach was applied to the set of data, and pair wise comparison between treatments was tested for significance. The significance level was set at P<0.05.

Results

Milk yield
The daily milk yield patterns during 8 weeks shows that there were no significant differences between days or groups. Goats in the T-16h group tended to have a higher milk yield on day 19, day 22 and day 33 than T-24h goats.

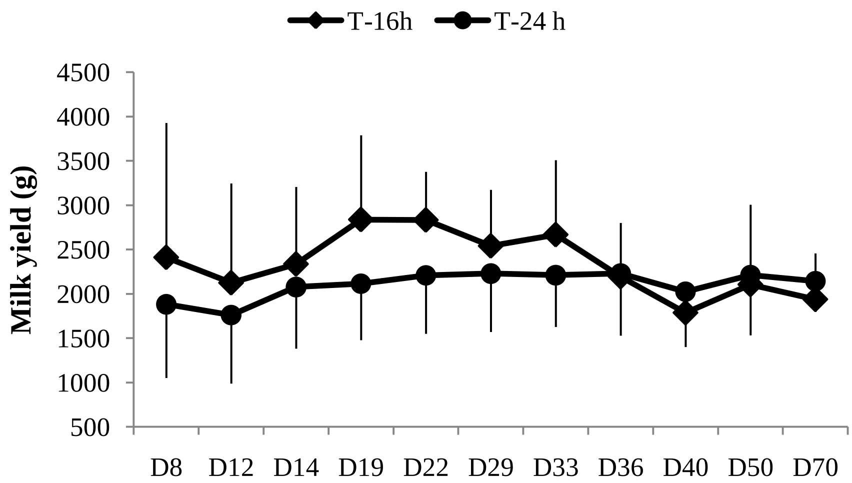

Figure 1. Average daily milk yield from lactating goats kept in 2 different rearing systems (MIX = both suckling and milking). Milk yield was weighed in gram (g). Four goats were kept together with one kid during 16 hours night time (15:00-07:00; T-16h) and six goats were together with one kid during 24 hours (T-24h). The latter group had one teat covered with a bra, and the kid was only allowed to suckle the other teat. The goats were milked twice daily (morning = 7:30 and afternoon = 15:30) during 8 weeks (lactation weeks 1-8), and milk samples were collected on different days between lactation day 8 to day 70. One goat in the T-24h group kidded later than the other goats and milk samples were collected on other days due to that the milk analyser was out of function (D8=D6, D12 =D10, D14=D20, D19 =D41, D22=D43, D29=D44, D33=D50, D36=D52, D40=D57, D50= D59 and D70=D62). Kids in T-16h group were allowed to suckle in 30 minutes before each afternoon milking. There were no significant differences (P<0.05) between days and groups. Values are presented as mean ± SD.

Both groups had higher milk yields in the morning milking (MM) than in the afternoon milking (AM; P<0.05) but there was no difference between the groups from the MM (figure 2). The T-16h goats had higher milk yield thanT-24h in the AM (P<0.05), and the T-24h goats had higher milk yield in the milked teat than in the suckled (P<0.05). The total daily milk yield (11 days) was higher (P<0.05) for T-16h goats (2547g) compared to T-24h goats (2099 g). Total daily milk yield within the groups differed between individuals (T-16h: max 3.3 kg; min 1.8 kg; T-24h: max 2.9 kg, min: 1.2kg).

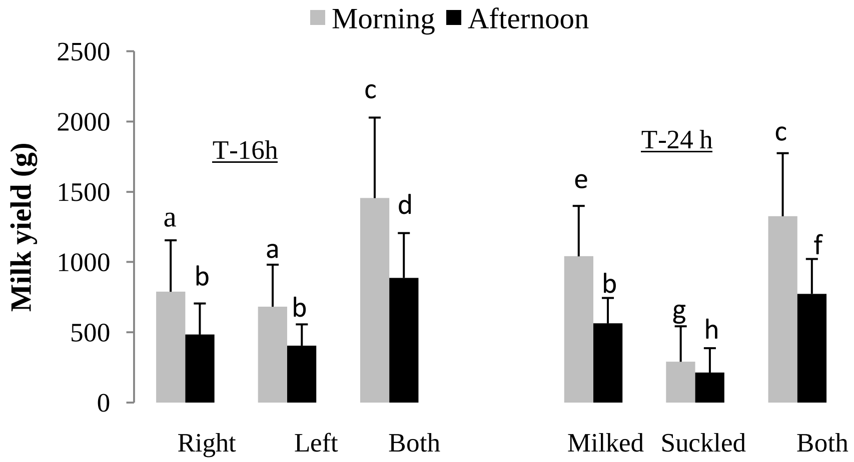

Figure 2. Average daily milk yield from lactating goats kept in 2 different rearing systems (MIX = both suckling and milking). The daily milk yield was weighed in gram (g). Four goats were kept together with one kid during 16 hours nighttime (15:00-07:00; T-16h) and six goats were together with one kid during 24 hours (T-24h). The latter group had one teat covered with a bra, and the kid was only allowed to suckle the other teat. The goats were milked twice daily (morning = 7:30 and afternoon = 15:30) during 8 weeks (lactation weeks 1-8), and milk samples were collected from both udder halves (left, right in T-16h and milked or suckled in T-24h) both morning and afternoon. Milk samples were collected on different days between days 8 to day 70 of lactation. Kids in the T-16h group had free access to suckling before each morning milking and were allowed to suckle during 30 minutes before each afternoon milking. Values are presented as mean ± SD. Different letters differ significantly (P<0.05).

Milk composition

Fat content

The fat content was highest for both groups in the beginning of lactation and declined over time (figure 3). The T-16h goats had higher fat content on day 8 and day 40 of lactation than T-24h goats (P<0.05), and tended to be higher day 12 (P=0.07) and day 33(P=0. 08). Fat content over total period was higher (P<0.05) in T-16h goats (4.9 ± 0.9%) than T-24h goats (4.4 ± 0.7%).

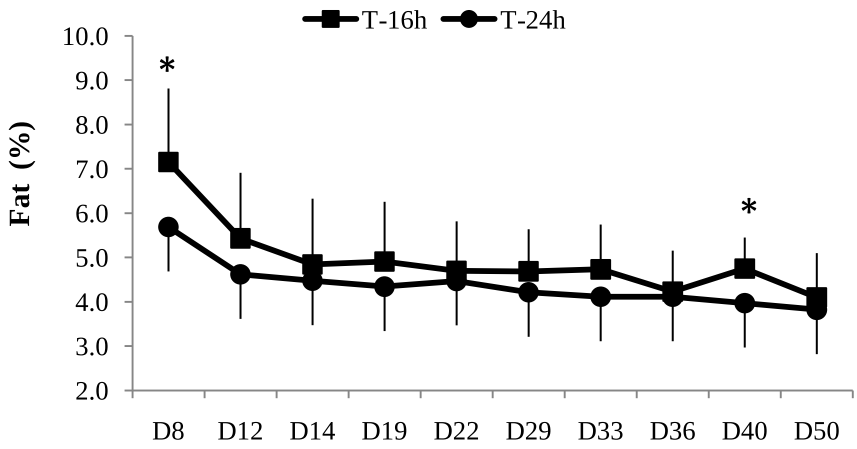

*Figure 3. Average daily fat content during 10 different days of lactation (day 8 to 50). Lactating goats were kept in 2 different rearing systems (MIX= both suckling and milking). There was no significant difference between the groups. *differs significantly between the groups (P<0.05). For further information, see figure 1.*

Fat content was higher in the AM than in the MM for both groups (P<0.05). T-16 goats had a higher fat content both MM and AM than in T-24h goats (P<0.05). Differences between teats were significantly affected by either suckling or milking. The suckled teat (T-24h) had a higher fat content than the milked teat in the MM (P<0.05) and reverse in the AM where the milked teat had a higher fat content than the suckled one (P<0.05). There were no differences between the left or right teat in the T-16h goats (figure 4). The total daily fat content was higher for T-16h goats (4.9 ± 0.9%) compared to T-24h goats (4.4 ± 0.7%).

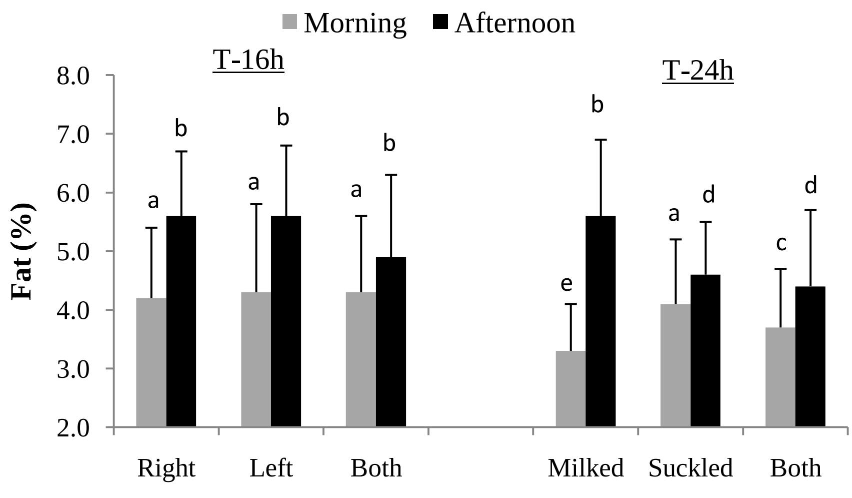

Figure 4. Average daily fat content from lactating goats kept in two different rearing systems (MIX = both suckling and milking). Milk samples were analyzed during lactation weeks 1-8, on different days, day 8 to 50 of lactation. Different letters differ significantly (P<0.05). For further information, see figure 2.

Protein content

The protein content in milk was highest in the beginning of lactation (day 8) and declined over time for both groups (figure 5). The total daily protein content did not differ significantly between the groups; T-16h had 3.2 ± 0.4% and T-24h goats had 3.1 ± 0.3% of total milk protein.

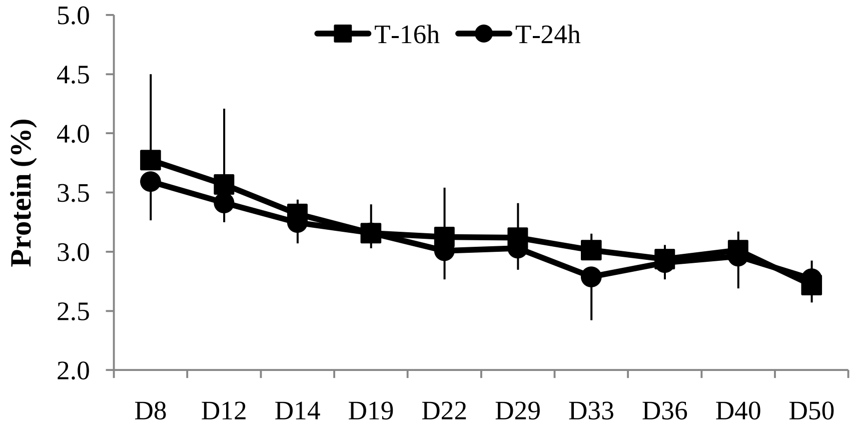

Figure 5. Average daily protein content during 10 different days of lactation (day 8 to 50.) Lactating goats were kept in 2 different rearing systems (MIX= both suckling and milking). There was no significant difference between the groups. For further information, see figure 1.

Lactose content

The T-16h goats had higher lactose content on day 36, day 40 and on day 50 of lactation compared to T-24h goats (P<0.05). The highest lactose concentration was seen during day 22 for both groups and the lowest on day 50 of lactation (figure 6). The total daily lactose content was 4.8 ± 0.4% for the T-16h goats and 4.7 ± 0.3% for T-24h goats, and did not differ significantly between the groups over total period.

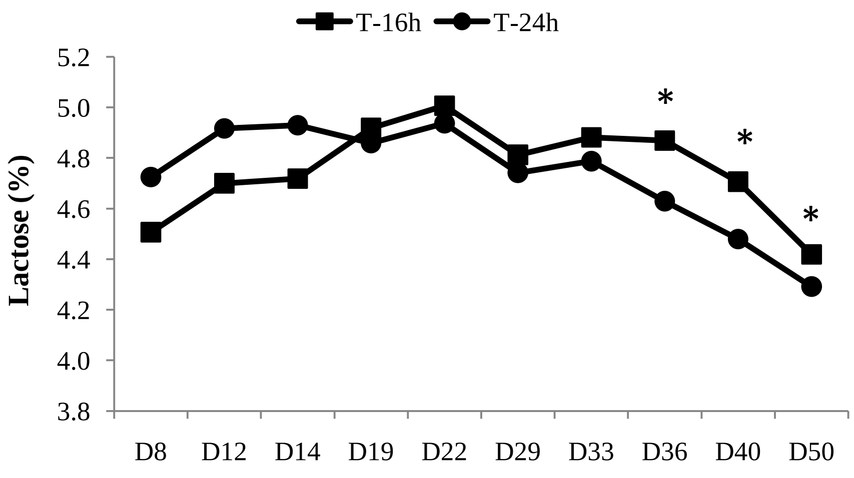

*Figure 6. Average daily lactose content during 10 different days (day 8 to day 50 of lactation) Lactating goats were kept in 2 different rearing systems (MIX= both suckling and milking). * differs significantly between groups (P<0.05). For further information, see figure 1.*

Casein content

Both casein (c-n) and protein content were higher on day 75 of lactation in T-24h goats compared to T-16h goats ($P<0.05$), other days showed no significantly differences in casein between the groups.

The c-n number (% of total protein) did not differ between the groups and was in total (all days) 72 ± 5% for both groups. The c-n number was higher for both groups on day 70 and day 75 of lactation than on day 36 and day 40 ($P<0.05$). There were individual differences in both casein and protein (max, min) among and between the groups (table 3).

Table 3. Daily variations in protein, casein and casein-number in goats kept in two different MIX systems. The goats were milked twice daily and milk samples were collected for four days.

	Together with kid 16 h a day (T-16h)				Together with kid 24h a day (T-24h)			
	D36	D40	D70	D75	D36	D40	D70	D75
Protein (%)	2.9[a]	3.1[b]	2.7[c]	2.6[c]	3.0[a]	3.2[a]	2.8[b]	2.8[b]
Max	3.1	3.1	3.1	3.1	4.2	3.8	3.1	3.2
Min	2.6	2.9	2.5	2.1	2.6	2.8	2.5	2.5
C-n (%)	2.0[ab]	2.2[a]	2.0[ab]	1.9[b]	2.1[a]	2.2[a]	2.1[a]	2.1[a]
Max	2.2	2.4	2.3	2.3	2.8	2.7	2.7	2.4
Min	1.8	2.0	1.9	1.5	1.7	1.9	1.8	1.8
C-n-number (%)	69[a]	70[a]	74[b]	74[b]	68[a]	69[a]	76[b]	74[b]
Max	74	74	78	77	72	72	89	80
Min	66	66	64	69	57	65	69	69

D= day, C-n = casein, C-n number = casein of total protein in percent. Different letters differ significantly ($P<0.05$).

The c-n number did not differ significantly between groups, milkings (MM, AM) or between udder-halves (figure 7).

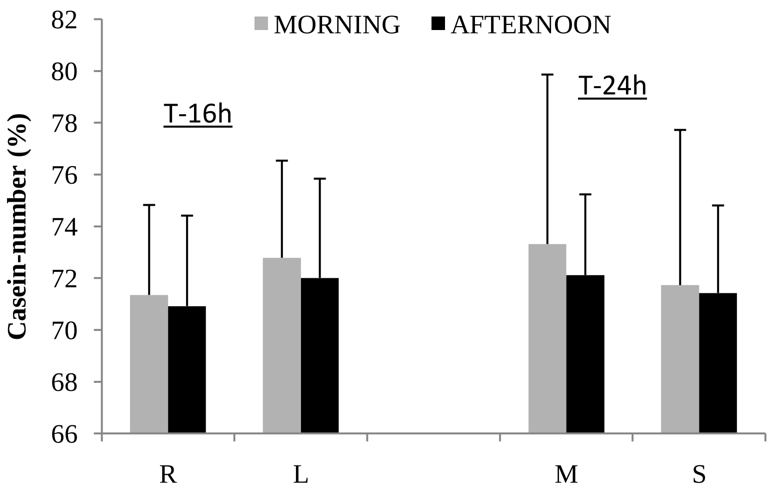

Figure 7. Average casein number from lactating goats kept in 2 different rearing systems (MIX = both suckling and milking). Milk samples were collected twice daily for 4 days, divided in right (R) and left (L) udder-halves for T-16h goats and in milked (M) or suckled (S) teats for T-24h goats. For further information, see figure 2.

Sodium

T-24h goats had lower concentration of sodium in the milked teat than in the suckled ($P<0.05$). Both udder halves from the T-16h goats had higher concentration of sodium than the milked teat from the T-24h group (figure 8). T-16h goats had in total (7 lactation days; day 8 to day 33) a higher concentration of sodium in milk than T-24h goats ($P<0.05$).

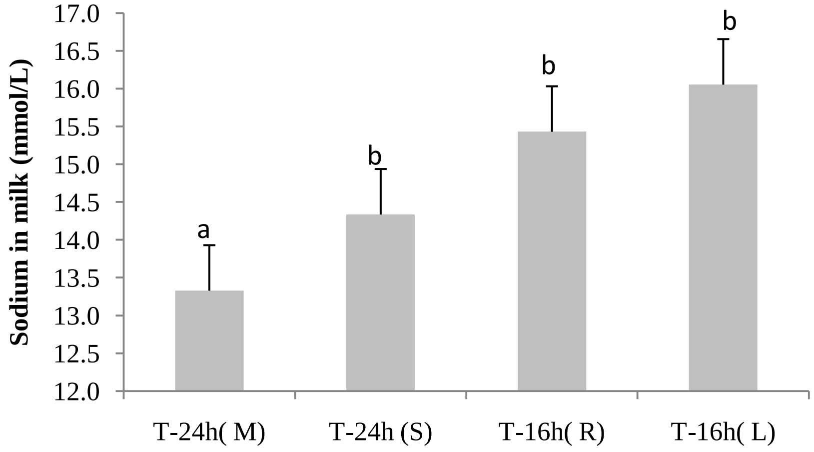

Figure 8. Sodium in milk from lactating goats kept in two different rearing systems (MIX=both suckling and milking). Milk samples were collected twice daily for7 different days (day 8, day12, day 14, day 19, day22, day 29, day 33 of lactation) from both udder- halves; milked (M) and suckled (S) from the T-24h group and, right (R) and left (L) from the T-16h group. Different letters differ significantly (P<0.05), and figures are presented as mean ± SD.

Potassium

The milked teats had higher concentration of potassium than the suckled ones in T-24h goats ($P<0.05$), and higher than the right (R) and left (L) udder-halves in the T-16h goats ($P<0.05$). The right udder-halves in the T-16h goats tended ($P=0.07$) to have higher concentrations of potassium than the left ones (figure 9).

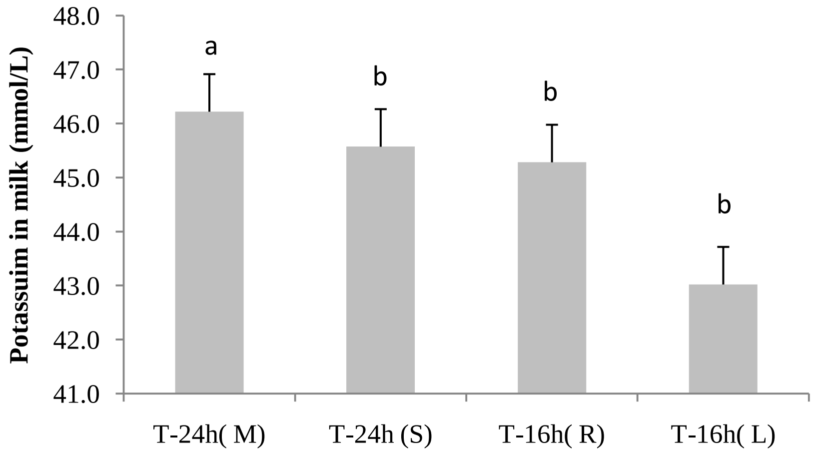

Figure 9. Potassium in milk from lactating goats kept in two different rearing systems (MIX=both suckling and milking). Milk samples were collected twice daily for 7 different days (day 8, day12, day 14, day 19, day22, day 29, day 33 of lactation) from both udder-halves; milked (M) and suckled (S) from the T-24h group and, right (R) and left (L) from the T-16h group. Different letters differ significantly (P<0.05). Figures are presented as mean ± SD.

Daily weight gain in kids
There was no difference in average daily weight gain (ADG) in total, between the groups during weeks 1-9. The ADG of kids was irregular both between and within the groups as the kids for example compensated lower ADG during one week with increased ADG for the coming week (table 4).

Table 4. Live weight and average daily weight gain (ADG) during 9 weeks in Swedish landrace kids reared in three different systems.

	Rearing system				Rearing system		
	T-16h[1] (n=6)	T-24h[2] (n=6)	AR [3](n=10)		T-16[1] (n=6)	24h[2] (n=6)	AR[3] (n=10)
Live weight Weeks (g)				ADG (g/day)			
Birth weight	2860 ± 460	2730 ± 490	2880 ± 330	W1	180 ± 20	180 ± 40	150 ± 30
W1	4120 ± 560	4000 ± 570	3900 ± 470	W2	180 ± 30	170 ± 30	200 ± 50
W2	5160 ± 650	5280 ± 710	5310 ± 640	W3	165 ± 30	160 ± 60	160 ± 50
W3	6430 ± 870	6430 ± 760	6440 ± 630	W4	115 ± 50	170 ± 60	210 ± 70
W4	7240 ± 960	7620 ± 740	7880 ± 870	W5	250 ± 60	140 ± 50	170 ± 90
W5	9020 ± 1230	8620 ± 690	8960 ± 1030	W6	160 ± 70	190 ± 70	240 ± 60
W6	10130 ± 1180	9930 ± 640	10650 ± 1230	W7	260 ± 90	180 ± 40	150 ± 80
W7	11900 ± 1540	11160 ± 810	11720 ± 1430	W8	150 ± 60	130 ± 100	160 ± 120
W8	12850 ± 1240	12040 ± 1250	12840 ± 1920	W9	220 ± 180	260 ± 140	170 ± 90
W9	14700 ± 1740	13600 ± 1080	14000 ± 1530	Total	190 ± 80	180 ± 70	180 ± 80

[1]Together with dams for 16 hours a day = T-16h (3 females and 3 males). [2]Together with dams for 24 hours a day, but only allowed to suckle one teat = T-24h (5 females and 1 male). [3]Separated from dams 4 days after birth and were raised artificially = AR (9 males and 1 female). Numbers are presented as mean ± SD.

Weight in goats
Goats in both groups weighed more before kidding than after ($P<0.05$), and the weekly weights during lactation weeks 1-9 weeks were similar in both groups (figure 10). Mean weights for total period were 56 ± 5 kg for T-16 goats and 54 ± 5 kg for T-24h goats.

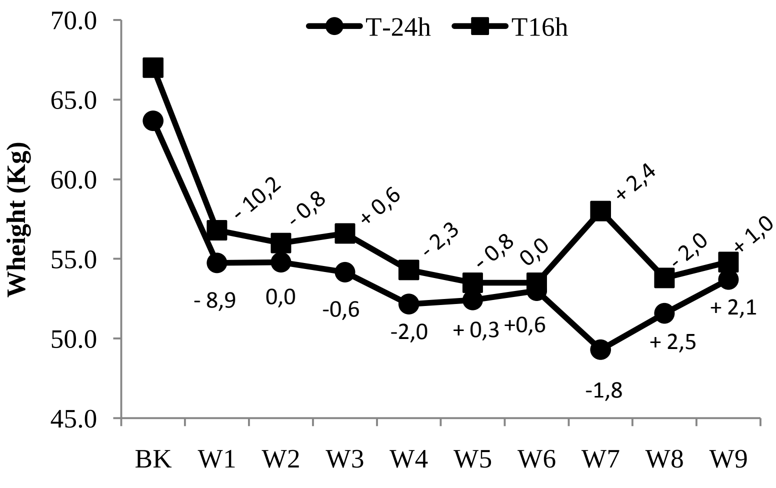

Figure 10. The goats were weighed before kidding (BK), and then once a week during lactation weeks 1-9.

Discussion

This study confirms that it is possible to maintain marketable milk yield during 8 weeks in Swedish dairy goats kept in MIX-systems (separated for 8 h daytime, or allowed to suckle one teat for 24h a day). The daily milk yield in Swedish dairy herds is estimated to be 2.8 L per day and goat (Brandt, 2009). The goats in this study had lower milk yield in comparison, but only with small differences (2.5 kg and 2.1 kg/day and goat). However, the goats of this study produced more milk in comparison to other breeds kept in MIX-systems. For example, the daily production of marketable milk for Payoya dairy goats was 2.0 L during the suckling period and 2.1 L after weaning (Delgado-Pertinez *et al*., 2009). Florida dairy MIX-goats yielded 1L marketable milk (Delgado-Pertinez *et al.*, 2009). In addition, these two studies are comparing milk yields between MIX-goats and AR-goats. Interestingly the total daily milk yield (210 days of lactation) was higher in MIX-goats (2.4 L/day) compared to AR-goats (1.9 L/day) in the Payoya breed, and the authors suggested that goats of the Payoya breed cannot be stimulated by machine milking as effectively as by suckling.

Norwegian and Swedish dairy goats are in principle the same breed. In comparison to a study on Norwegian goats by Eknaes *et al*. (2006) our goats produced similar or higher amounts of milk than the goats from that study (2.2 L/day). Those goats were kept in AR-systems and were fed with similar amounts of concentrate (0.2-0.5 kg/day) as our goats (< 0.5 kg/day), and hay was given *ad. lib*. The study also showed that increased levels of concentrate increased the milk yield to 2.7 kg of milk daily and free access to pasture and high levels of concentrate increased milk yields further (3.1 kg). Another Norwegian study by Dønnem *et al*. (2011) demonstrated that AR kept goats fed with low levels of concentrate (0.6 kg/day) and late harvested silage yielded 2.9 L of milk per day, but with increased levels of concentrate, milk yields increased to 3.2 L per day and to 4.1 L when the goats were given early harvested silage. According to these results milk yield in goats might rather be more dependent upon feed intake than whether the dams are suckled by their kids or not.

The difference in milk yield between the different rearing systems in our study could depend on that the kids had free access to suckle both teats in T-16h group, and thereby increased the milk yield by a more frequent removal of milk (Bruckmaier, 2005). Only one teat was suckled in the T-24h goats and the other teat (machine milked only) had milk presence in the secretory tissue for longer periods, which might have reduced the milk secretion (Fitzergald *et al*., 2007) in that gland. In addition, the higher milk yield in the T-16h goats could also be explained by the suckling managements. These goats were separated from their kid during 8 hours daytime and were able to store milk in the cistern between milkings. Before each AM, the kids were allowed to suckle their dams during 30 minutes, which led to a more complete milk let down. If milking instead have occurred in reverse order (milking before suckling), the milk yield probably had been lower in the AM because of a less effective milk let down.

Individual differences in milk yield, both within and between groups, which seemed to be connected to udder size could be seen in this study. It has earlier been shown that udder morphology and milk yields are positively correlated (Marnet and McKusick, 2001; Salama *et al*., 2004; Capote *et al*., 2006). For example, one goat (in T-16h group) with the largest udder yielded over 4 kg/day during top lactation and 3.3 kg over total period even though one kid was allowed to suckle freely during 16 hours a day. Moreover, 3 other goats in the T-24h group yielded about 3 kg/day over total period. This further confirms that that the milk can be shared between kid and human, and that Swedish goats are able to store high amounts of milk within the cistern. Animals with small cisterns, for example cows have higher losses in milk yield during suckling compared to AR reared cows (Marnet and McKusick, 2008; Mendoza *et al*., 2010). After milk let down, goats are able to store the ejected milk in their big cistern, since the kids are not able to empty all milk (especially high producing animals). Salama *et al.* (2004) further describes that once the milk is ejected no milk returns from the cistern to the alveoli if the milking is delayed. Frequent sucklings would therefore enhance milk synthesis in big cisternal goats and prevent that lesser amounts of milk accumulated in the alveoli (Marnet and Komara, 2007), which otherwise inhibit milk synthesis (Wilde *et al*., 1987; Li *et al*., 1999; Fitzgerald *et al*., 2007). This could be an explanation of why animals with small cisterns have higher milk losses during MIX or naturally suckling practices.

The milk composition in this study was positively affected when one kid suckled their dam during 8 weeks and both groups had higher fat content than expected (4.9% and 4.4%). This is higher than from other Swedish dairy breeds (2.6 -3.4%; Torsta getgård, 2010; Norman, 2010) and from Norwegian breeds (3.4%; Geiteboka, 2002). These present findings are in agreement with Cetin *et al*. (2010) who found a higher fat content in suckled goats compared to machine milked goats. The milk protein content in this study also seemed to differ from Swedish dairy goats (AR) in early lactation, where the average protein content in milk from 10 goats was 2.6% between February to May (unpublished data, Torsta getgård, 2010). Both protein (3.2% and 3.1%) and lactose (4.8% and 4.7%) contents in our study differed from Norwegian goats where protein and lactose contents are 2.7% vs. 4.2% respectively (Geiteboka, 2002).

Our study demonstrates that goats kept with one kid increases fat content in milk compared to artificial reared goats. This can be explained by a more efficient milk let down during suckling, since milk rich in fat is only present in the alveoli, and needs a contraction of the myoepithelial cells to be available during milking (Bruckmeier, 2005). More evidently it has been observed that goats reared together with their kids increases oxytocin in plasma during suckling but not during hand milking (Olsson and Högberg, 2008) and that increased levels of oxytocin correlates positively with milk yield, fat and proteins during milking in ewes (Negrao and Marnet, 2003). Furthermore, it has been demonstrated *in vitro* that oxytocin also stimulates intracellular transport off newly synthesized caseins (αS_1-cn). The emptying of the mammary epithelial cells might avoid a negative feedback of accumulation of the milk constituents and may stimulate synthesis of new milk protein (Lolliver *et al*., 2006). Hernandez *et al*. (2002) found that maternal selectivity has a strong influence of prolactin and oxytocin release in goats. The selectivity is dependent of individual olfactory signature from offspring. Both oxytocin and prolactin levels increased over basal levels when suckled by their own kids, but not when suckled by alien kids. Furthermore, in goats with impaired olfactory mucosa were both oxytocin and prolactin levels were similar during suckling by own kids as by suckling by alien kids. Thus, stimuli from the kids play an important role in the modulation of maternal endocrinology in the goat.

Conflicting results has been shown in ewes reared in MIX-systems since they had sufficient milk let down during milking and a cisternal fat content of 2.1% (McKusick *et al*., 2002). The impaired milk ejection described by Marnet and McKusick (2002) is probably due to different rearing systems and different milking managements compared to our study. For example, ewe and lamb were separated for longer periods during night (14h) and was machine milked once daily in the morning, before suckling. Similar results has been found when milking occurred before suckling in natural suckled goats, where the fat content was 1.6-2.2% (Högberg and Dahlborn, 2008, unpublished), These kinds of systems might lead to deficient oxytocin release, where only cisternal milk is available during milking (Cetin *et al*., 2010).

The goats in our study were only separated during 8 hours daytime and were allowed to suckle before each milking, which resulted in a more complete milk let down (both high yield and fat). Further has both Peris *et al*. (1997) and Delgado–Pertinez *et al*. (2009) demonstrated that the fat content is similar between dams reared in MIX-systems compared to AR-goats. In both studies, sucking was performed before milking and kids were separated in some hours before each milking, similar to our study.

Another factor that might be of importance for animals reared in MIX-systems is when the adaption to milking occurs. The successful results from this study (both high fat content and high milk yield) could also be due to that our goats were adapted to machine milking in an early stage of lactation (on day 5). This is not always the case, for example dairy ewes are suckled freely by their lambs without being milked in the beginning of the lactation (Marnet and Komara, 2007). Late adaption to machine milking may affect the milk yield negatively, in particular for animals that give single births. High yielding animals often produce more milk than the offspring can consume, which lead to one udder may halve partly drying off.

In addition, it is not necessary to have the kids present during milking of animals reared in mixed systems (if not suckling and milking occurs simultaneously), since oxytocin levels only increases during suckling, and not when kid is in front of the dam (Olsson and Högberg, 2008).

There were no differences in ADG between T-16h kids, T-24h kids and AR kids. These results are in agreement both Payoya and Florida kids where no differences in ADG were found between natural suckled kids and AR kids (Delgado–Pertinez *et al.*, 2009). Our AR kids had free access to raw goat milk and maybe the results have been different if they have been fed restricted replacer.

Conclusion

This study confirms that it is possible to maintain the amount of milk for human consumption in dairy goat production using MIX–systems, and that the milk composition is positively affected by having goats and kids kept together. It also shows that it is possible to measure casein content in a simple way on-farm, and that the casein number in this study is measured to be 72 ± 5%. Taken together, the results of this study show that improving animal welfare by using MIX-systems also can improve the financial situation for the farmer since the reduced work load of not having to artificially rear the kids can be combined with improved milk properties for goat cheese production.

Acknowledgments

First I would like to thank my supervisor Kristina Dahlborn for your inspiration, support and patience. I could not have done it without you! Also special thanks to Åsa Eriksson for all help with milkings, good handling of the animals and everything else. Thanks to Lisa Olausson for milkings and more, Emma Ternman for making the bras, milkings and more, Louise Vinblad von Walter and her mother for all help and also thanks to Karin Alvåsen for everything. Thank you Sofia, Lars-Ove and Tony for all help with MIRIS.
Thanks to Börje and Lena at Kungsängens lab for help with the calibration for goat milk.
Further thanks to Sören Johansson, Gunilla Drugge, Kerstin Olsson and Eva Sandberg.
And, last but not least, thanks to all the goats and kids at the department!

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