Production of sheep and goat milk depending on breed, forage quality and concentrate level

Doctoral Thesis

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CHAPTER I

INTRODUCTION

The results presented in this thesis emerge from an extensive study focusing on sheep and goat milk production, carried out at the HBLFA Raumberg-Gumpenstein Research and Education Centre for Agriculture in Austria in the years 1998 to 2002. This thesis gives a large part of the results of the project aimed at discovering the influence of different forage quality and different amounts of concentrate supplementation on milk yield and milk contents of different breeds of small ruminants. Sheep and goat husbandry is a promising branch within Austrian agricultural industry with excellent prospects for the future, because goat and sheep milk products are becoming increasingly important for human nutrition and can be the sole alternative for anyone suffering from cow milk allergies. In Austria, consumers' demand for goat and sheep milk products cannot be met, so that large amounts of these products have to be imported.

Only little research has been done on sheep and goat feeding and milk production in Alpine regions, particularly not experiments of this dimension. Results from studies in the Mediterranean area or Africa are only partly applicable to conditions in Austria and regions with similar climate and soil. Therefore, to be able to publish recommendations for practical application on farms, studies need to be conducted close to the particular real life conditions. While many experiments have been carried out with cattle, little attention has been paid to small ruminants. Under prevailing economic circumstances it is important to direct more interest to these species.

Profitableness of goat and sheep milk production depends on the systematic use of feed stuff, as feed intake is one of the most important factors determining milk performance. In Alpine livestock production it is of economic interest to obtain a large proportion of milk from forage, as concentrate is not usually produced on the farm but has to be purchased. Therefore, this study aims at analysing the influence of different forage quality (as received by different times of cutting of grassland) and different amounts of concentrate supplementation on milk performance and milk contents of Austrian Mountain Sheep (AMS), East Friesian Milk Sheep (EMS) and German Dairy Goats (DGD). So far no data on the milking performance of Mountain sheep were available. This study examines whether this breed, which is better adapted to Alpine climate and allows for out-of-season milk production thanks to its breeding behaviour, could represent a true alternative to the Milk sheep.

Furthermore, fattening performance of lambs and kids is determined in the study. If fattening is carried out in a cost-efficient way, meat from progeny of milk sheep and goats can be an important economic factor in dairy farming. Differences in feed intake, daily gains, feed efficiency, and dressing percentage between sheep and goats were examined.

For the feeding trial, 18 animals of each breed were selected and allocated to different groups. They received forage of two different qualities and varying amounts of concentrate. Hay and concentrate intake as well as milk yield and contents were regularly recorded.

Chapter II deals with the aspect of feed intake as affected by forage quality and concentrate administration. The effect on feed intake of hay from meadows cut two or three times was evaluated. Furthermore, the influence of three different levels of concentrate administration (5, 25 and 50% of dry matter intake) on overall feed intake was recorded. The reduction of hay intake due to concentrate supplementation was measured. Breed differences were of special interest. In addition, development of feed intake over the lactation cycle was observed.

Chapter III presents the impact of feed intake on milk production. By influencing energy and protein intake, forage quality and concentrate feeding do not only affect milk yield but also milk contents. The impact of dietary treatments on the different breeds as well as the change in milk yield and content from onset to close of lactation was evaluated.

Results of the fattening experiment are presented in Chapter IV. Twenty-four male Germain Dairy Goat × Boer kids, 35 Mountain Sheep × Suffolk lambs and 21 Milk Sheep × Suffolk lambs were chosen for the experiment. Like their mothers, they received hay from meadows cut two or three times, but concentrate for ad libitum consumption. Breed differences in feed intake, daily gains, feed efficiency, fattening performance, and carcass composition were detected.

Chapter V gives a summary of the results obtained and the conclusions that can be drawn. Chapter VI discusses the outcome of the study and gives a future perspective on the possible impact of the findings, but also demonstrates that application of results regarding high concentrate feeding should be taken with care.

CHAPTER II

Production of sheep and goat milk depending on breed, forage quality and concentrate level
I. Live weight, feed intake and nutrient supply

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Abstract

A three-factorial experiment was carried out to investigate the impact of species/breed, forage quality and concentrate level on live weight (LW) and feed intake (DMI) of female sheep and goats during total lambing intervals. Austrian Mountain Sheep (AMS), East-Friesian Milk Sheep (EMS) and German Dairy Goats (GDG) were chosen for the experiment. By cutting an alpine permanent grassland 2 or 3 times a year (F 2, F 3; 56.8 and 59.8% digestibility of OM), two levels of forage quality were received. Concentrate levels were 5, 25 or 50% of DMI. A total of 235 lactations was tested (100 for AMS, 67 for EMS, 68 for GDG), using 25, 26 and 24 different dams per species/breed. Every new lactation, animals were allocated to a different concentrate level (but not forage quality), according to a latin square design.

Mean live weight was 75, 66 and 54 kg for AMS, EMS and GDG, respectively, as well as 63, 64 and 68 kg for concentrate levels 5, 25 and 50%. Whereas absolute values for DMI were not significantly different between species/breeds (mean of 2.16 kg), DMI related to $LW^{0.75}$ revealed significant differences between species/breeds (78, 85, 100 g/ kg $LW^{0.75}$), showing that animals of higher milk yield potential display a higher feed intake capacity. Increasing the concentrate proportion from 5 to 25 and 50% significantly promoted DMI (1.88, 2.14 and 2.46 kg/d, during lactation). Substitution rate, determined by linear regression, was on average 0.38, the value being higher with high forage quality (0.32 vs. 0.44 in F 2 and F 3). Improving forage quality enhanced DMI from 1.97 to 2.09 kg/d. Diet selection was more pronounced with milk sheep (EMS) than with dairy goats (GDG).

It is concluded that all of the three factors investigated exerted a significant impact on feed intake of lactating as well as dry sheep and goats. Moreover, interactions were discovered between the factors. In general, feed intake was determined either by ruminal fill (high milk

yield – low diet energy concentration) or by energy balance (low energy requirement – high energy concentration). This principally supports the feed intake model established by Mertens (1994), although, in the present study, the animals consumed an amount of more than 12.5 g NDF per kg LW (upper limit for ruminal fill).

Keywords: Sheep, goats, feed intake, forage quality, concentrate level, lactation

1. Introduction

As the demand for goat and sheep milk products is on the rise, goat and sheep husbandry is a promising branch in agricultural industry in Austria, especially in areas where landscape and climate do not permit the keeping of cattle. Profitability of goat and sheep husbandry depends on revenues for milk and expenses for feeding, which normally consists of grass or preserved forage supplemented with procured concentrate. Quality of forage, considered to be one of the most important factors determining feed intake and hence also milk production, depends largely on the time of cutting, i.e. vegetative stage. Apart from Germain Dairy Goats and East-Friesian Milk Sheep, Austrian Mountain Sheep were included in the study. The Mountain sheep is not only more robust and better adapted to alpine climate but also allows for out-of-season milk production due to its breeding behaviour. It was therefore investigated whether this breed could represent a true alternative to the Milk sheep.

Feed intake is influenced by animal-related factors, namely live weight, breed and performance, as well as feed-related factors, especially time spent eating, amount of feed offered, quality and amount of roughage and concentrate (Gruber et al., 1995). The main factors influencing voluntary forage dry matter intake are the quality of forage and the amount of concentrate administered. The composition of plant components, determining feed value, changes over the course of the vegetation period and thus makes time of cutting an essential factor on the quality of roughage and consequently the productivity of livestock. Digestibility of organic matter decreases with advanced stage of vegetation due to an increase of cell wall fractions that are low in digestibility. Relative reduction of leave fraction in proportion to stem fraction leads to a decrease of crude protein in the course of vegetation (Ombabi et al., 2001). Time of cutting therefore has a significant influence on feed intake. At a later stage of growth forage shows lower ingestibility owing to the higher cell wall content. High cell wall

percentage decreases digestion rate and increases the duration of mastication, leading to a reduced intake capacity due to physical feed intake regulation (Dulphy and Demarquilly, 1994).
Concentrate administration reduces the intake of forage (Faverdin et al., 1991; Trabalza-Marinucci et al., 1992), a phenomenon known as substitution effect. Concentrates normally are rich in easily degradable carbohydrates and cause a reduction in pH value in the rumen as a result of reduced rumination and a reduction of buffering saliva. This in turn reduces the activity of cellulolytic bacteria which are responsible for fibre degradation. As a consequence, forage intake decreases (Orskov, 1986). Forage-to-concentrate substitution rate varies with type of animal, amount of concentrate, nature and quality of forage, and energy requirements of the animal (Dulphy, 1987), as well as with the energy balance of the animal (Faverdin et al., 1991).

Animal performance markedly influences feed intake. During the last weeks of pregnancy, a decline in feed intake is observed which results from the compression of the rumen by the growing uterus as well as hormonal changes and discomfort (Forbes, 1968; Forbes, 1971). Lactating goats and sheep reach their maximum feed intake about six to eight weeks after parturition, whereas milk yield peaks earlier. During the first weeks after parturition energy intake from feed cannot meet the high energy demand for milk production which results in intense mobilization of body lipids. Weight loss is more pronounced with poor quality food and forage diets compared to concentrates (Forbes, 1971). During the second half of lactation, energy intake by feed is higher than requirements for maintenance and milk production so that body fat can be restored (INRA, 1989; Cannas, 2004). Higher feed and energy requirements during lactation in high producing animals can only be met by feed stuff with higher energy concentration (Cannas, 2004).

Differences between goats and sheep concerning diet selection, feed intake and feed digestibility have been discussed repeatedly with controversial findings. Goats markedly select feeds at the trough (Morand-Fehr, 2003) and their browsing characteristic is reflected by the considerable difference in nutrient content of feed offered and feed refused (Randy et al., 1988). Sheep do not seem to have developed as distinct a capacity to select the more nutritious parts of the forage offered (Lu, 1988) and therefore make less refusals than goats do (Morand-Fehr, 2003). Goats prefer pellets or coarse flour as they are easier to ingest than fine particle flour (Morand-Fehr, 2003). By selecting hay parts that are richer in protein, as are leaves and tips, goats are able to augment the protein content of the diet (Fedele et al., 2002). If goats are able to apply diet selection on account of high food allowances, they are able to improve dry matter intake, diet nutrient balance and subsequently also potential production

(Lindberg and Gonda, 1997). Selective feeding behaviour has also been found in sheep. Fernàndez-Rivera et al. (1994) stated that, if food was offered in excess, sheep chose parts of food with a lower concentration of ADF. Abijaoudé et al. (2000) conclude that because of their more pronounced selective feeding behaviour, goats have lower intake rates, whereas Simiane et al. (1981) found higher intakes in goats. Dulphy et al. (1994) stated that dry matter intakes were similar in sheep and goats except for low quality roughages where intake by goats was higher. This is in line with the long prevailing assumption that goats are superior to sheep in digesting diets rich in fibre (Devendra and Burns, 1980; cit. Lindberg and Gonda, 1997). However, recent reports indicate that there is no species difference in fibre digesting capacity between sheep and goats (Lindberg and Gonda, 1997). Several studies suggest that sheep are able to more completely digest low quality, high roughage diets due to longer retention times while goats show higher DM intakes and faster removal of non digested particles from the rumen (Brown and Johnson, 1985). Huston et al. (1986) as well as Quick and Dehority (1986) suggest that sheep and goats may differ in passage rate of rumen digesta, but differences are inconsistent and affected by the nature of diet. Tolkamp and Brouwer (1993) conclude that the overall difference in organic matter digestibility between goats and sheep is very small. Other factors, such as voluntary intake level and selecting capacity, are considered to be more important for animal production levels. Also, Ndosa (1980; cit. Tolkamp and Brouwer, 1993) states that differences in digestibility between different breeds within species may be of the same order of magnitude as differences between species.

The objective of this study was to investigate the influence of different times of cutting of alpine permanent grassland and different amount of concentrate supplementation as well as breed and species on feed and nutrient intake of sheep and goats. The milk production data are presented by Pöckl et al. (in preparation).

2. Material and methods

2.1 Experimental design

The experimental design was a three-factorial arrangement consisting of the following treatments and their levels, including all possible interactions, and resulting in 18 subclasses (3 species/breed × 2 forage quality × 3 concentrate levels, Table 1):

Factor Species/Breed: Austrian Mountain Sheep (AMS)
East-Friesian Milk Sheep (EMS)
German Dairy Goat (GDG)

Factor Forage quality: 2 cuts per year (F 2)
3 cuts per year (F 3)

Factor Concentrate level: 5% of DM intake (C 05)
25% of DM intake (C 25)
5% of DM intake (C 50)

Table 1: Experimental design

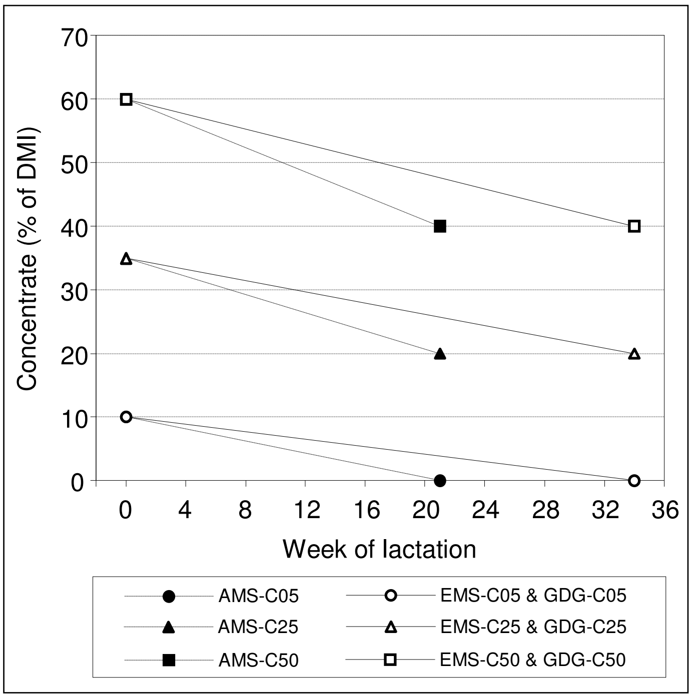
Species/Breed	Austrian Mountain Sheep		East-Friesian Milk Sheep		German Dairy Goat	
Grassland cuts per year	2	3	2	3	2	3
Concentrate level 5%	AMS-2-05	AMS-3-05	EMS-2-05	EMS-3-05	GDG-2-05	GDG-3-05
Concentrate level 25%	AMS-2-25	AMS-3-25	EMS-2-25	EMS-3-25	GDG-2-25	GDG-3-25
Concentrate level 50%	AMS-2-50	AMS-3-50	EMS-2-50	EMS-3-50	GDG-2-50	GDG-3-50

2.2 Animals and diets

Animals (30 Austrian Mountain Sheep, 30 East-Friesian Milk Sheep, 30 German Dairy Goats were reared under identical conditions with ad libitum hay intake plus concentrate. Eighteen animals (9 for each forage group) of each species/breed were chosen for the feeding experiment based on their milking performance and feed intake in first lactation to obtain groups with animals of similar milk production potential. The remaining dams were kept as a reserve to replace animals that had to be removed from the experiment due to diseases or death. In total, for cutting frequency 2 and 3, respectively, 11 and 14 AMS were used, while number of animals was 12 and 14 for EMS and 11 and 13 for GDG.

Diets consisted of hay of two different qualities resulting from either two or three cuttings of a homogenous alpine permanent grassland area (that had been divided into two parts at the beginning of the experiment). The harvests of the two, respective three cuttings were thoroughly mixed to receive one quality of forage within forage group (F) which was fed throughout the whole year. Additionally, three levels of concentrate (C) were administered to the animals (5%, 25% or 50% of daily dry matter (DM) intake), resulting in six different treatments. However, concentrate supplementation was to some extent adjusted to the productive requirements of the animals in so far as the administration of concentrate was slightly beyond the given percentage in early lactation and slightly below in late lactation (see Fig. 1). The concentrate was composed of 30% barley, 15% maize, 15% oats, 15% dried sugar beet pulp, 9% soybean meal, 8% rapeseed meal, 3% molasses, 3% minerals and 2% limestone (on as fed basis). The concentrate was designed to contain 16.7% CP, 12.2 MJ ME, 1.2% Ca and 9.0% P (on a DM basis). The amount of concentrate was calculated every Monday based on the average daily feed intake of the previous week.

Fig. 1. Concentrate proportion of the diet in the experimental groups during lactation



Goats and sheep were randomly assigned to one of the six treatments (3 animals of each breed per block). With every new lactation the animals were allocated to a different dietary treatment (i.e. concentrate level, but not forage quality) following the principles of a latin square as shown in Table 2. During the experimental period, lactations two to five of EMS and GDG were examined. AMS completed five to eight lactations during the same period of time. A full lactation lasted 240 days for EMS and GDG whereas it was only 150 days for AMS.

Animals were kept in individual tie stalls with free access to water. They were exercised for one hour a day. Feeding took place twice a day (in the morning and late afternoon). Feed offered and refused was weighed daily for the individual animals to determine daily feed intake. Daily adjustments were made for the hay offered to ensure ad libitum intake. In the dry period, animals were fed solely with forage; only in the last weeks before parturition did they receive small amounts of concentrate.

Table 2: Allocation of the animals to the concentrate levels according to a latin square design

Forage quality		Concentrate level		
		C 05	C 25	C 50
2 cuttings per year	2nd lactation	1, 2, 3	4, 5, 6	7, 8, 9
	3rd lactation	7, 8, 9	1, 2, 3	4, 5, 6
	4th lactation	4, 5, 6	7, 8, 9	1, 2, 3
	5th lactation	1, 4, 7	2, 5, 8	3, 6, 9
3 cuttings per year	2nd lactation	10, 11, 12	13, 14, 15	16, 17, 18
	3rd lactation	16, 17, 18	10, 11, 12	13, 14, 15
	4th lactation	13, 14, 15	16, 17, 18	10, 11, 12
	5th lactation	10, 13, 16	11, 14, 17	12, 15, 18

1, 2, 3 – 4, 5, 6 – 7, 8, 9 are animals which were allocated to the concentate levels in different lactations within low forage quality (2 cuts)
10, 11, 12 – 13, 14, 15 – 16, 17, 18 are animals which were allocated to the concentate levels in different lactations within high forage quality (3 cuts)

2.3 Determination of feed value by chemical analysis and digestibility in vivo

Daily samples of feed offered and feed refused were analysed for dry matter content. Samples were combined to a composite and sent to the laboratory for chemical analysis every fortnight. Samples of hay refused were analysed separately for each breed and each forage quality. Samples of forage and concentrate were analysed for crude protein (CP), crude fat (EE), crude fibre (CF), N free extracts (NFE) and crude ash (Cash) according to conventional methods (Weende analysis), as described by VDLUFA (1976) and ALVA (1983) using devices of Tecator®. The cell wall substances (NDF, ADF, ADL) were analyzed as proposed by Van Soest et al. (1991), also using equipment of Tecator®. Additionally, content of minerals (Ca, P, Mg, K, Na) and trace elements (Mn, Zn, Cu) were determined using atomic absorption spectroscopy.

The digestibility of the two hays (mixtures of 2 and 3 cuttings, respectively) was determined *in vivo* in each of the 4 harvest years (1997, 1998, 1999, 2000) using 4 adult wethers per forage. The digestibility of the concentrate was measured according to the difference principle (50% test feed, 50% hay), underlying the known digestibility of the hay. The digestibility trials were carried out according to the guidelines for the determination of digestibility of nutrients in ruminants as proposed by GfE (1991). The animals received an amount of 1.0 kg DM of the experimental feed in order to reach a feeding level of about 1.2 – 1.5 of maintenance requirements. The trials lasted 4 weeks (2 weeks preliminary period, 2 weeks collection period). The animals were equipped with harnesses and bags for sampling of faeces. The amount of feed ingested and faeces excreted was weighed twice daily. The faeces were sampled and stored at 4°C. At the end of the collection period, all samples were mixed and subsequently analysed.

The energy and protein evaluation of the feeding stuffs was carried out according to the proposals of GfE (2001) and GfE (2003):

$$ME\ (MJ/kg) = 0.0312 \times g\ DEE + 0.0136 \times g\ DCF + 0.0147 \times g\ (DOM - DEE - DCF) + 0.00234 \times g\ CP \quad (1)$$

ME = metabolizable energy (MJ/kg)

DEE, DCF, DOM = digestible EE, CF, OM (g/kg); CP = crude protein (g/kg)

$$uCP\ (g/kg) = [11.93 - (6.82 \times (UDP/CP))] \times ME + 1.03 \times UDP \quad (2)$$

uCP = utilizable crude protein at duodenum (g/kg)

UDP = undegraded crude protein (g/kg), CP = crude protein (g/kg)

ME = metabolizable energy (MJ/kg)

$$RNB\ (g/kg) = (CP - uCP)/6.25$$

RNB = ruminal nitrogen balance (g/kg)

CP = crude protein (g/kg), uCP = utilizable crude protein at duodenum (g/kg)

2.4 Live weight

Live weight (LW) was recorded once a week after milking during the first three months of lactation and every two weeks during the following months. Weight of wool was recorded after shearing. AMS were shorn at lambing whereas EMS were clipped at lambing as well as before mating. Live weight change (LWC) was calculated from the first derivative of polynomial regressions of LW on experimental weeks.

2.5 Mating

Milk sheep and goats were mated in September or October, whereas AMS were mated every six months. EMS were bred to a Suffolk ram, goats were covered with a Boer buck. Weights of dams after lambing as well as birth weight of lambs were recorded. Lambs were weaned immediately after birth and male lambs were allocated to the fattening experiment (Pöckl et al., in preparation) in order to get information of the total productivity of the species/breed (milk <u>and</u> meat performance).

2.6 Statistical analysis

The number of total lactations in the several subclasses available for statistical evaluation is presented in Table 3. It was aimed at receiving a minimum of 10 full lactations per subclass in

EMS and GDG, whereas AMS completed 16 – 18 lactations during the same experimental period.

Data were analyzed by multifactor analysis of variance procedures, the main effects being species/breed, cutting frequency, level of concentrate administration and parity, together with their two-way interactions, and considering the animal as a random effect, using the statistical package of Harvey (1987). Multiple comparisons were carried out to identify statistically significant differences among means, applying the test of Student-Newman-Keuls ($P \leq 0.05$) of Statgraphics (2000). Significant differences between means are indicated by different superscripts in the tables of results. The values in the tables of results are least squares-means, RSD is the pooled standard deviation within treatment groups (root mean square of remainder).

Table 3: Number of total lactations in the subclasses

Forage quality	Concentrate level			
	Total	C 05	C 25	C 50
Austrian Mountain Sheep				
2 cuttings per year	51	16	17	18
3 cuttings per year	52	17	18	17
East-Friesian Milk Sheep				
2 cuttings per year	33	12	11	10
3 cuttings per year	34	10	12	12
German Dairy Goat				
2 cuttings per year	35	12	11	12
3 cuttings per year	34	11	11	12

3. Results

3.1 Experimental feed stuff

The average chemical composition of hay and concentrate during the four years of experimentation is presented in Table 4. The intended difference in energy and protein content between the 2-cut and 3-cut hay was not attained to the expected extent. Protein content averaged 118 and 127 g/kg DM, respectively, while crude fibre content was 326 and 306 g. The corresponding values for NDF were 619 and 594 g/kg DM. The difference in OM digestibility between the 2-cut and the 3-cut hay was only 3.0% (56.8 vs. 59.8%). Resulting energy concentration was 7.98 and 8.41 MJ ME/kg DM. The content of utilizable crude protein (uCP) was below that of crude protein, leading to a slightly positive ruminal N balance (RNB). The concentrate showed very high OM digestibility (87.0%) and energy concentration (12.30 MJ ME/kg DM). The protein content and degradability of the concentrate was designed to result in similar RNB as that of the forages (-0.6 g/kg DM). Hence, a similar RNB was attained in all forage quality and concentrate level subclasses.

Table 4: Nutrient content of the experimental feeds (means ± standard deviations)

		2-cut hay	3-cut hay	concentrate
Number of samples		49	50	49
Dry matter	g/kg FM	926 ± 13	927 ± 13	914 ± 9
Crude nutrients				
crude protein	g/kg DM	118 ± 9	127 ± 16	171 ± 11
crude fat	g/kg DM	16 ± 2	17 ± 2	20 ± 3
crude fibre	g/kg DM	326 ± 17	306 ± 14	77 ± 5
N free extracts	g/kg DM	479 ± 16	488 ± 16	645 ± 15
crude ash	g/kg DM	61 ± 7	63 ± 6	87 ± 4
Cell walls				
NDF	g/kg DM	619 ± 20	594 ± 17	199 ± 6
ADF	g/kg DM	373 ± 14	356 ± 12	97 ± 4
ADL	g/kg DM	46 ± 1	45 ± 1	21 ± 0.5
Digestibility				
organic matter	%	56.8 ± 2.5	59.8 ± 2.1	87.0
crude protein	%	57.2 ± 0.8	58.2 ± 0.7	83.8
crude fat	%	23.2 ± 1.1	24.5 ± 0.9	76.4
crude fibre	%	55.5 ± 1.2	56.9 ± 1.0	37.5
N free extracts	%	58.6 ± 3.7	63.1 ± 3.2	93.8
NDF	%	54.7 ± 2.2	57.4 ± 1.9	63.3
ADF	%	52.4 ± 2.1	54.9 ± 1.7	54.6
ME content	MJ/kg DM	7.98 ± 0.34	8.41 ± 0.32	12.30 ± 0.06
Protein value				
uCP	g/kg DM	110 ± 4	116 ± 6	175 ± 4
UDP	% of CP	22.3 ± 0.7	21.4 ± 0.7	30.8
RNB	g/kg DM	1.3 ± 1.1	1.7 ± 1.7	-0.6 ± 1.2
Minerals				
Calcium	g/kg DM	5.5 ± 0.6	5.7 ± 0.7	12.8 ± 2.4
Phosphorus	g/kg DM	2.7 ± 0.3	3.0 ± 0.3	5.4 ± 0.6
Magnesium	g/kg DM	2.4 ± 0.4	2.5 ± 0.4	4.8 ± 1.0
Potassium	g/kg DM	14.8 ± 1.8	15.6 ± 2.0	11.5 ± 1.7
Sodium	g/kg DM	0.27 ± 0.07	0.23 ± 0.07	2.84 ± 0.40
Trace elements				
Manganese	mg/kg DM	162 ± 7	171 ± 6	84 ± 4
Zinc	mg/kg DM	41 ± 1	43 ± 1	208 ± 5
Copper	mg/kg DM	7.2 ± 0.2	7.5 ± 0.2	9.8 ± 0.3

3.2 Live weight and live weight change

The mean live weight and live weight change in lactation and dry period is presented in Table 5 for the main effects and in Table 6 for the interaction species/breed × concentrate level, together with their significance levels (P values) and the pooled residual standard deviation (RSD). The tables give values for the different production phases: *lactation*, *dry period* and the total cycle of production (*lambing interval*). The mean live weight of the animals was 78.2, 68.6 and 55.9 kg during the total production cycle for the species/breeds AMS, EMS and GDG, respectively. Live weight was considerably higher in the dry period than during lactation (72.2 vs. 64.9 kg, over all species/breeds). Mean live weight gain in AMS was higher than in EMS and GDG (496, 369 and 325 g/day). The development of live weight during the whole lambing interval is shown in Fig. 2. Apart from the factor species/breed, the development of live weight is significantly influenced by the level of concentrate. During lactation, change of live weight is only small (and clearly depending on concentrate level), whereas there is a distinct increase in live weight in the dry period due to foetal development and retention of body mass. With low concentrate feeding, the animals of all species/breeds lost weight in the first weeks of lactation whereas (with the exception of week one) they gained weight with concentrate levels 25 and 50%. Live weight was also significantly influenced by the quality of forage (65.8 vs. 69.2 kg in treatments F2 and F3) and the concentrate level (65.1, 66.2 and 71.4 kg in concentrate levels 5, 25 and 50%). Regarding live weight, no interaction between the main effects was found. However, as to live weight change, the effect of concentrate level was significantly influenced by species/breed. When fed on higher amounts of concentrate, animals of higher milk yield potential (EMS and GDG) increased live weight to a lesser extent than the lower yielding AMS (Table 6).

Fig. 2. Development of live weight during lambing interval as influenced by species/breed and concentrate level

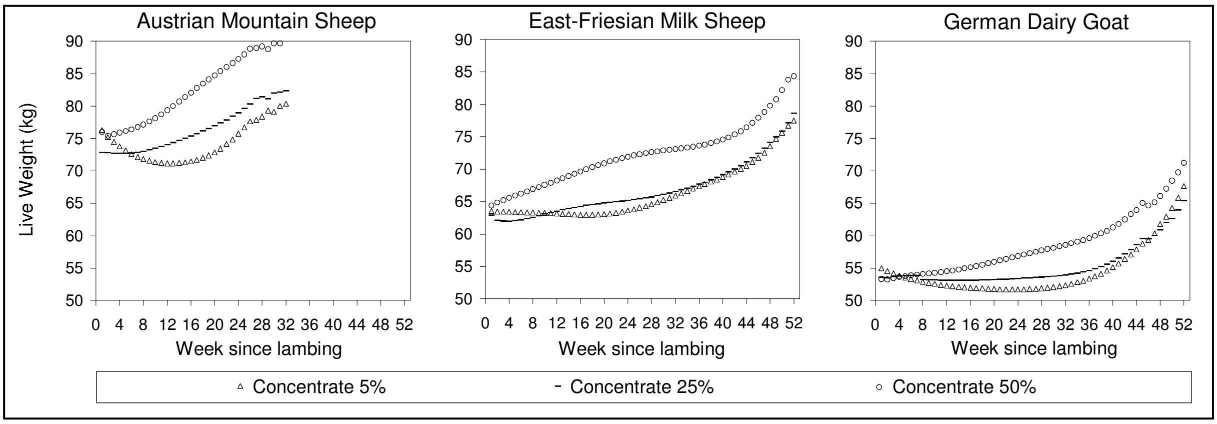


Table 5: Feed and nutrient intake during lactation and dry period (Main effects)

Parameter	Unit	Phase	Species/Breed (S/B)			Forage quality (F)		Concentrate level (C)			P values			RSD
			AMS	EMS	GDG	2 cuts	3 cuts	C 05	C 25	C 50	S/B	F	C	
Number of observations			100	67	68	116	119	77	78	80				
Live weight	kg	L	75.1^{a}	65.7^{b}	53.8^{c}	63.1^{a}	66.6^{b}	62.5^{a}	63.6^{a}	68.4^{b}	0.000	0.001	0.000	7.8
	kg	D	83.2^{a}	72.8^{b}	60.6^{c}	70.2^{a}	74.2^{b}	68.7^{a}	70.6^{a}	77.3^{b}	0.000	0.000	0.000	7.9
	kg	T	78.2^{a}	68.6^{b}	55.9^{c}	65.8^{a}	69.2^{b}	65.1^{a}	66.2^{a}	71.4^{b}	0.000	0.001	0.000	7.7
Live weight	g/d	L	197^{a}	134^{a}	57^{b}	109	150	-75^{a}	133^{b}	329^{c}	0.000	0.128	0.000	200
change	g/d	D	988^{a}	701^{b}	887^{a}	820	897	891	844	841	0.000	0.085	0.594	335
	g/d	T	496^{a}	369^{b}	325^{b}	381	412	308^{a}	389^{b}	493^{c}	0.000	0.138	0.000	154
Forage	g DM/d	L	1555	1478	1524	1453^{a}	1585^{b}	1761^{a}	1546^{b}	1250^{c}	0.127	0.000	0.000	230
	g DM/d	D	1608	1707	1637	1616	1685	1701	1611	1640	0.099	0.064	0.137	281
	g DM/d	T	1571	1567	1556	1514^{a}	1615^{b}	1741^{a}	1571^{b}	1381^{c}	0.915	0.001	0.000	225
Concentrate	g DM/d	L	648	637	635	630	650	120^{a}	590^{b}	1210^{c}	0.681	0.120	0.000	100
	g DM/d	D	206^{a}	108^{b}	171^{a}	161	163	153	164	168	0.000	0.886	0.691	115
	g DM/d	T	463	447	485	454	476	127^{q}	421^{b}	847^{c}	0.131	0.130	0.000	110
Total	g DM/d	L	2203	2115	2159	2083^{a}	2235^{b}	1881^{a}	2136^{b}	2460^{c}	0.207	0.000	0.000	302
	g DM/d	D	1814	1814	1808	1776^{a}	1848^{b}	1854	1775	1808	0.986	0.054	0.222	278
	g DM/d	T	2033	2014	2041	1968^{a}	2091^{b}	1868^{a}	1992^{b}	2228^{c}	0.842	0.001	0.000	272
Total	g/kg $LW^{0.75}$	L	86.9^{a}	91.5^{b}	109.2^{c}	94.0^{a}	97.7^{b}	85.9^{a}	96.5^{b}	105.2^{c}	0.000	0.025	0.000	12.4
	g/kg $LW^{0.75}$	D	66.3^{a}	73.0^{b}	83.3^{c}	74.2	74.3	78.4^{a}	73.8^{b}	70.5^{c}	0.000	0.959	0.000	9.6
	g/kg $LW^{0.75}$	T	77.8^{a}	84.5^{b}	100.2^{c}	86.2	88.8	82.6^{a}	87.4^{b}	92.5^{c}	0.000	0.074	0.000	10.8
ME	MJ/d	L	20.85	20.07	20.35	19.48^{a}	21.36^{b}	15.99^{a}	20.02^{b}	25.25^{c}	0.234	0.000	0.000	2.85
	MJ/d	D	15.87	15.36	15.45	14.88^{a}	16.24^{b}	15.88	15.26	15.54	0.404	0.000	0.314	2.49
	MJ/d	T	18.69	18.42	18.74	17.75^{a}	19.48^{b}	15.90^{a}	18.12^{b}	21.83^{c}	0.737	0.000	0.000	2.55
ME	kJ/kg $LW^{0.75}$	L	820^{a}	866^{b}	1028^{c}	878^{a}	932^{b}	731^{a}	904^{b}	1080^{c}	0.000	0.001	0.000	117
	kJ/kg $LW^{0.75}$	D	580^{a}	618^{b}	714^{c}	622^{a}	653^{b}	671^{a}	635^{b}	606^{c}	0.000	0.008	0.000	88
	kJ/kg $LW^{0.75}$	T	715^{a}	771^{b}	919^{c}	777^{a}	827^{b}	704^{a}	795^{b}	907^{c}	0.000	0.000	0.000	102
CP	g DM/d	L	309	295	297	288^{a}	313^{b}	240^{a}	295^{b}	366^{c}	0.097	0.000	0.000	42
	g DM/d	D	239^{a}	227^{b}	223^{b}	224^{a}	235^{b}	235	225	229	0.017	0.036	0.304	38
	g DM/d	T	279	271	273	264^{a}	285^{b}	238^{a}	267^{b}	318^{c}	0.457	0.000	0.000	38
NDF	g DM/kg LW	L	14.45^{a}	15.58^{b}	19.77^{c}	16.51	16.68	17.84^{a}	17.01^{b}	14.95^{c}	0.000	0.592	0.000	2.36
	g DM/kg LW	D	12.26^{a}	14.55^{b}	17.02^{c}	15.00^{a}	14.22^{b}	15.64^{a}	14.57^{b}	13.63^{c}	0.000	0.004	0.000	2.04
	g DM/kg LW	T	13.48^{a}	15.17^{b}	18.78^{c}	15.91	15.71	16.93^{a}	16.06^{b}	14.45^{c}	0.000	0.478	0.000	2.09

Phase: L = lactation, D = dry period, T = total period (lactation and dry period)

Table 6: Feed and nutrient intake during lactation and dry period (Interaction Species/Breed × Concentrate level)

Parameter	Unit	Phase	Austrian Mountain Sheep			East-Friesian Milk Sheep			German Dairy Goat			P values		
			C 05	C 25	C 50	C 05	C 25	C 50	C 05	C 25	C 50	S/B × C	S/B × F	C × F
Number of observations			33	33	34	22	23	22	22	22	24			
Live weight	kg	L	72.0	73.8	79.4	62.9	64.2	70.0	52.6	52.8	55.9	0.686	0.297	0.985
	kg	D	77.9	81.8	89.9	69.3	71.3	77.7	58.8	58.6	64.4	0.323	0.602	0.982
	kg	T	74.4	77.0	83.1	66.2	67.0	72.6	54.7	54.6	58.5	0.590	0.363	0.987
Live weight	g/d	L	-174	230	534	20	117	265	-69	52	189	0.000	0.799	0.164
change	g/d	D	1108	950	905	666	707	730	899	875	888	0.281	0.428	0.802
	g/d	T	323	508	657	339	349	420	263	309	403	0.000	0.645	0.718
Forage	g DM/d	L	1749	1617	1298	1749	1478	1207	1785	1543	1244	0.553	0.063	0.054
	g DM/d	D	1675	1592	1559	1779	1686	1654	1649	1554	1706	0.339	0.328	0.849
	g DM/d	T	1718	1599	1395	1771	1572	1358	1734	1542	1391	0.769	0.108	0.278
Concentrate	g DM/d	L	109	608	1227	130	582	1198	121	579	1205	0.652	0.007	0.871
	g DM/d	D	203	197	218	100	108	115	154	187	172	0.917	0.851	0.751
	g DM/d	T	138	423	826	114	390	838	129	450	877	0.576	0.229	0.501
Total	g DM/d	L	1858	2225	2526	1879	2060	2406	1906	2123	2449	0.509	0.019	0.242
	g DM/d	D	1878	1788	1777	1879	1795	1769	1803	1741	1879	0.404	0.422	0.818
	g DM/d	T	1856	2023	2221	1885	1961	2197	1863	1992	2267	0.864	0.051	0.495
Total	g/kg $LW^{0.75}$	L	75.7	89.0	95.9	84.3	90.9	99.3	97.7	109.5	120.5	0.491	0.002	0.210
	g/kg $LW^{0.75}$	D	71.8	66.1	61.1	78.3	73.2	67.6	84.9	82.2	82.8	0.147	0.188	0.761
	g/kg $LW^{0.75}$	T	73.7	78.3	81.5	81.4	83.8	88.3	92.9	100.0	107.7	0.391	0.008	0.420
ME	MJ/d	L	15.76	20.87	25.91	16.05	19.39	24.75	16.16	19.80	25.09	0.470	0.025	0.272
	MJ/d	D	16.32	15.64	15.64	15.91	15.18	14.99	15.40	14.95	16.00	0.577	0.506	0.780
	MJ/d	T	15.85	18.46	21.77	16.00	17.74	21.53	15.84	18.17	22.20	0.857	0.060	0.475
ME	kJ/kg $LW^{0.75}$	L	642	835	983	720	856	1022	829	1021	1234	0.234	0.002	0.181
	kJ/kg $LW^{0.75}$	D	625	578	539	664	619	573	726	708	707	0.275	0.181	0.741
	kJ/kg $LW^{0.75}$	T	631	715	799	691	758	866	789	913	1055	0.119	0.008	0.322
CP	g DM/d	L	237	310	380	242	285	358	242	289	361	0.252	0.034	0.251
	g DM/d	D	244	238	237	237	224	219	223	214	230	0.528	0.588	0.801
	g DM/d	T	238	277	322	241	261	312	235	264	320	0.713	0.088	0.417
NDF	g DM/kg LW	L	15.12	15.07	13.15	17.28	15.70	13.76	21.11	20.28	17.92	0.370	0.002	0.301
	g DM/kg LW	D	13.54	12.30	10.95	15.79	14.65	13.20	17.59	16.76	16.72	0.171	0.250	0.777
	g DM/kg LW	T	14.43	13.77	12.25	16.56	15.37	13.59	19.79	19.04	17.51	0.899	0.015	0.569

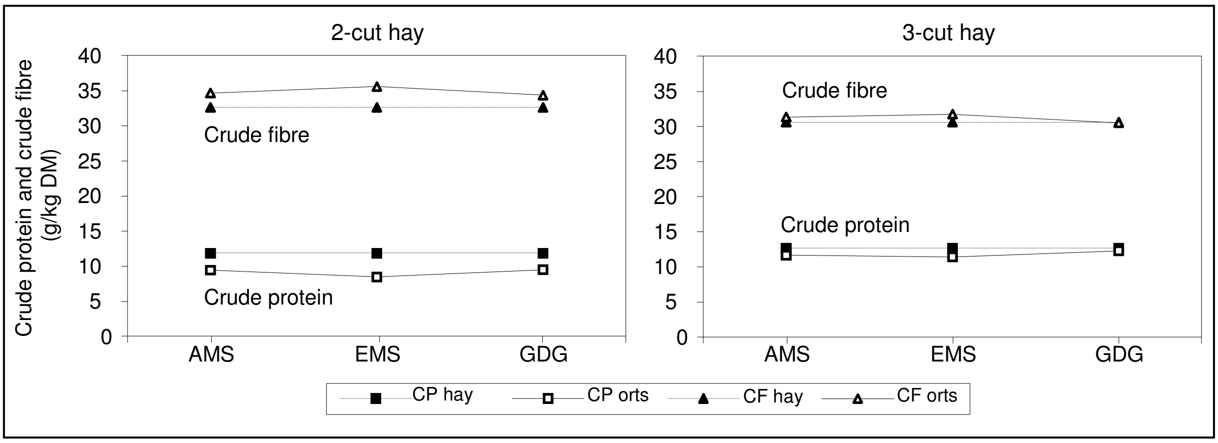
Phase: L = lactation, D = dry period, T = total period (lactation and dry period)

3.3 Feed intake in lactation and dry period

During the whole lambing interval, total DM intake was not significantly influenced by species/breeds (2.03, 2.01 and 2.04 kg DM per day for AMS, EMS and GDG). On the other hand, both forage quality (1.97 vs. 2.09 kg DM in F2 and F3) and concentrate level (1.87, 1.99, 2.23 kg DM in C 05, C 25 and C 50) significantly influenced DM intake (Table 5). During lactation, a substitution rate of 0.38 was evaluated (based on linear regression), the value being higher with high forage quality (0.32 vs. 0.44 in 2-cut and 3-cut hay). Even though DM intakes as absolute values did not differ for the species/breeds, GDG consumed significantly more feed when intake was expressed as g/kg $LW^{0.75}$ (78, 85 and 100 g DM/kg $LW^{0.75}$ for AMS, EMS and GDG). Regarding forage quality, feed intake related to metabolic live weight was below level of significance (P = 0.074), as animals in the high forage quality group were heavier than those in the low forage quality group.

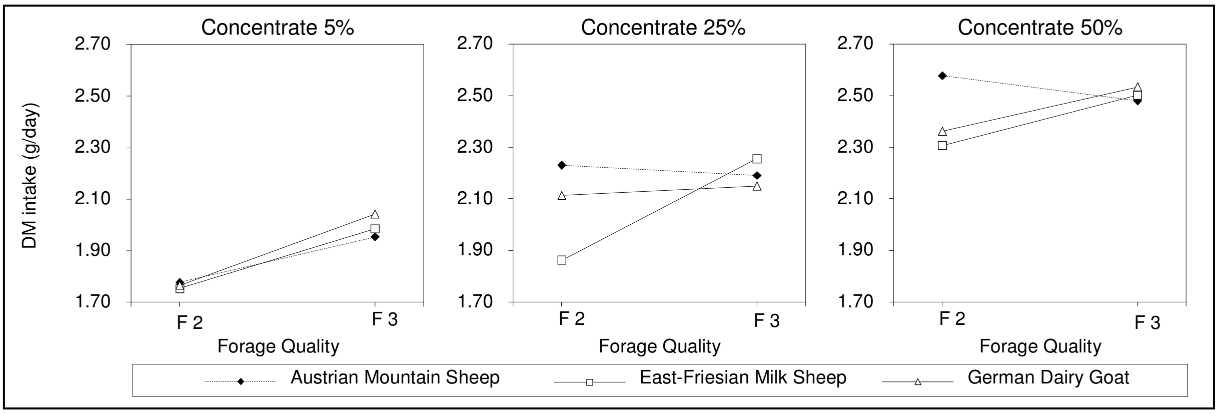
All experimental factors (species/breed, concentrate level and forage quality) influenced the extent of diet selection. The amount of orts was 13.4, 12.4 and 13.8% of hay offered for species/breeds AMS, EMS and GDG (P = 0.033); 11.4, 13.1 and 15.1% for concentrate levels 5, 25 and 50% (P = 0.000) and 13.3 and 13.1% for 2-cut and 3-cut hay (P = 0.536). There was no interaction between main effects concerning relative amount of feed refusals. These results are confirmed by the nutrient content of orts (Fig. 3). Protein content of orts was reduced (and crude fibre content was increased) to a greater extent in the 2-cut hay than in the 3-cut hay. The difference in nutrient content between forage offered and refused was greatest in EMS (which also had the smallest amount of refusals). Diet selection was reduced with forage of better quality, especially in dairy goats.

Fig. 3. Nutrient content of the orts as influenced by forage quality and species/breed



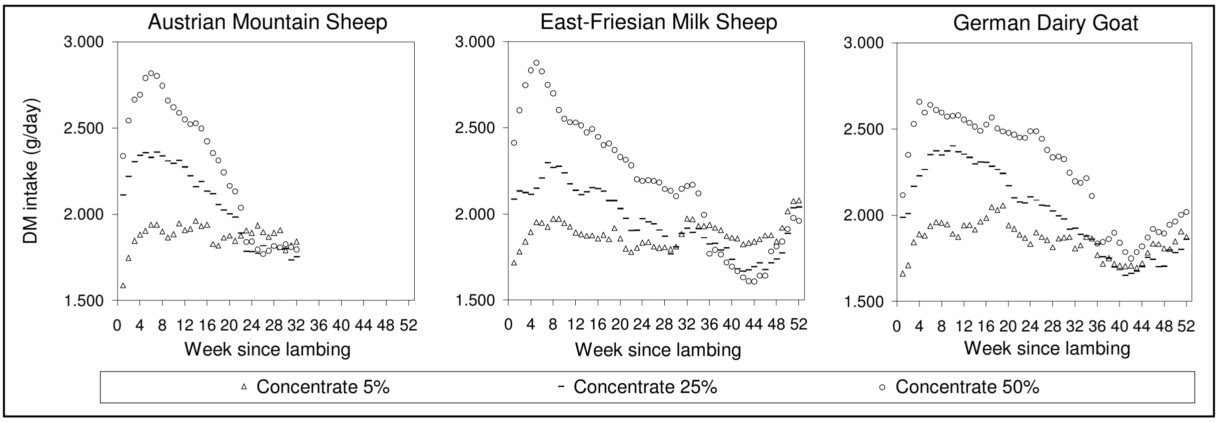
According to the experimental plan, concentrate intake during lactation increased from 0.12 to 0.59 and 1.21 kg DM per day in concentrate levels 5, 25 and 50%, whereas there was no difference in concentrate intake in the dry period (0.15, 0.16 and 0.17 kg DM). Regarding the whole production cycle, forage intake was very similar for the species/breeds (1.57, 1.57 and 1.56 kg for AMS, EMS and GDG). No significant interaction was found between species/breeds and concentrate level concerning forage, concentrate and total DM intake (Table 6). However, animals of different species/breeds reacted to forage quality in a significantly different way. AMS did not increase DM intake with forage quality (2.20 vs. 2.21 kg DM with low and high forage quality), whereas both EMS and GDG showed the expected increase in DM intake with higher forage quality (1.98 vs. 2.25 kg DM for EMS and 2.08 vs. 2.24 kg DM for GDG, data not shown). Moreover, the interaction species/breed × forage quality interfered with concentrate level (Fig. 4). At the 5% concentrate level AMS increased feed intake with forage quality, but with higher concentrate levels AMS reduced feed intake with the 3-cut hay.

Fig. 4. Mean DM intake as influenced by species/breed, concentrate level and forage quality



The development of total DM intake during the whole lambing interval is shown in Fig. 5. The influence of concentrate level on the development of DM intake during lactation was similar in all species/breeds. There was only a small increase of feed intake at the onset of lactation with concentrate level C 05, whereas higher levels of concentrate administration (C 25 and C 50) induced a distinct rise, followed by a steep decline after peak of lactation. The decrease in intake after climax was especially strong with concentrate level C 50. There was an increase in feed intake in the dry period in EMS and GDG, but not in AMS.

Fig. 5. Development of DM intake of the diet during lambing interval depending on species/breed and concentrate level



3.4 Nutrient intake in lactation and dry period

As with DM intake, energy intake did not differ significantly between species/breeds when regarded as absolute values (18.7, 18.4 and 18.7 MJ ME per day for AMS, EMS and GDG, respectively). However, when intake was related to kg metabolic live weight, energy intake showed significant differences between species/breeds (820, 866 and 1028 kJ ME/kg $LW^{0.75}$ for AMS, EMS and GDG, lactational phase). As expected, ME intake significantly increased with forage quality (19.5 and 21.4 MJ ME) and concentrate level (16.0, 20.0 and 25.3 MJ ME), due to the higher DM intake as well as elevated ME concentration of the diet.

Crude protein intake was not significantly different for the three breeds (279, 271 and 273 g CP/day in AMS, EMS and GDG). However, CP intake increased with forage quality (264 vs. 285 g CP) and concentrate level (238, 267, and 318 g CP), due to enhanced DM intake and CP content of the forage. NDF intake significantly differed between species/breeds, the values being 13.5, 15.2 and 18.8 g NDF/kg LW and indicating that NDF intake increased with milk yield potential of the animals. NDF intake was the same in the two forage qualities (15.9 vs. 15.7 g NDF/kg LW), but was reduced with increasing concentrate level (16.9, 16.1 and 14.5 g NDF/kg LW). As with DM intake, an interaction of the main effects was found only between species/breeds and forage quality. Regarding nutrient intake, AMS did not respond to increased forage quality to the same extent as EMS and GDG.

3.5 Nutrient concentration of the diet

There were only minor differences between species/breeds regarding the nutrient concentration of the diet (although partly significant). The mean protein content was 13.8% of DM during lactation and 12.7% in the dry period (Table 7). The ruminal N balance was slightly positive in all subclasses, implying that there was no deficiency of rumen microbes for degradable protein (GfE, 2003). The average crude fibre and NDF content was 24.9 and 49.2% during lactation. As expected and intended by the experimental design, both forage quality and concentrate level exerted a highly significant impact on the essential nutritional parameters of the diet (Table 7). During lactation, the mean crude fibre content in forage quality groups F 2 and F 3 was 25.4 and 24.4%, while that of NDF was 49.8 and 48.6%. The different cutting frequencies resulted in an OM digestibility of 65.5 and 67.1% and an energy concentration of 9.26 and 9.49 MJ ME in F 2 and F 3. An even more pronounced difference in the nutrient content of the diet was induced by the 3 concentrate levels. The protein content rose from 12.8 (C 05) to 13.8 (C 25) and 14.9% (C50) of DM. On the other hand, the crude fibre content decreased from 30.0 to 24.9 and 19.7% and that of NDF from 58.0 to 49.2 and 40.4%. The mean energy concentration in the concentrate groups C 05, C 25 and C 50 amounted to 8.49, 9.37 and 10.26 MJ ME/kg DM. Concentrate accounted for 6.4, 27.7 and 49.2% of the total ration DM, well in line with the experimental plan. Significant interactions between the main effects only emerged between forage quality and concentrate level, resulting from the fact that the impact of forage on nutrient intake is lower at high concentrate levels (Table 8). As the intake of concentrate was quite low in the dry period (on average 162 g per day), the influence of forage quality on nutrient concentration was especially high in this period (Table 5). Therefore, concentrate level exerted no impact on nutrient concentration in this phase.

The course of the crude fibre concentration of the diet during the whole lambing interval is illustrated in Fig. 6 for the different species/breeds and concentrate levels. On an average, there were no great differences between species/breeds, but the shape of the curve depended to a high degree on the level of concentrate. According to the experimental plan, the course of crude fibre concentration was very flat in the low concentrate group (C 05) and followed more or less the crude fibre content of the forage. However, crude fibre concentration increased in the concentrate groups C 25 and C 50 with the ongoing lactation, going back to the decreasing concentrate proportion (Fig. 2). The crude fibre concentration never reached the critical limit of less than 18% of DM (Kaufmann, 1976).

Fig. 6. Development of the crude fibre content of the diet during lambing interval depending on species/breed and concentrate level

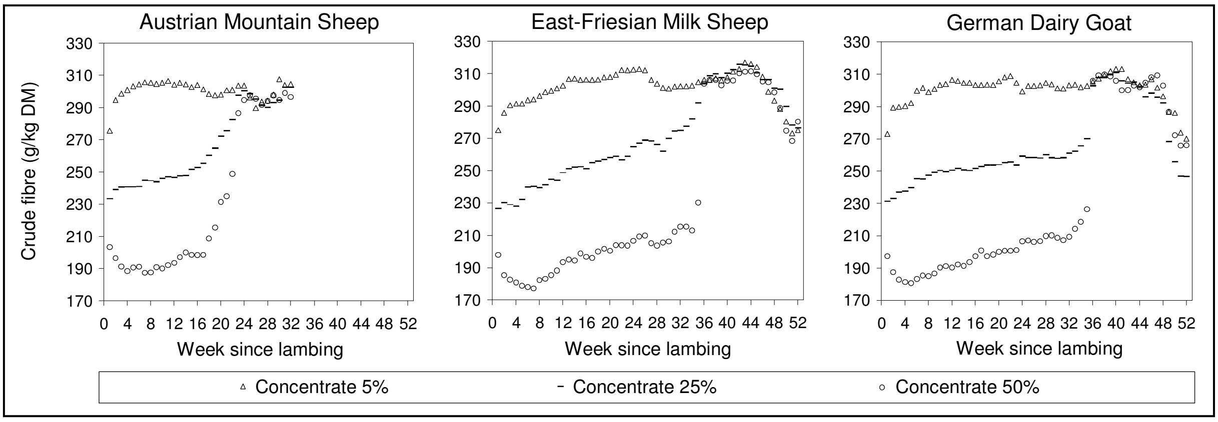


Table 7: Nutrient concentration of the total diet (DM) during lactation and dry period (Main effects)

Parameter	Unit	Phase	Species/Breed (S/B)			Forage quality (F)		Concentrate level (C)			P values			RSD
			AMS	EMS	GDG	2 cuts	3 cuts	C 05	C 25	C 50	S/B	F	C	
Number of observations			100	67	68	116	119	77	78	80				
Crude protein	g/kg DM	L	139	139	137	137[a]	139[b]	128[a]	138[b]	149[c]	0.168	0.003	0.000	5.8
	g/kg DM	D	132[a]	125[b]	124[b]	126	128	127	127	127	0.000	0.258	0.973	9.6
	g/kg DM	T	136[a]	134[b]	134[b]	134[a]	136[b]	127[a]	134[b]	143[c]	0.020	0.005	0.000	6.5
Crude fibre	g/kg DM	L	250[a]	247[b]	250[a]	254[a]	244[b]	300[a]	249[b]	197[c]	0.030	0.000	0.000	7.3
	g/kg DM	D	287[a]	301[b]	294[c]	304[a]	284[b]	296	293	293	0.000	0.000	0.608	18.9
	g/kg DM	T	262	264	262	270[a]	255[b]	299[a]	265[b]	224[c]	0.350	0.000	0.000	10.5
Crude ash	g/kg DM	L	66[a]	68[b]	68[b]	67	67	62[a]	67[b]	73[c]	0.000	0.728	0.000	2.9
	g/kg DM	D	63	64	64	62[a]	65[b]	64	63	63	0.745	0.000	0.776	3.6
	g/kg DM	T	65[a]	67[b]	67[b]	66[a]	67[b]	63[a]	66[b]	70[c]	0.001	0.011	0.000	2.7
NDF	g/kg DM	L	494[a]	489[b]	493[a]	498[a]	486[b]	580[a]	492[b]	404[c]	0.003	0.000	0.000	9.3
	g/kg DM	D	558[a]	580[b]	568[c]	581[a]	557[b]	572	567	567	0.000	0.000	0.520	29.4
	g/kg DM	T	516	519	514	525[a]	507[b]	578[a]	520[b]	451[c]	0.233	0.000	0.000	16.4
ADF	g/kg DM	L	290[a]	287[b]	290[a]	293[a]	285[b]	347[a]	289[b]	232[c]	0.004	0.000	0.000	6.3
	g/kg DM	D	332[a]	347[b]	339[c]	348[a]	331[b]	342	339	338	0.000	0.000	0.529	19.4
	g/kg DM	T	305	307	303	311[a]	299[b]	345[a]	307[b]	262[c]	0.245	0.000	0.000	10.8
ADL	g/kg DM	L	39[a]	38[b]	39[a]	39[a]	38[b]	44[a]	39[b]	33[c]	0.005	0.000	0.000	0.6
	g/kg DM	D	43[a]	44[b]	43[c]	44[a]	43[b]	43	43	43	0.000	0.000	0.535	1.8
	g/kg DM	T	40	40	40	41[a]	40[b]	44[a]	40[b]	36[c]	0.253	0.000	0.000	1.0
Digestibility OM	%	L	66.2	66.5	66.2	65.5[a]	67.1[b]	60.2[a]	66.2[b]	72.4[c]	0.046	0.000	0.000	1.06
	%	D	61.8[a]	60.2[b]	60.8[b]	59.4[a]	62.4[b]	60.7	61.0	61.0	0.000	0.000	0.683	2.40
	%	T	64.7	64.4	64.7	63.5[a]	65.7[b]	60.3[a]	64.3[b]	69.2[c]	0.467	0.000	0.000	1.31
ME	MJ/kg DM	L	9.37[ab]	9.40[a]	9.35[b]	9.26[a]	9.49[b]	8.49[a]	9.37[b]	10.26[c]	0.077	0.000	0.000	0.14
	MJ/kg DM	D	8.73[a]	8.47[b]	8.57[b]	8.38[a]	8.79[b]	8.56	8.60	8.61	0.000	0.000	0.654	0.37
	MJ/kg DM	T	9.15	9.10	9.14	8.97[a]	9.28[b]	8.50[a]	9.09[b]	9.79[c]	0.256	0.000	0.000	0.19
uCP	g/kg DM	L	131[ab]	132[a]	131[b]	130[a]	133[b]	118[a]	131[b]	145[c]	0.050	0.000	0.000	2.2
	g/kg DM	D	122[a]	117[b]	118[b]	117[a]	121[b]	119	119	119	0.000	0.000	0.689	5.6
	g/kg DM	T	128	127	127	126[a]	129[b]	118[a]	127[b]	138[c]	0.117	0.000	0.000	3.2
RNB	g/kg DM	L	1.2	1.1	1.0	1.1	1.1	1.6[a]	1.1[b]	0.7[c]	0.238	0.808	0.000	0.67
	g/kg DM	D	1.6[a]	1.3[b]	1.0[c]	1.5[a]	1.1[b]	1.3	1.3	1.3	0.000	0.004	0.876	0.99
	g/kg DM	T	1.4[a]	1.2[ab]	1.0[b]	1.2	1.1	1.5[a]	1.2[b]	0.9[c]	0.011	0.161	0.000	0.69

Phase: L = lactation, D = dry period, T = total period (lactation and dry period)

Table 8: Nutrient concentration of the total diet (DM) during lactation and dry period (Interaction Species/Breed × Concentrate level)

Parameter	Unit	Phase	Austrian Mountain Sheep			East-Friesian Milk Sheep			German Dairy Goat			P values		
			C 05	C 25	C 50	C 05	C 25	C 50	C 05	C 25	C 50	S/B × C	S/B × F	C × F
Number of observations			33	33	34	22	23	22	22	22	24			
Crude protein	g/kg DM	L	127	140	150	129	138	149	127	137	148	0.414	0.764	0.498
	g/kg DM	D	130	133	133	126	124	125	125	124	123	0.529	0.162	0.753
	g/kg DM	T	128	137	145	128	133	142	126	133	142	0.648	0.659	0.291
Crude fibre	g/kg DM	L	302	249	198	298	247	195	301	251	198	0.924	0.300	0.007
	g/kg DM	D	289	287	284	301	301	299	297	291	295	0.808	0.999	0.945
	g/kg DM	T	297	264	225	301	269	224	300	262	224	0.410	0.911	0.027
Crude ash	g/kg DM	L	61	66	72	63	68	74	63	68	73	0.932	0.822	0.586
	g/kg DM	D	64	63	63	64	64	63	64	64	64	0.904	0.691	0.565
	g/kg DM	T	62	65	69	63	66	71	63	67	71	0.938	0.970	0.520
NDF	g/kg DM	L	582	493	406	577	489	402	580	495	405	0.880	0.335	0.015
	g/kg DM	D	562	559	553	581	581	578	573	562	570	0.790	0.986	0.895
	g/kg DM	T	575	519	453	580	525	450	578	514	449	0.281	0.908	0.042
ADF	g/kg DM	L	348	290	233	345	287	230	347	291	232	0.885	0.332	0.014
	g/kg DM	D	335	333	329	348	348	346	342	335	340	0.792	0.989	0.901
	g/kg DM	T	344	307	264	347	311	261	346	304	261	0.293	0.907	0.039
ADL	g/kg DM	L	44	39	33	44	38	33	44	39	33	0.889	0.329	0.013
	g/kg DM	D	43	43	42	44	44	44	44	43	43	0.793	0.990	0.905
	g/kg DM	T	44	40	36	44	41	36	44	40	36	0.302	0.907	0.038
Digestibility OM	%	L	59.9	66.2	72.3	60.5	66.5	72.6	60.1	66.0	72.3	0.932	0.310	0.007
	%	D	61.5	61.8	62.2	60.2	60.1	60.3	60.6	61.3	60.7	0.819	0.996	0.966
	%	T	60.5	64.4	69.1	60.2	63.9	69.2	60.3	64.6	69.2	0.541	0.897	0.018
ME	MJ/kg DM	L	8.47	9.38	10.26	8.52	9.40	10.28	8.47	9.33	10.24	0.865	0.296	0.003
	MJ/kg DM	D	8.67	8.73	8.78	8.47	8.45	8.49	8.53	8.63	8.54	0.820	0.978	0.959
	MJ/kg DM	T	8.54	9.12	9.79	8.48	9.02	9.79	8.49	9.13	9.79	0.538	0.874	0.017
uCP	g/kg DM	L	117	132	145	119	132	145	118	131	144	0.504	0.386	0.036
	g/kg DM	D	121	122	123	117	117	117	118	119	118	0.735	0.682	0.830
	g/kg DM	T	119	128	138	118	126	137	118	127	137	0.686	0.810	0.035
RNB	g/kg DM	L	1.5	1.3	0.9	1.7	1.1	0.6	1.5	1.0	0.6	0.489	0.939	0.782
	g/kg DM	D	1.5	1.8	1.7	1.5	1.2	1.2	1.1	0.9	0.9	0.487	0.089	0.803
	g/kg DM	T	1.5	1.5	1.1	1.6	1.1	0.8	1.4	1.0	0.7	0.326	0.634	0.878

Phase: L = lactation, D = dry period, T = total period (lactation and dry period)

4. Discussion

4.1 Live weight

Tessmann et al. (1991) described that in cows, during early lactation, a great part of uptaken nutrients are directed towards the mammary gland for milk production at the expense of other tissues. As requirements for maintenance and milk production exceed the animal's intake capability, the resulting negative energy balance leads to the mobilization of body reserves (AFRC, 1998). As was already described by NRC (1985) for ewes, the extent of weight loss varied greatly, depending on quality and amount of feed available as well as the animal's genetic background. Whereas C 25 and, especially, C 50 treatments did not induce weight loss at all, dams in C 05 seemed to direct so much energy to milk production that body reserves were mobilized until week 16. Kawas et al. (1991) fed goats with different forage-to-concentrate ratios and found that live weight gains in does fed lower forage-to-concentrate ratios were higher. El-Gallad et al. (1988) reported that goats fed high energy diets had the lowest losses in body weight and were faster recovering body weights. This is in line with our findings as live weight gain in animals fed high concentrate diets was much steeper.

Forbes (1971) found that weight loss in the first part of lactation is common, particularly with poor quality food, and that the lag is longer with forage diets than with concentrates. This is very well underlined by our data. Whereas overall weight loss was insignificant with 3-cut hay, the poor quality forage induced mobilization of body reserves until the 6^{th} week of lactation. Elevation of concentrate supply could sustain energy intakes that were high enough to result in no weight loss at all.

4.2 Diet selection

Diet selection in this study was most distinct in EMS, whereas, contrary to expectations, goats did not exert a prominent selection in relation to feed. Goats are well known for their capacity to choose hay parts richer in energy and protein content (Morand-Fehr, 2003) and to leave feed that is higher in NDF content. The reason why goats were the least selective breed in this experiment could originate from the nature of the forage. Hay consisted mainly of stems, whereas leaves were broken down to hay dust during the process of hay making. Ouédrago et al. (1996) as well as Morand-Fehr (1981) reported that goats preferred dry feeds offered in pelleted form to flour form and favoured course feed compared to very fine-sized particles because of their sensitivity to the irritation of the respiratory tract induced by very small feed particles. Therefore, goats in our study might have preferred the stem fraction with its higher contents of NDF and lower protein concentration, whereas sheep, especially EMS, did not seem to react very sensible to hay dust.

Diet selection was more intense with the 2-cut hay than with the 3-cut hay. Morand-Fehr (1981) concluded that selectivity in goats, but also in sheep, is related to the quality of forage and is more prominent with forage of poor quality. Therefore, when poor forage is fed, high levels of feed intake can only be maintained if roughage is fed in excess, as animals are able to exert selectivity in relation to feed. In general, is seems that diet selection is, among other things, a function of energy balance. Metabolic and feeding situations that induce a highly negative energy balance, i.e. animals of great milk yield potential and diets of low energy content (low forage quality and/or low concentrate percentage) lead to elevated diet selection (high refusals and selection of more nutritive parts). It is well established that in lactating female mammals, energy balance is a main factor regulating feed intake (Wangsness and Muller, 1981; Forbes 1995c).

4.3 Feed intake

Species/breeds

The observed DM intake (DMI) of 109 g/kg $LW^{0.75}$ in goats is in the range given by Sauvant (1978) who reported DMI of 47 to 181 g/kg $W^{0.75}$ in lactating goats. Hussain et al. (1996) gave a value of 96 g/kg $W^{0.75}$ which is very close to the 95 g/kg $W^{0.75}$ reported by Abijaoudé et al. (2000) for goats in mid-lactation and corresponds well to the results of our experiment.

For lactating ewes fed on hay and concentrates, the ARC (1990) gives a value of 80 g/kg $W^{0.75}$ (one lamb) to 85 g/kg $W^{0.75}$ (two lambs) as the mean for the first 10 – 12 weeks of lactation. This is in good agreement with the mean DMI of 87 g/kg $W^{0.75}$ in AMS and 92 g/kg $W^{0.75}$ in EMS recorded in our study. McDonald et al. (2000a) gave slightly lower DMI of about 2.0 kg for a 75 kg ewe suckling a single lamb (78.5 g/kg $W^{0.75}$) and 2.1 kg DMI for ewes suckling twins (82.4 g/kg $W^{0.75}$).

In our experiment, DMI in goats was 26% higher than in AMS and 19% higher than in EMS (on a metabolic LW basis). These data are confirmed by values recorded by Simiane et al. (1981) who reported 17% higher DMI in goats compared to sheep. It is assumed that the higher intake in goats is a reflection of their elevated maintenance requirements. As a comparison of animals with similar milk energy output still shows significantly higher feed intakes in goats than in sheep, elevated DMI cannot sufficiently be explained by higher milk production of goats.

Forage quality

EMS and GDG that were fed the 3-cut hay increased DMI compared to dams fed the 2-cut hay, whereas the response of AMS to forage quality interfered with concentrate level (Fig. 4). At the low concentrate level they, too, increased DMI. However, with higher concentrate levels DMI was reduced, presumably due to regulation of energy balance (according to the theory proposed by Wangsness and Muller (1981)). As forage matures, plant cell wall content increases, and thus, voluntary intake decreases due to decreased digestion rate and longer rumen retention time. In contrast, ingestibility increases with better forage quality because of lower NDF content and concomitant faster breakdown of feed and accelerated rate of passage (Dulphy and Demarquilly, 1994). It is possible that goats were better digesters with the low quality hay, as difference between GDG and EMS in hay intake was more pronounced with the 2-cut hay. Intake in EMS approached that of GDG with the 3-cut hay. Tisserand et al. (1991) concluded that voluntary intake in sheep and goats does not differ when they receive good quality forage. However, when forage is rich in lignified cell wall and poor in nitrogen, goats tend to consume more than sheep.

As NDF is regarded the most important factor limiting feed intake (Mertens, 1994), NDF intake varies less than that of DM (Dulphy and Demarquilly, 1994; Buxton et al., 1996). Therefore, it is not surprising that NDF intake per kg LW did not differ for goats whether fed 2-cut or 3-cut hay. AMS reduced NDF intake per kg LW when fed 3-cut hay, suggesting metabolic regulation of feed intake. Why EMS increased overall NDF intake when fed the hay of better quality remains to be established. It is possible that, because of elevated milk production in connection with the 3-cut hay, feed intake increased due to accelerated rate of passage. NDF intake related to LW was higher for all species/breeds than reported by other authors. Andrade et al. (1996) gave a value of 11.4 g/kg LW for goats, while Mertens (1994) suggested 12.5 g/kg LW for dairy cattle. Average NDF intake was 13.5 g/kg LW in AMS, 15.2 g in EMS and 18.8 g in GDG. However, milk performance was higher in our experiment than in the study by Andrade et al. (1996), possibly explaining the higher NDF and feed intake. Dams may, therefore, have adapted to high cell wall concentrations by increasing gut fill or ruminal clearance rate (Buxton et al., 1996).

Crude fibre content of feed significantly influenced DMI. Dulphy et al. (1980) noted that a 10 g/kg increase in crude fibre of forage leads to a decrease in food intake of 38 g/d for a 60 kg sheep. Results of our study give very similar values. Applied to a 60 kg ewe, AMS reduced feed intake by 35 g/d, EMS by 32 g/d and GDG by 46 g/d. This result is rather inconsistent, as it leads to the assumption that GDG react most sensibly to high crude fibre content but, on the other hand, were not able to profit from better hay quality in terms of feed intake.

Concentrate

Feeding high energy diets, like concentrate supplements, increases DMI, as concentrates, due to their low fibre content, are easier to digest and do not limit gut fill (McDonald, 2002b; Avondo and Lutri, 2004). However, feeding concentrate supplements reduces hay intake, first because energy requirements can partly be met by the supplement, but also because concentrates, containing high amounts of starch, induce a decrease in ruminal pH and a reduced activity of cellulolytic bacteria, thus slowing down digestion of fibre (Archimède et al., 1996). Whereas with low quality feed, feed intake regulation is physical, it tends to be metabolic, if diets contain large amounts of concentrates, following the NDF/NEL model of feed intake regulation by Mertens (1994).

DMI increased with elevated concentrate levels in all breeds. Feeding C 50 diets could not significantly improve feed intake in GDG and AMS compared to C 25 treatments, implying that intake control in animals was metabolic. Whereas Trabalza-Marinucci et al. (1992) found that concentrate administration increased DMI of hay at low levels but depressed ingestion at high levels in sheep, in our experiment hay intake was reduced at all levels of concentrate feeding.

Substitution rates

Faverdin et al. (1991) found that the higher the quantity of concentrates, the lower the quantity of roughage intake. Substitution rate changed with type of roughage, type and amount of concentrate, but was finally influenced by energy balance. In our experiment, EMS were not able to improve milk yield to the same extent as GDG in reaction to better energy and nutrient provision, thus the high substitution rates suggest metabolic regulation of feed intake. In their study on Saanen goats, Mowlem et al. (1985) gave values of forage intake reduction in response to elevated concentrate levels that were a little below our findings.

Substitution rates in AMS were as low as that of GDG, even though they did not improve milk energy output with elevated concentrate feeding to a similar extent as goats. Furthermore, AMS did not divert more energy to live weight gain than did EMS, which could explain the lower substitution rate compared to EMS. It is possible that the additional energy was directed towards wool production and the gravid uterus, as most Mountain sheep were already pregnant before they were dried off. Substitution rates were higher with the 3-cut hay in all breeds, suggesting a better nutrient provision with this forage and therefore a reduction in feed intake as a consequence of metabolic feed intake control. Our findings are in line with Forbes (1995a) who suggests, that substitution rates are between 0.2 – 0.4 for forages of poor to medium quality and approach unity with high quality forages.

Milk production

Milking performance is one of the most important factors determining feed intake. In goats, an additional intake of 300 to 400 g of feed per kg milk was supposed by Daccord and Kessler (1994). In our study goats consumed about 490 g more feed DM as milk yield increased by 1 kg. In reaction to better energy supply, sheep responded not so much with improved milk yield but rather with an elevation of milk contents, thus extra feed intake in AMS per kg milk was 679 g, and even 844 g in EMS. Milk yield is described in more detail in the paper of Pöckl et al. (in preparation).

Dry period

Dams that were fed low amounts of concentrate during lactation tried to compensate for the lower energy intake with an increased feed intake after they were dried off. Requirements for pregnancy become noteworthy only in the last third before parturition (GfE, 2003). Since the development of the foetus reduces the gastrointestinal capacity in the last weeks of pregnancy, DMI is reduced in this physiologic state, thus making it difficult for the animal to meet its high nutritional requirements (INRA, 1989; Trabalza-Marinucci et al., 1992). Consequently, mobilization of body lipids takes place and becomes intense in the fifth month of pregnancy (INRA, 1989). However, a reduction in feed intake as gestation progressed was not observed in our experiment. In contrast, there was a steady increase in DMI, as was also found by Sahlu et al. (1995), who attributed these results to a possible decline in mean retention time of digesta in the rumen.

Course of lactation

It is generally accepted that intake capacity in early lactation is reduced. This phenomenon might go back to physical limitation (diminished volume of the reticulo-rumen before parturition), slow metabolic adaptation to increased nutrient requirements and slow recovery from the effects of endocrine changes in late pregnancy (Forbes, 1995c; Allen, 1996). Hadjipanayiotou (1987) and Morand-Fehr (1981) reported that, in goats, DMI rises after parturition and reaches a maximum between week 6 and 10 after parturition, trailing behind peak milk yield. The same was described for ewes by Treacher and Caja (2002), who found a rapid increase in DMI at the onset of lactation followed by a minor rise for several weeks. While Morand-Fehr (1981) noted that, in goats, during the first weeks of lactation feed intake increases by 30 – 40%, it only did so by 21% in our study. Increase in feed intake from parturition to peak intake was 19% in AMS and 12% in EMS. Hadjipanayiotou (1987) gave a value of 135 g/kg $W^{0.75}$ for suckling Damascus goats at peak intake. This value is slightly above intakes observed in our experiment, where highest DMI in goats was 131 g/kg $W^{0.75}$ in C 50 treatments. Due to the insignificance of physical fill with concentrate in contrast to roughages, high levels of concentrate in the diet may result in an early intake peak. However, this was not observed in our experiment, where climax of intake was noted in week 6 for C 05 as well as for C 50 treatments. In line with conclusions by Morand-Fehr and Sauvant (1989), DMI decreased after maximum intake was reached. The decrease was rather linearly in sheep but not so steady in goats.

Shape of feed intake curve was similar for all breeds, the only difference being a much smaller decline in intake after peak in goats which is reflected by a reduced decline in milk yield. Hadjipieris and Holmes (1966) described that intake rises slowly when ewes are fed low-quality forage and peak often occurs not before 3 to 4 months post partum. Even though elevation in DMI and peak DMI was much higher with the 3-cut hay, peak intake was not delayed with poor quality forage in our study.

It can be concluded from the results obtained that all of the three factors investigated (species/breed, forage quality and concentrate level) exerted a significant impact on feed intake of lactating as well as dry sheep and goats. Moreover, between the factors, interactions were found. In general, feed intake was mainly determined either by ruminal fill (in case of high milk yield and low energy concentration of the diet) or by energy balance (low energy requirements and high energy concentration of the diet). This principally supports Merten's model of feed intake prediction (1994), although the animals in the present study consumed an amount of more than 12.5 g NDF per kg LW, which is given as the upper limit for ruminal fill.

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CHAPTER III

Production of sheep and goat milk depending on breed, forage quality and concentrate level
II. Milk yield and nutrient supply

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Abstract

A three-factorial experiment was carried out to investigate the impact of species/breed, forage quality and concentrate level on milk production and nutrient supply of female sheep and goats during total lambing intervals. Austrian Mountain Sheep (AMS), East-Friesian Milk Sheep (EMS) and German Dairy Goats (GDG) were chosen for the experiment. Two levels of forage quality were received by cutting an alpine permanent grassland 2 or 3 times a year (F 2, F 3; 56.8 and 59.8% digestibility of OM). Concentrate levels were 5, 25 or 50% of DMI. A total of 235 lactations was examined (100 for AMS, 67 for EMS, 68 for GDG), using 25, 26 and 24 dams per species/breed. Every new lactation, animals were allocated to a different concentrate level (but not forage quality), according to a Latin square design.

Mean milk fat content was 6.1, 4.9 and 2.9% for AMS, EMS and GDG, respectively, as well as 4.74, 4.63 and 4.56% for concentrate levels 5, 25 and 50% (C 05, C 25, C 50). Corresponding values for milk protein were 5.5, 5.0 and 2.9% (AMS, EMS, GDG) and 4.3, 4.5 and 4.6% (C 05, C 25, C 50). AMS, EMS and GDG yielded 983, 1022 and 2028 g actual milk, equivalent to 4.3, 3.9 and 5.5 MJ milk energy (LE) per day. Due to their lower LW, superiority of goats was even more obvious when LE output was related to $LW^{0.75}$ (160, 198, 255 kJ/d). Efficiency of concentrate feeding was significantly influenced by species/breed as proved by the linear regression coefficients (0.30, 0.55 and 1.31 kg milk per kg concentrate DM in AMS, EMS and GDG). Actual milk yield per lactation was 143, 228 and 492 kg in AMS, EMS and GDG as well as 201, 276 and 385 kg in concentrate levels C 05, C 25 and C 50. Gross ME utilisation for LE production was 8.3, 9.0 and 5.5 MJ ME per MJ LE for species/breeds AMS, EMS and GDG as well as 9.0, 7.5 and 6.4 in C 05, C 25 and C 50.

Results demonstrate that all three species/breeds show equal feed intakes at the three concentrate levels investigated. However, feed intake related to metabolic LW was lowest in AMS and highest in GDG, the discrepancy increasing with higher concentrate levels. As a consequence, actual milk yield (per day) was by far highest in dairy goats, while Mountain and Milk sheep showed similar milk yields. High feeding levels, e.g. high concentrate proportions of the diet and the relation of milk yield to metabolic LW, underlines the outstanding milk production potential of this breed. Per year, Mountain sheep yielded slightly more actual milk and LE than Milk sheep on a low concentrate diet whereas Milk sheep were somewhat superior when offered diets with high concentrate portions. Milk yield in goats was by far highest. However, the low milk content of goats compared to sheep must be taken into account. Regarding feed conversion, goats were more effective than sheep in terms of gross ME expenditure per milk energy output, since their maintenance requirement is relatively lower as a result of their higher feed intake capacity. In order to evaluate the effective energy cost for milk production, the different length of dry period must be considered as well. Milk sheep show extended dry periods and therefore an unfavourable feed conversion efficiency, especially when offered low concentrate diets.

Keywords: Sheep, goats, milk yield, feed conversion, forage quality, concentrate level, lactation

1. Introduction

Sheep and goat milk and its products play a more and more important role in human nutrition and they can be the sole alternative for anyone suffering from cow milk allergies. Profitableness of goat and sheep milk production depends on the systematic use of feeding stuff, as feed intake is one of the most important factors determining milk performance. In alpine livestock production, obtaining large proportions of milk from forage is of economic interest, as concentrate usually is not produced on the farm but has to be purchased. So far no data on the milk performance of Mountain sheep were available. This study examines whether this breed, which is better adapted to alpine climate and allows for out-of-season milk production thanks to its breeding behaviour, could represent a true alternative to the Milk sheep.

With a total solids concentration of 15 – 20% in sheep milk and 12 – 18% in goat milk, the composition of milk is very different for the two species (Haenlein, 1993). During the 10 months of a standard lactation, goats may produce up to 1350 kg of milk. For the German Dairy Goat (Improved Whites), an average of 900 kg milk containing about 3.6% fat, 3.2%

protein, and 4.5% lactose, resulting in an energy concentration of about 2.8 to 3.0 MJ/kg milk, can be obtained (McDonald et al., 2002a; GfE, 2003). The lactation cycle of the goat shows a peak of milk yield at week 6 to 8 and a constant and slow decline over the following months (Sutton and Mowlem, 1991). In contrast, the content of fat and solids-non-fat reaches a minimum at about four months post partum and rises afterwards until the end of lactation (McDonald et al., 2002a). Amount and composition of milk from various sheep breeds differs significantly, with values ranging from 5 – 9% fat, 4 – 6% protein and 4 – 5% lactose (Jeroch et al., 1999). In their research on the East-Friesian Milk Sheep, Horstick et al. (2001) reported the average milk performance to be 500 – 700 kg of milk with a content of about 5.4% fat and 4.9% protein. Milk yield peaks immediately after the colostral period and decreases constantly thereafter. Milk fat content increases throughout lactation from 3.9% to 8.9%, whereas protein augments slowly and continuously at the beginning of lactation followed by a sharp rise at the close of lactation. Lactose is relatively constant and declines not until the end of lactation before drying off from about 5.5% to 3.7%.

Milk yield and composition is affected by breed and genetic potential, age and parity, number of lambs, level of production, season of kidding and feed intake. Composition of milk is primarily influenced by breed, with breeds producing larger yield normally giving milk with lower concentration of milk constituents (McDonald et al., 2002b). Differences in breeds affect peak yield, time of peak yield and persistency. Saanens reach the peak of lactation at about 50 days of lactation and seem to be more persistent than other breeds (Gipson and Grossman, 1990). In goats, lactation curves for high producing breeds are similar in shape to that of lower producing breeds, except for an upward shift of the curve for higher producers (Gipson and Grossman, 1990). Persistency seems to be greater in first-parity does and decreases with increasing parity. Initial and peak milk yield increases from first to second parity and then either keeps the level or rises even higher until the fourth lactation when milk yield starts to fall again (Gipson and Grossman, 1990; Wahome et al., 1994). In ewes, the situation is similar with ewes in second parity producing more milk in comparison to first parity ewes and maximum milk yield being observed in third to sixth lactation (Casoli et al., 1989; Peeters et al., 1992; De la Fuente et al., 1997).

Number of lambs suckled is another determinant for milk yield and composition. Snell (1996) reported that goats with only one kid produce 32% less milk than does suckling two ore more kids. For ewes, number of lambs also significantly influences milk yield, with 20 – 40 percent more milk for ewes nursing twin lambs (NRC, 1985). The effect of number of lambs nursed showed to significantly affect fat, protein as well as lactose percentage in goats and sheep.

Milk fat concentration was about 30% lower in does with two kids compared to does with singletons. Protein concentration showed only slightly lower values for goats with two kids (Snell, 1996). Fuertes et al. (1998) reported a significant influence of number of lambs on fat and protein percentage in sheep, with lower fat concentration but slightly higher protein concentrations for does with two lambs.

Milk yield and content is also affected by composition of feed. Milk yield is highly depending on the total amount of energy consumed (Morand-Fehr and Sauvant, 1980). Consequently, diets with high proportion of concentrate lead to high milk production, whereas high roughage diets are negatively correlated with milk performance, as NDF content in the diet is considered to be the most limiting nutrient for voluntary feed intake in ruminants (Van Soest, 1982). Although Sanz Sampelayo et al. (1998) stated that milk production and composition seem to be more sensitive to energy intake than to the physical characteristics of the consumed diet, it has been shown that diets high in grain increase milk protein percentage and decrease milk fat percentage in goats and cows (El-Gallad et al., 1988; Kawas et al., 1991; Tessman et al., 1991). A decrease in NDF intake, as induced by a low roughage diet, reduces the animal's chewing time, ruminal pH and acetate-to-propionate-ratio, leading to a depression in milk fat percentage (Santini et al., 1983). Concentrates that are rich in readily fermentable carbohydrates, a decrease in the forage-to-concentrate-ratio and a decrease in the particle size of the fibre all tend to reduce the amount of ruminally produced acetic acid, the principal precursor of the fatty acid synthesized in the mammary gland. In the first weeks of lactation, when feed intake cannot meet energy demand, milk fat content is also augmented by mobilization of body fat (Nudda et al., 2004).

Effects of dietary treatments on protein content are far more inconsistent. Dietary manipulation of milk protein can be achieved by the increase of the overall quantity of amino acids reaching the small intestine (microbial protein and undegraded dietary protein), resulting in an increased absorption and availability at the mammary gland or by altering the profile of the amino acids so that more essential amino acids are available (Murphy and O'Mara, 1993). However, increasing the protein level in the diet has shown only a small and inconsistent effect on milk protein concentration, apart from the case of severe protein undernutrition (Murphy and O'Mara, 1993). El-Gallad et al. (1988) as well as DePeters and Cant (1992) reported that increasing the energy intake in goats resulted in a significant augmentation of milk protein percent. Findings in cows let assume a negative correlation of proportion of roughage with protein content. In contrast, Goetsch et al. (2001) suggested that mean milk protein concentration and levels do not change with higher concentrate administration and

energy intake. Lactose content seems to correlate positively with milk yield and energy intake (Morand-Fehr et al., 1991) and remains relatively constant over the course of lactation (Pulina and Nudda, 2004). It can be concluded that a reduction in forage-to-concentrate-ratio leads to an increased energy intake which, in turn, does not only result in an increased milk yield but also in a higher milk protein concentration and yield (Murphy and O'Mara, 1993).
This study aims at analysing the influence of different forage quality (as received by different times of cutting of alpine permanent grassland) and different amount of concentrate supplementation on milk performance and milk contents of Austrian Mountain Sheep, East-Friesian Milk Sheep and German Dairy Goats. Results of live weight and feed intake are published in a companion paper by Gruber et al. (1^{st} communication).

2. Material and methods

2.1 Experimental design

The experimental design was a three-factorial arrangement consisting of the following treatments and their levels, including all possible interactions and resulting in 18 subclasses (3 species/breed × 2 forage quality × 3 concentrate levels, Table 1):

Factor Species/Breed: Austrian Mountain Sheep (AMS)
East-Friesian Milk Sheep (EMS)
German Dairy Goat (GDG)

Factor Forage quality: 2 cuts per year (F 2)
3 cuts per year (F 3)

Factor Concentrate level: 5% of DM intake (C 05)
25% of DM intake (C 25)
5% of DM intake (C 50)

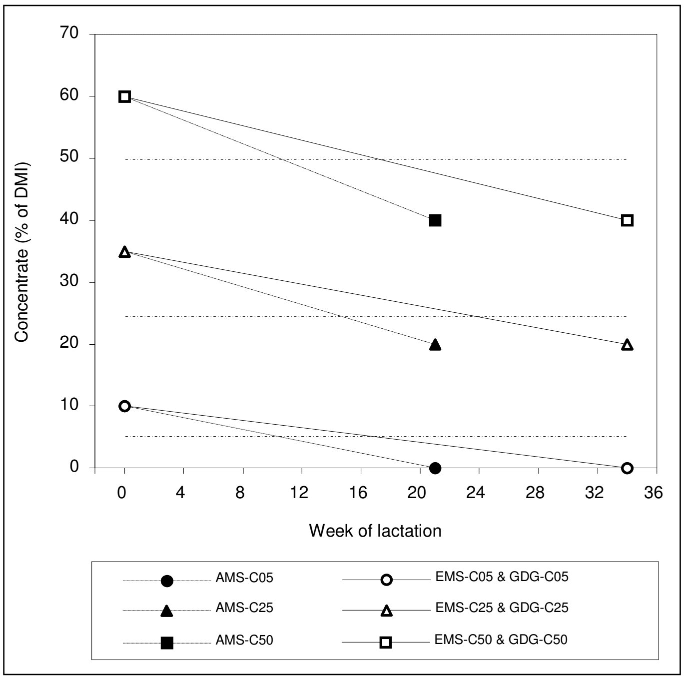
Table 1: Experimental design

Species/Breed	Austrian Mountain Sheep		East-Friesian Milk Sheep		German Dairy Goat	
Grassland cuts per year	2	3	2	3	2	3
Concentrate level 5%	AMS-2-05	AMS-3-05	EMS-2-05	EMS-3-05	GDG-2-05	GDG-3-05
Concentrate level 25%	AMS-2-25	AMS-3-25	EMS-2-25	EMS-3-25	GDG-2-25	GDG-3-25
Concentrate level 50%	AMS-2-50	AMS-3-50	EMS-2-50	EMS-3-50	GDG-2-50	GDG-3-50

2.2 Animals and diets

Animals (30 Austrian Mountain Sheep, 30 East-Friesian Milk Sheep, 30 German Dairy Goats were reared under identical conditions with ad libitum hay intake plus concentrate. Eighteen animals (9 for each forage group) of each species/breed were chosen for the feeding experiment based on their milking performance and feed intake in first lactation to obtain groups with animals of similar milk production potential. The remaining dams were kept as a reserve to replace animals that had to be removed from the experiment due to diseases or death. In total, for cutting frequency 2 and 3, respectively, 11 and 14 AMS were used, while number of animals was 12 and 14 for EMS and 11 and 13 for GDG. Diets consisted of hay of two different qualities resulting from either two or three cuttings of a homogenous alpine permanent grassland area (that had been divided into two parts at the beginning of the experiment). The harvest of the two, respective three cuttings were thoroughly mixed to receive one quality of forage within forage group (F) which was fed throughout the whole year. Additionally, three levels of concentrate (C) were administered to the animals (5%, 25% or 50% of daily dry matter (DM) intake), resulting in six different treatments. However, concentrate supplementation was to some extent adjusted to the productive requirements of the animals in so far as the administration of concentrate was slightly beyond the given percentage in early lactation and slightly below in late lactation (see Fig. 1). The concentrate was composed of 30% barley, 15% maize, 15% oats, 15% dried sugar beet pulp, 9% soybean meal, 8% rapeseed meal, 3% molasses, 3% minerals and 2% limestone (on as fed basis). The concentrate was designed to contain 16.7% CP, 12.2 MJ ME, 1.2% Ca and 9.0% P (on a DM basis). The amount of concentrate was calculated every Monday based on the average daily feed intake of the previous week.

Fig. 1. Concentrate proportion of the diet in the experimental groups during lactation



Goats and sheep were randomly assigned to one of the six treatments (3 animals of each breed per block). With every new lactation the animals were allocated to a different dietary treatment (i.e. concentrate level, but not forage quality) following the principles of a Latin square as shown in Table 2. During the experimental period, lactations two to five of EMS and GDG were examined. AMS completed five to eight lactations during the same period of time. A full lactation lasted 240 days for EMS and GDG whereas it was only 150 days for AMS.

Animals were kept in individual tie stalls with free access to water. They were exercised for one hour a day. Feeding took place twice a day (in the morning and late afternoon). Feed offered and refused was weighed daily for the individual animals to determine daily feed intake. Daily adjustments were made for the hay offered to ensure ad libitum intake. In the dry period, animals were fed solely with forage; only in the last weeks before parturition did they receive small amounts of concentrate.

Table 2: Allocation of the animals to the concentrate levels according to a latin square design

Forage quality		Concentrate level		
		C 05	C 25	C 50
2 cuttings per year	2nd lactation	1, 2, 3	4, 5, 6	7, 8, 9
	3rd lactation	7, 8, 9	1, 2, 3	4, 5, 6
	4th lactation	4, 5, 6	7, 8, 9	1, 2, 3
	5th lactation	1, 4, 7	2, 5, 8	3, 6, 9
3 cuttings per year	2nd lactation	10, 11, 12	13, 14, 15	16, 17, 18
	3rd lactation	16, 17, 18	10, 11, 12	13, 14, 15
	4th lactation	13, 14, 15	16, 17, 18	10, 11, 12
	5th lactation	10, 13, 16	11, 14, 17	12, 15, 18

1, 2, 3 – 4, 5, 6 – 7, 8, 9 are animals which were allocated to the concentrate levels in different lactations within low forage quality group (2 cuts)
10, 11, 12 – 13, 14, 15 – 16, 17, 18 are animals which were allocated to the concentrate levels in different lactations within high forage quality (3 cuts)

2.3 Determination of feed value by chemical analysis and digestibility in vivo

Daily samples of feed offered and feed refused were analysed for dry matter content. Samples were combined to a composite and sent to the laboratory for chemical analysis every fortnight. Samples of hay refused were analysed separately for each breed and each forage quality. Samples of forage and concentrate were analysed for crude protein (CP), crude fat (EE), crude fibre (CF), N free extracts (NFE) and crude ash (Cash) according to conventional methods (Weende analysis), as described by VDLUFA (1976) and ALVA (1983) using devices of Tecator®. The cell wall substances (NDF, ADF, ADL) were analyzed as proposed by Van Soest et al. (1991), also using equipment of Tecator®. Additionally, content of minerals (Ca, P, Mg, K, Na) and trace elements (Mn, Zn, Cu) were determined using atomic absorption spectroscopy.

The digestibility of the two hays (mixtures of 2 and 3 cuttings, respectively) was determined *in vivo* in each of the 4 harvest years (1997, 1998, 1999, 2000), using 4 adult wethers per forage quality. The digestibility of the concentrate was measured according to the difference principle (50% test feed, 50% hay), given the digestibility of the hay. The digestibility trials were carried out according to the guidelines for the determination of digestibility of nutrients in ruminants as proposed by GfE (1991). The animals received an amount of 1.0 kg DM of the experimental feed to maintain a feeding level of ca. 1.2 – 1.5 of maintenance requirement. The trials lasted for 4 weeks (2 weeks preliminary period, 2 weeks collection period). The animals were equipped with harnesses and bags for sampling of faeces. The amount of feed ingested and faeces excreted was weighed twice daily. The faeces were sampled and stored at 4°C. At the end of the collection period, all samples were mixed and subsequently analysed.
The energy and protein evaluation of the feeding stuffs was carried out according to the proposals of GfE (2001) and GfE (2003):

$$\text{ME (MJ/kg)} = 0.0312 \times \text{g DEE} + 0.0136 \times \text{g DCF} + 0.0147 \times \text{g (DOM} - \text{DEE} - \text{DCF)} + 0.00234 \times \text{g CP} \quad (1)$$

ME = metabolizable energy (MJ/kg)

DEE, DCF, DOM = digestible EE, CF, OM (g/kg); CP = crude protein (g/kg)

$$\text{uCP (g/kg)} = [11.93 - (6.82 \times (\text{UDP/CP}))] \times \text{ME} + 1.03 \times \text{UDP} \quad (2)$$

uCP = utilizable crude protein at duodenum (g/kg)

UDP = undegraded crude protein (g/kg), CP = crude protein (g/kg)

ME = metabolizable energy (MJ/kg)

$$\text{RNB (g/kg)} = (\text{CP} - \text{uCP})/6.25 \quad (3)$$

RNB = ruminal nitrogen balance (g/kg)

CP = crude protein (g/kg), uCP = utilizable crude protein at duodenum (g/kg)

2.4 Milk yield

Animals were milked twice daily on the milking parlour. The amount of morning and evening milking was recorded Monday to Thursday for each animal. Samples of Wednesday p.m. and Thursday a.m. milking were analyzed for fat, protein and lactose (Milcoscan) every week during the first three months of lactation and every fortnight afterwards. As soon as milk yield of sheep and goats fell below 200 g, they were dried off. Therefore some animals did not complete a full lactation.

2.5 Live weight

Live weight (LW) was recorded once a week after milking during the first three months of lactation and every two weeks during the following months. Weight of wool was recorded after shearing. AMS were shorn at lambing whereas EMS were clipped at lambing as well as before mating. Live weight change (LWC) was calculated from the first derivative of polynomial regressions of LW on experimental weeks.

2.6 Mating

Milk sheep and goats were mated in September or October, whereas AMS were mated every six months. EMS were bred to a Suffolk ram, goats were covered with a Boer buck. Weights of dams after lambing as well as birth weight of lambs were recorded. Lambs were weaned immediately after birth and male lambs were allocated to the fattening experiment (Pöckl et al., in preparation) in order to get information of the total productivity of the species/breed (milk <u>and</u> meat performance).

2.7 Calculation of requirements

Principally, energy requirements were calculated according to GfE (1996) for sheep and GfE (2003) for goats. Requirements for pregnancy in sheep were computed as described by ARC (1980) and AFRC (1993). Energy content of milk was calculated using the equation of Tyrell and Reid (1965). The equations used are summarized in Table 3.

Table 3: Calculation of energy requirements

Requirements		Sheep	Goats
Maintenance	kJ ME/kg $LW^{0.75}$	430	450
Lactation		Tyrell & Reid (1965) [1]	Tyrell & Reid (1965) [1]
Pregnancy		ARC (1980) [2], AFRC (1993) [2]	Voicu et al. (1993) [3]
Efficiency of utilization of ME			
Lactation	k_l	0.60	0.63
Pregnancy	k_c	0.20	–

[1] LE (MJ/kg) = 0.38 × fat (%) + 0.21 × protein (%) + 0.95 (cit. GfE 2003) (4)

[2] CE_t (MJ) = 10^(3.322 – 4.979 × exp(–0.00643 × t)) (5)

CE_t = energy content of gravid uterus at day t of gestation

CE (MJ/d) = 0.25 × birth weight × (CE_t × 0.07372 × exp(–0.00643 × t)) (6)

CE = energy retention of gravid uterus at day t of gestation

[3] ME per day (MJ/kg $LW^{0.75}$) = 0.118056 × exp(0.0116 × t) (7)

Protein requirements for sheep and goats were calculated according to the German uCP system as outlined by GfE (2001) for cows and by GfE (2003) for goats.

Endogenous losses of N:

FN_e (g/d) = 2.2 × DMI (kg/d) (8)

FN_e = endogenous faecal N losses (g/d)

DMI = dry matter intake (kg/d)

UN_e (g/d) = 5.9206 × log(10) LW (kg) (9)

UN_e = endogenous urinary N losses (g/d)

log(10) LW = decadic logarithm of live weight (kg)

N losses via skin:

VN (g/d) = 0.018 × $LW^{0.75}$ (kg) (10)

VN = N losses via skin (g/d)

$LW^{0.75}$ = metabolic live weight (kg)

Protein requirements for milk yield were derived from the respective milk protein yield of the animals [N content of milk (%) × 6.38 × 10 × milk yield (g)]. For calculating the quantities of utilizable CP at the duodenum required by the host animal, the following factors were assumed:

efficiency of intermediary utilisation of absorbed amino acid N for milk formation: 0.75

absorbability of amino acid N: 0.85

proportion of amino acid N in total non-ammonia N of duodenal chyme: 0.73

Analogous to cows (GfE, 2001) it was assumed that protein requirements in time of pregnancy are mainly determined by the requirements of rumen microbes for rumen degradable N (RDP). RDP was received indirectly from equation (2):

MP (g/kg) = uCP – (1.03 × UDP)

RDP (g/kg) = MP (g/kg)

CP (g/kg) = RDP/deg

MP = microbial crude protein (g/kg)

uCP = utilizable crude protein at duodenum (g/kg)

UDP = undegradable protein (g/kg)

RDP = rumen degradable protein (g/kg)

deg = degradability of crude protein (CP), as a coefficient

CP = required CP content of the diet during pregnancy (g/kg)

2.8 Statistical analysis

The number of total lactations in the several subclasses available for statistical evaluation is presented in Table 4. It was aimed at receiving a minimum of 10 full lactations per subclass in EMS and GDG, whereas AMS completed 16 – 18 lactations during the same experimental period.

Data were analyzed by multifactor analysis of variance procedures, the main effects being species/breed, cutting frequency, level of concentrate administration and parity, together with their two-way interactions, and considering the animal as a random effect, using the statistical package of Harvey (1987). To describe the development of parameters during lactation (or the total production cycle) the effect of week after lambing was considered in the statistical model. Multiple comparisons were carried out to identify statistically significant differences among means, applying the test of Student-Newman-Keuls ($P \leq 0.05$) of Statgraphics (2000). Significant differences between means are indicated by different superscripts in the tables of results. The values in the tables of results are least squares-means, RSD is the pooled standard deviation within treatment groups (root mean square of remainder).

Table 4: Number of total lactations in the subclasses

Forage quality			Concentrate level	
	Total	C 05	C 25	C 50
Austrian Mountain Sheep				
2 cuttings per year	49	15	16	18
3 cuttings per year	51	18	17	16
East-Friesian Milk Sheep				
2 cuttings per year	33	12	11	10
3 cuttings per year	34	10	12	12
German Dairy Goat				
2 cuttings per year	34	12	10	12
3 cuttings per year	34	10	12	12

3. Results

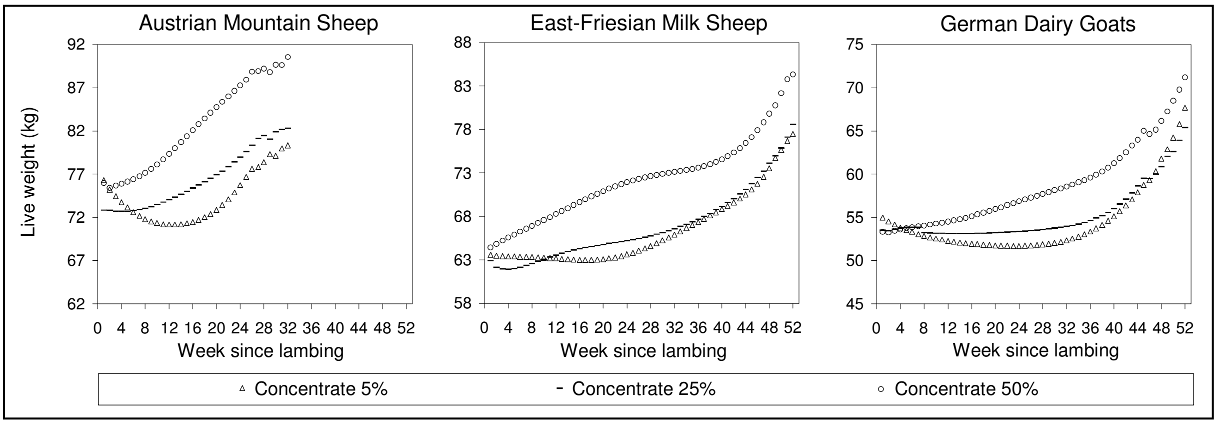
3.1 Live weight and live weight change

The mean live weight and live weight change in lactation and dry period is presented in Table 5 for the main effects and in Table 6 for the interaction species/breed × concentrate level, together with their significance levels (P values) and the pooled residual standard deviation (RSD). The tables give values for the different production phases: *lactation*, *dry period* and the total cycle of production (*lambing interval*).

The mean live weight of the animals was 78.2, 68.6 and 55.9 kg for AMS, EMS and GDG, respectively, during the total production cycle. Live weight was considerably higher in the dry period than during lactation (72.2 vs. 64.9 kg, averaged over all species/breeds). Mean live weight gain was higher for AMS than EMS and GDG (496, 369 and 325 g/day, Table 7 and 8). The development of live weight during the whole lambing interval is shown in Fig. 2. Apart from to the factor species/breed, the development of live weight was significantly influenced by the level of concentrate. During lactation, change of live weight was only small (and clearly depending on concentrate level), whereas there was a distinct increase in live weight in the dry period due to foetal development and retention of body mass. With low concentrate feeding, the animals of all species/breeds lost weight in the first weeks of lactation, whereas (with the exception of week one) they gained weight with concentrate levels 25 and 50%.

Furthermore, live weight was significantly influenced by the quality of forage (65.8 vs. 69.2 kg in treatments 2-cut and 3-cut hay) and the concentrate level (65.1, 66.2 and 71.4 kg in concentrate levels 5, 25 and 50%). No interactions between the main effects were found. However, concerning live weight change, the effect of concentrate level was significantly depending on species/breed. With increasing concentrate levels, animals of higher milk yield potential (EMS and GDG) increased live weight gain to a lesser extent than the lower yielding AMS (results on LW and LWC are discussed in more detail by Gruber et al., 1st communication).

Fig. 2. Development of live weight during lambing interval depending on species/breed and concentrate level

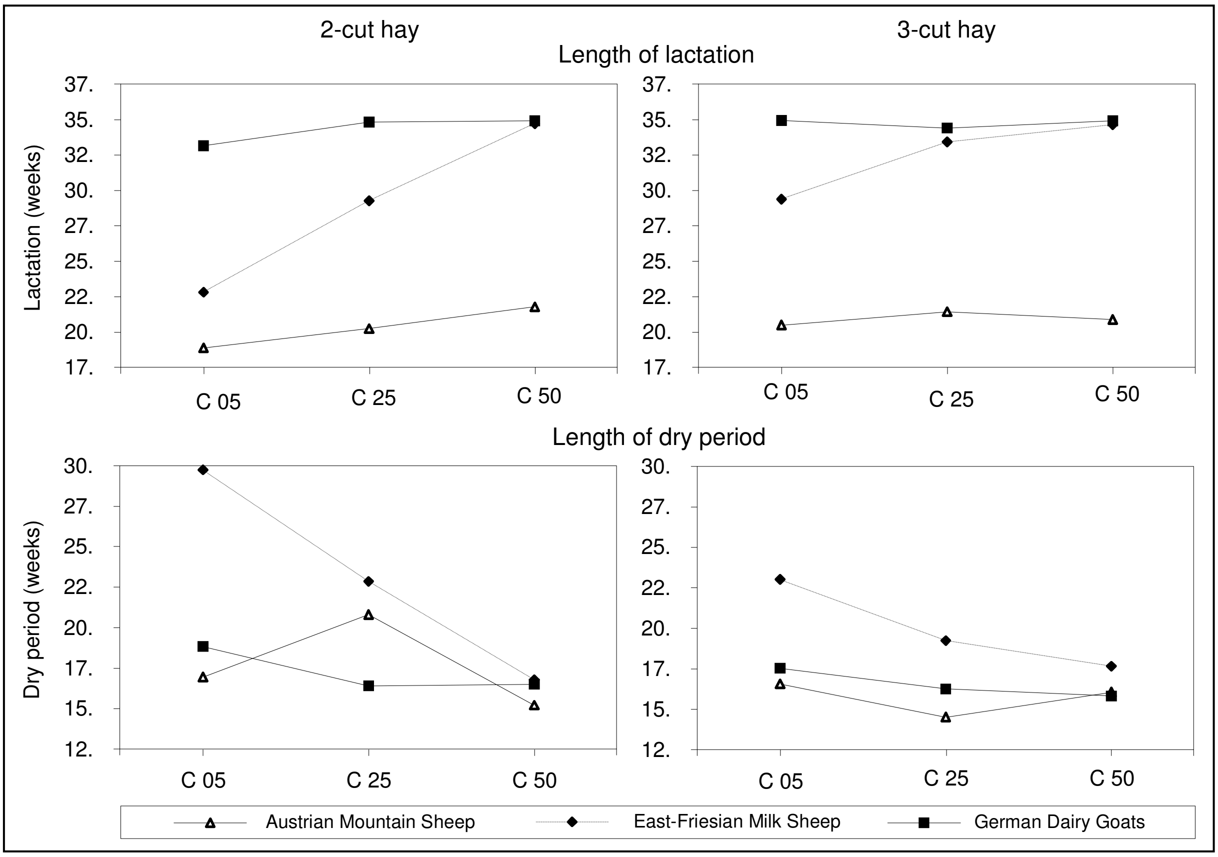


3.2 Duration of lactation

Due to their breeding behaviour, Austrian Mountain sheep were characterized by shorter lactations than dairy sheep and goats (20.6, 30.7 and 34.5 lactation weeks for AMS, EMS and GDG, respectively, Table 5 and 6), but also by short dry periods and thereby, shorter lambing intervals. Therefore, mean lactation number for the total experiment was higher for AMS than for the other two breeds (3.87, 3.54 and 3.52 for AMS, EMS and GDG). Length of dry period was greater for EMS than for AMS and DG (16.7, 21.6 and 16.9 weeks for AMS, EMS and GDG). Consequently, the whole production cycle (lambing interval) lasted exactly one year for EMS and GDG but was considerably shorter for AMS (37.3, 52.3 and 51.4 weeks for AMS, EMS and GDG). Increased energy supply - as obtained by feeding forage of higher quality and elevated levels of concentrate - extended lactation period in all experimental groups (27.8 and 29.4 lactation weeks in F 2 and F 3; 26.6, 28.9 and 30.3 lactation weeks in C 05, C 25 and C 50). Additionally, dry period was shorter with diets of higher energy concentration (19.4 and 17.4 weeks in F 2 and F 3; 20.5, 18.4 and 16.3 weeks in concentrate levels C 05, C 25 and C 50). As a consequence, total lambing interval was not significantly influenced by forage quality and concentrate level (47.2 and 46.8 weeks in F 2 and F 3; 47.1, 47.3 and 46.6 weeks in C 05, C 25 and C 50).

Significant interactions were found between species/breeds and concentrate level concerning duration of lactation, dry period and total lambing interval (Fig. 3). When fed low quality forage, concentrate level exerted a greater influence on length of lactation in milk sheep than when fed 3-cut hay (34.7 to 22.8 weeks in F 2 for C 50 and C 05 compared to 34.7 and 29.4 weeks in F 3 for C 50 and C 05), indicating also an interaction between forage quality and concentrate level (Table 6). Time in milk was not reduced to the same extent in Mountain sheep and dairy goats (Table 6 and Fig. 3). Length of dry period showed corresponding values. It was especially long (29.8 weeks) in milk sheep fed on low concentrate levels and low forage quality (Fig. 3), whereas it was only 17.3 weeks in concentrate level C 25 (mean of both forage qualities). For total lambing intervals no interactions between the main factors were detected.

Fig. 3. Mean length of lactation and dry period as influenced by species/breed, concentrate level and forage quality



3.3 Milk composition

The results for milk composition are presented in Tables 5 (main effects) and 6 (interactions). All parameters for milk composition (content of fat, protein and lactose as well as energy) were significantly influenced by species/breed (P = 0.000), but not by forage quality. Mean fat content was 6.05, 4.94 and 2.93% for AMS, EMS and GDG, respectively. Corresponding values for protein content were 5.52, 4.96 and 2.90%. Lactose content was similar in Mountain and Milk sheep, whereas it was lower in dairy goats (4.92, 4.97 and 4.45% for AMS, EMS and GDG). There was a tendency (P = 0.167) for milk fat content to decrease with rising concentrate levels (4.74, 4.63 and 4.56% in C 05, C 25 and C 50). As expected, the protein content of milk was significantly increased by elevated concentrate administration (4.30, 4.49 and 4.59% in C 05, C 25 and C 50). The concentration of lactose rose only with C 50 treatments. However, total content of milk constituents (FPL) was not significantly affected by concentrate level (13.81, 13.87 and 13.97 for concentrate levels C 05, C 25 and C 50), showing that changes in individual milk constituents cancelled each other out. The same applied to the energy content of milk.

With regard to milk constituents, level of concentrate affected milk fat and protein content of the three species/breeds in a similar manner (Fig. 4). However, the interaction between species/breeds and forage quality reached level of significance in all milk constituents except protein. No interactions were found between level of concentrate and forage quality.

Fig. 4. Mean fat and protein content of milk as influenced by species/breed, concentrate level and forage quality

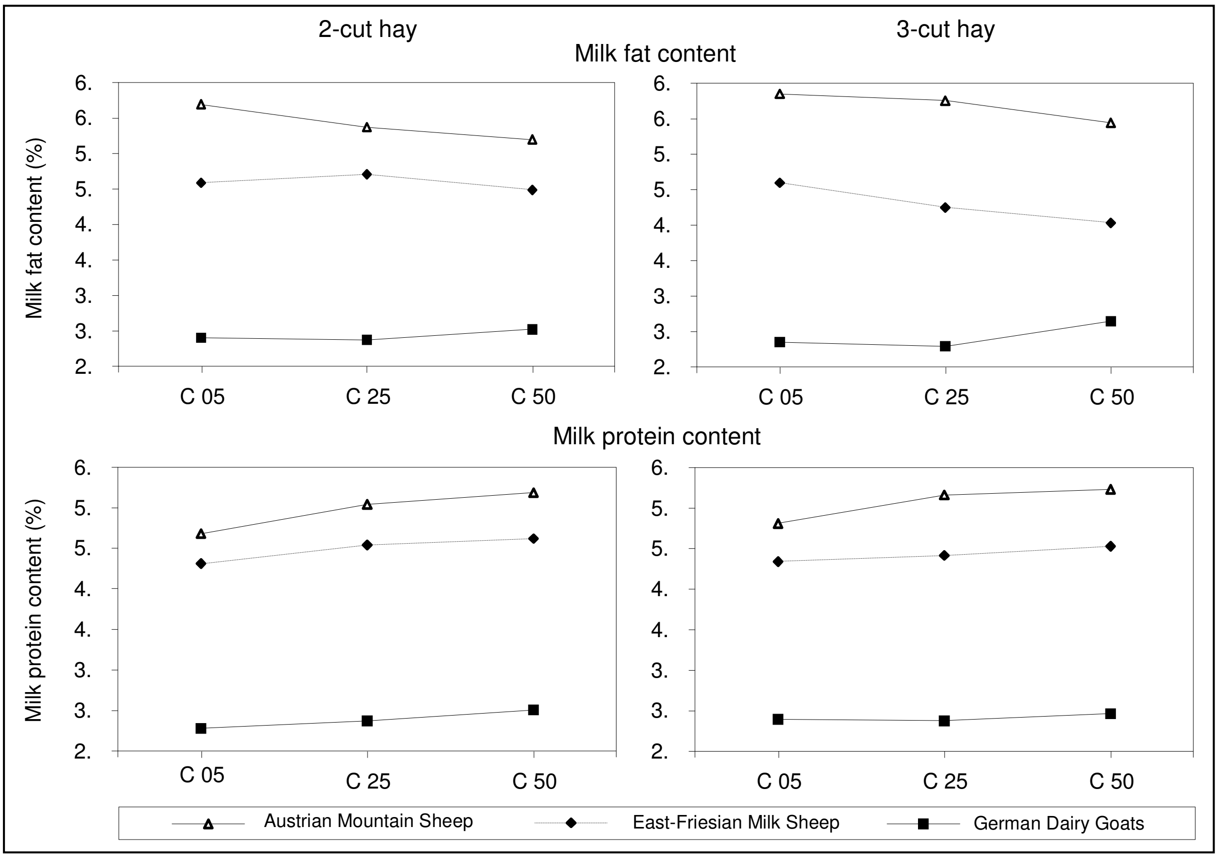
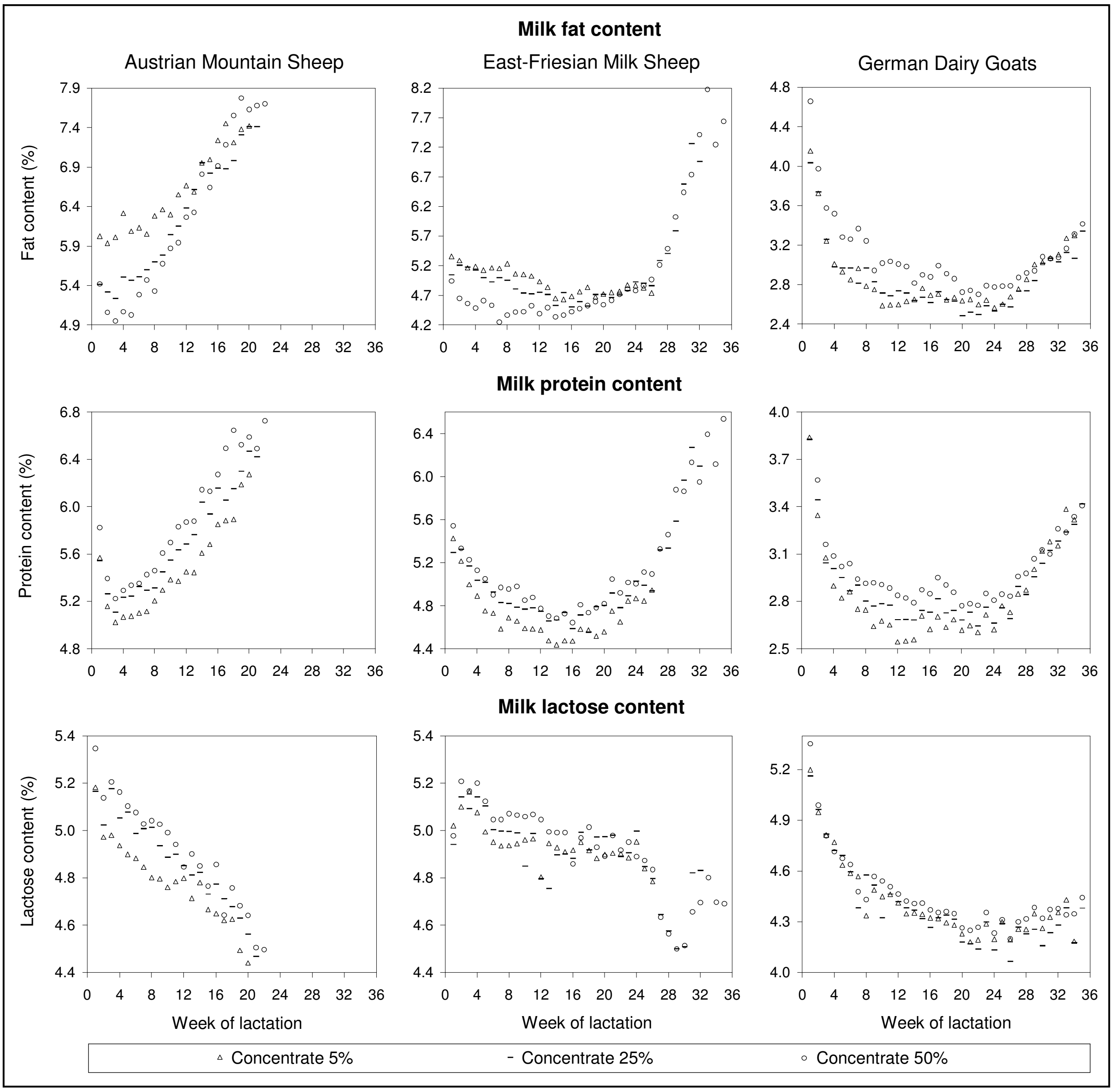


Fig. 5 illustrates the development of milk constituents during lactation. The evolution of fat content was influenced by species/breed and level of concentrate. In AMS, fat content was significantly higher with low concentrate levels during the first third of lactation, whereas it differed only to a small degree thereafter. On the other hand, fat content in EMS did not change markedly over the course of lactation. Only in the last weeks of lactation was there a distinct increase in milk fat content at medium and high concentrate levels. No such increase was observed with low concentrate feeding, presumably because sheep were already dried off before entering this stage. In dairy goats, milk fat content was high at the onset of lactation, followed by a long phase of low fat concentration and an increase in the last 2 months before drying off, a shape typically also for dairy cows (Wood, 1976).

In contrast to fat content, the course of milk protein concentration during lactation was similar for all species/breeds and all levels of concentrate and followed the model by Wood (1976) for cows. Immediately post partum the protein content was very high but decreased for the following weeks. Whereas protein concentration remained low for a long period of time in Milk Sheep and goats, it started to increase in Mountain sheep after three weeks. The influence of concentrate level on milk protein content was more pronounced in sheep than in goats and was especially obvious at the end of lactation. Lactose content decreased in the course of lactation in all species/breeds and concentrate levels in a similar way (Fig. 5).

Fig. 5. Development of milk constituent content during lactation depending on species/breed and concentrate level



3.4 Milk yield per day

The highly significant influence of all three investigated experimental factors (species/breed, forage quality and concentrate level) on important parameters of daily milk yield is presented in Table 5. In order to stress metabolic functions, actual milk yield, yield of milk constituents (FPL) and milk energy (LE) were not only regarded as absolute values but also related to metabolic body weight ($LW^{0.75}$), with similar results.

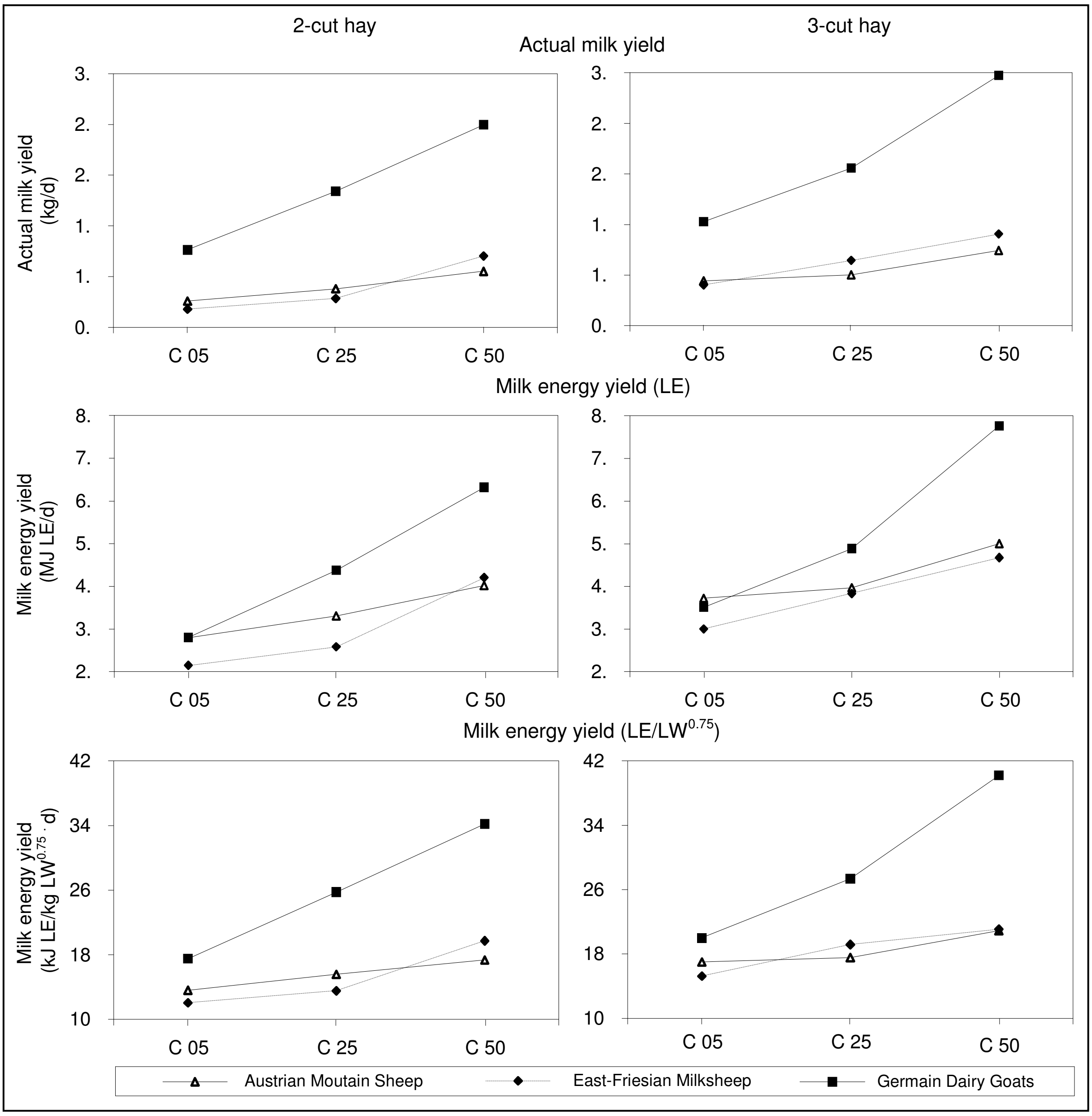
Actual daily milk yield was similar for the two sheep breeds, whereas it was twice as high in dairy goats (983, 1022 and 2028 g for AMS, EMS and GDG, respectively). Low content of milk constituents in goat milk diminished the impression of superiority of goats compared to sheep to a certain extent. As regards FPL, Mountain sheep tended to surpass milk sheep (161, 151 and 209 g FPL for AMS, EMS, GDG). Concerning daily yield of milk energy, there were significant differences between all breeds (4.3, 3.9 and 5.5 MJ for AMS, EMS and GDG).

As average live weight of the species/breeds differed significantly, milk yield was also related to metabolic live weight so that different maintenance requirements were considered. AMS had lowest and GDG highest daily milk yields, whereas EMS ranged in the middle (39, 44 and 102 g/kg $LW^{0.75}$ for AMS, EMS and GDG). Concerning milk constituents (FPL) and milk energy (LE), superiority of goats was still evident, whereas results for the two sheep breeds were similar (170, 168 and 275 kJ LE/kg $LW^{0.75}$ for AMS, EMS and GDG).

As expected, all parameters of milk yield were significantly improved by feeding forage of higher quality (Table 5). An elevation of forage ME content from 7.98 to 8.41 MJ/kg DM (Gruber et al., 1st communication) increased actual milk by 0.25 kg (1.22 and 1.47 kg in forage group F 2 and F 3) and milk energy yield by 0.87 MJ (4.12 and 4.99 MJ LE in F 2 and F 3).

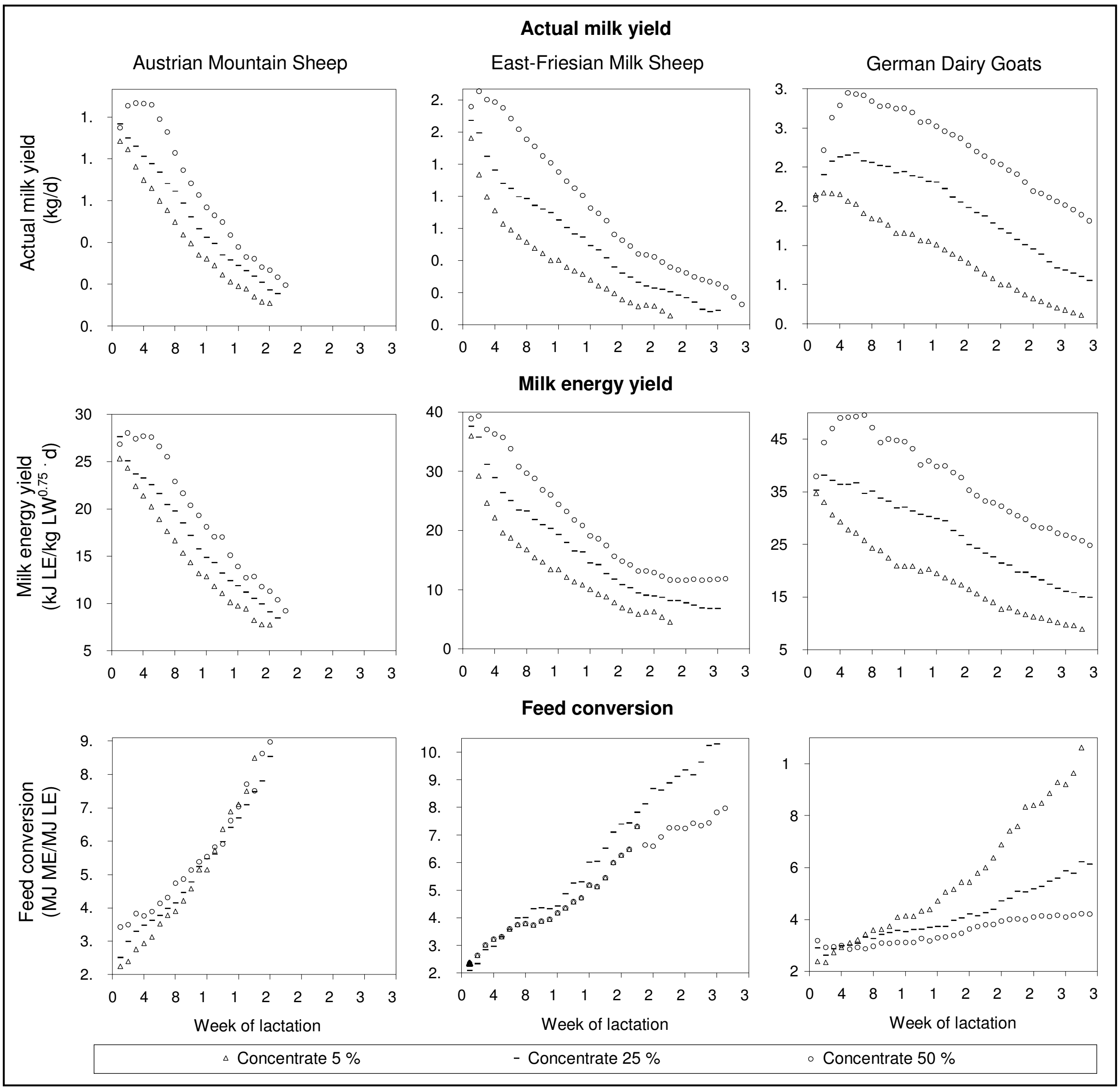
Milk yield was significantly improved by elevated concentrate proportion of the diet (Table 5). Actual milk yield was 1.02, 1.29 and 1.73 kg as well as 3.5, 4.3 and 5.8 MJ LE in concentrate levels C 05, C 25 and C 50, respectively. On average, actual milk yield was increased by 0.67 kg per one kg of concentrate DM. With linear regression coefficients of 0.30, 0.55 and 1.31 kg milk per kg concentrate DM in AMS, EMS and GDG, species/breed showed a significant influence on efficiency of concentrate feeding, implying that response to concentrate feeding depends to a high degree on milk production potential of the animals. This is confirmed by the significant interaction ($P = 0.000$) between species/breed and concentrate for all parameters of daily milk production (Table 6). With higher concentrate levels, dairy goats increased milk yield, FPL and LE yield to a greater extent than mountain and milk sheep, the response being more pronounced with higher forage quality (Fig. 6). Similar results were obtained for yield of milk constituents and milk energy - as absolute values but also when related to metabolic live weight (see Fig. 6).

Fig. 6. Mean yield of actual milk and milk energy as influenced by species/breed, concentrate level and forage quality



The development of milk yield during lactation is demonstrated in Fig. 7. In all species/breeds there was no increase in milk yield in the first weeks of lactation at the low concentrate level (C 05), whereas the shape of lactation curve followed the model established by Wood (1976) at the high concentrate level (C 50). The increase in milk yield in the first 5 to 6 weeks of lactation was more intense in dairy goats than in sheep. The subsequent decrease in milk yield was similar for all concentrate levels.

Fig. 7. Development of milk yield and feed conversion during lactation depending on species/breed and concentrate level



3.5 Milk yield per lactation and year

Since length of lactation differed between Mountain sheep on the one side, and Milk sheep and Dairy goats on the other, to compare performances of breeds it is important to consider not only yield per lactation but also per year. All three experimental factors exerted significant influences (P = 0.000) on the parameters of milk production, whether based on total lactation or on year. AMS, EMS and GDG yielded 143, 228 and 492 kg actual milk per lactation (Table 5). Forage quality improved milk yield by 63 kg per lactation (256 and 319 kg in F 2 and F 3). Values for concentrate levels were 201, 276 and 385 kg actual milk yield (C 05, C 25 and C 50).

As Mountain sheep realised an average of 1.4 lactations per year, milk yields for the two sheep breeds were similar, whereas dairy goats exceeded both of them (213, 227 and 501 kg actual milk as well as 34.9, 33.5 and 51.7 kg yield of milk constituents for AMS, EMS and GDG (Table 5)).

Interactions for species/breeds and concentrate level concerning lactation and year are presented in Table 6. Response to concentrate feeding was more prominent with animals of high milk yield potential, i.e. dairy goats.

3.6 Feed conversion

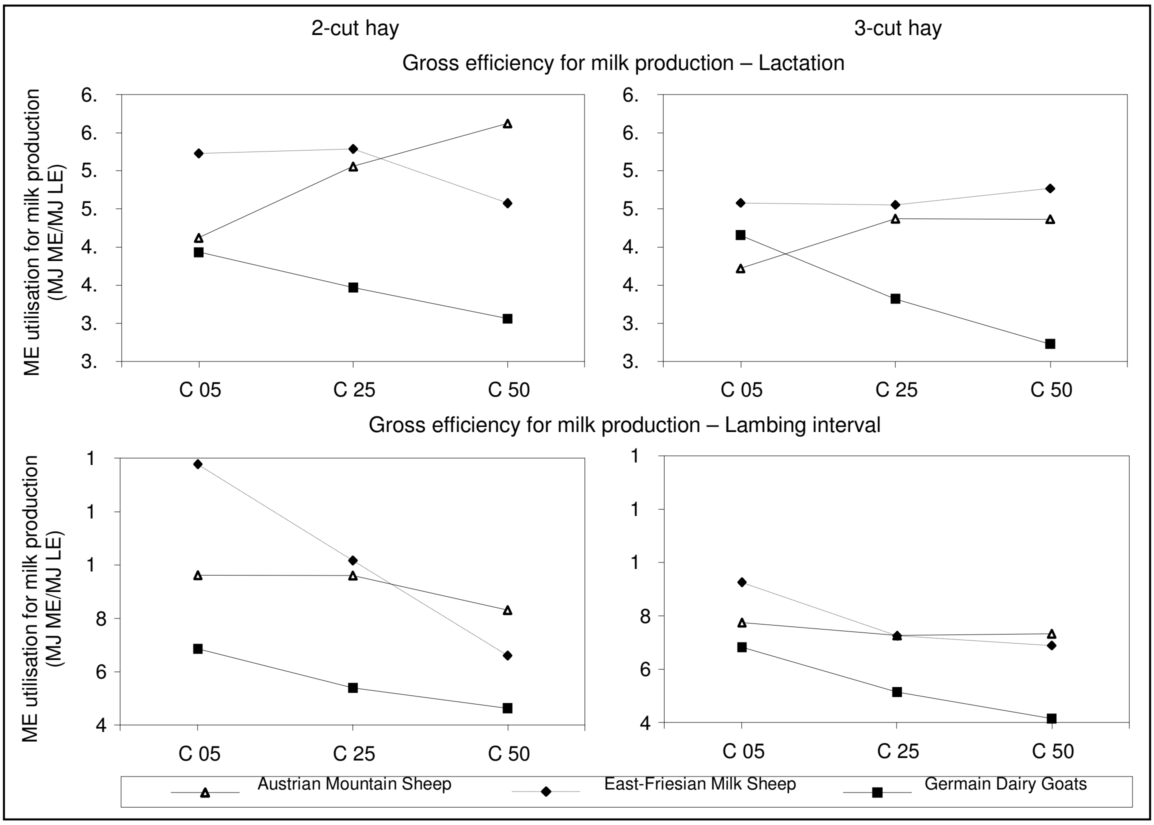
Feed conversion is a very expressive parameter for the comparison of breeds and production systems. Related to one lactation, energy intake per kg actual milk was 22.3, 20.7 and 10.5 MJ ME per kg milk for AMS, EMS and GDG, respectively (compare Table 5). However, energy expenditure in relation to milk energy output showed similar results for the two sheep breeds, whereas efficiency in dairy goats was higher (5.1, 5.4 and 3.9 MJ ME per MJ LE for AMS, EMS and GDG).

For evaluation of effective nutrient costs for milk production, the dry period must be taken into account as well. The two sheep breeds required similar amounts of metabolizable energy per actual milk yield as well as per yield of FPL or energy, with a small tendency for mountain sheep to be more effective than milk sheep. In contrast, dairy goats consumed significantly less than sheep, resulting in an energy intake of 8.3, 9.0 and 5.5 MJ ME per MJ LE for AMS, EMS and GDG (Table 5).

Elevated forage quality significantly reduced energy costs for milk production. Average ME intake per MJ LE was 5.0 and 4.6 MJ in treatments F 2 and F 3, respectively, in respect to lactation, and 8.4 and 6.9 MJ in relation to total lambing interval. Level of concentrate feeding did not influence the efficiency of milk production within lactation (4.80, 4.84 and 4.70 MJ ME per MJ LE in C 05, C 25 and C 50), but did so in a significant way in relation to the total lambing interval (9.04, 7.48 and 6.35 ML ME).

Significant interactions for feed conversion were found between species/breed and concentrate level as well as between species/breed and forage quality, implying that animals of different milk production potential responded to energy supply in a different way (Table 6, Fig. 8). Increasing levels of concentrate feeding influenced feed conversion efficiency in an unfavourable manner in Mountain sheep. The effect was similar in milk sheep, whereas feed conversion efficiency was improved by higher concentrate administration in dairy goats (Table 6). Fig. 8 shows the effect of forage quality on feed conversion efficiency in the lactation phase. Improvement of feed efficiency in dairy goats with increasing concentrate levels was more distinct with F 3 than with F 2 treatment, whereas the deterioration of feed efficiency in mountain sheep was smaller with high quality forage. No effect of concentrate level on feed conversion was found in milk sheep fed 3-cut hay, whereas with the low quality forage, feed efficiency improved with elevated concentrate feeding. Concerning the whole production cycle, increased administration of concentrates ameliorated feed efficiency in all breeds and levels of forage quality, but was especially pronounced with milk sheep fed 2-cut hay.

Fig. 8. Mean gross efficiency for milk production as influenced by species/breed, concentrate level and forage quality



The development of feed conversion efficiency during lactation is presented in Fig. 7. Feed efficiency significantly deteriorated with the proceeding lactation. However, the development was highly influenced by species/breed and concentrate level. Energy expenditure for milk production increased with the progressing lactation, the small differences between concentrate levels observed only at the onset of lactation. In milk sheep, differences between concentrate levels became more significant with the progress of lactation, with high concentrate levels leading to better efficiency. In dairy goats, C 25 and C 55 treatments led to an only small increase of energy expenditure for milk production, whereas, at the low concentrate level, shape of curve was similar to that of milk sheep.

Table 5: Live weight and milking performance (Main effects)

Parameter	Unit	Phase	Species/Breed (S/B)			Forage quality (F)		Concentrate level (C)			P values			RSD
			AMS	EMS	GDG	2 cuts	3 cuts	C 05	C 25	C 50	S/B	F	C	
Number of observations	n	T	100	67	68	116	119	77	78	80				
Number of lactations	n	L	3.87^{a}	3.54^{b}	3.52^{b}	3.64	3.65	3.64	3.64	3.65	0.000	0.936	0.973	0.51
Weeks of lactation	n	L	20.6^{a}	30.7^{b}	34.5^{c}	27.8^{a}	29.4^{b}	26.6^{a}	28.9^{b}	30.3^{c}	0.000	0.000	0.000	2.7
Weeks of dry period	n	D	16.7^{a}	21.6^{b}	16.9^{a}	19.4^{a}	17.4^{b}	20.5^{a}	18.4^{ab}	16.3^{b}	0.000	0.048	0.004	7.6
Weeks of lambing interval	n	T	37.3 ^{a}	52.3^{b}	51.4^{b}	47.2	46.8	47.1	47.3	46.6	0.000	0.668	0.852	7.5
Live weight	kg	L	75.1^{a}	65.7^{b}	53.8^{c}	63.1^{a}	66.6^{b}	62.5^{a}	63.6^{a}	68.4^{b}	0.000	0.001	0.000	7.8
	kg	D	83.2^{a}	72.8^{b}	60.6^{c}	70.2^{a}	74.2^{b}	68.7^{a}	70.6^{a}	77.3^{b}	0.000	0.000	0.000	7.9
	kg	T	78.2^{a}	68.6^{b}	55.9^{c}	65.9^{a}	69.2^{b}	65.1^{a}	66.2^{a}	71.4^{b}	0.000	0.001	0.000	7.7
Fat content	%	L	6.06^{a}	4.94^{b}	2.93^{c}	4.65	4.64	4.74	4.63	4.56	0.000	0.938	0.167	0.60
Protein content	%	L	5.52^{a}	4.96^{b}	2.90^{c}	4.45	4.47	4.30^{a}	4.49^{b}	4.59^{b}	0.000	0.618	0.000	0.35
Lactose content	%	L	4.92^{a}	4.97^{a}	4.45^{b}	4.77	4.78	4.76^{a}	4.76^{a}	4.81^{b}	0.000	0.658	0.025	0.14
FPL content	%	L	16.50^{a}	14.87^{b}	10.28^{c}	13.87	13.90	13.81	13.87	13.97	0.000	0.823	0.524	0.86
Energy content	MJ/kg	L	4.41^{a}	3.87^{b}	2.67^{c}	3.65	3.65	3.66	3.65	3.65	0.000	0.969	0.986	0.28
Milk yield actual	g/d	L	983^{a}	1022^{a}	2028^{b}	1218^{a}	1470^{b}	1017^{a}	1286^{b}	1729^{c}	0.000	0.000	0.000	319
Fat yield	g/d	L	58.9^{a}	49.3^{b}	60.0^{a}	50.6^{a}	61.5^{b}	44.4^{a}	52.9^{b}	70.8^{c}	0.000	0.000	0.000	13.9
Protein yield	g/d	L	54.0^{a}	50.6^{a}	59.1^{b}	49.2^{a}	59.9^{b}	40.6^{a}	52.1^{b}	70.9^{c}	0.001	0.000	0.000	12.6
Lactose yield	g/d	L	48.5^{a}	50.9^{a}	90.1^{b}	57.2^{a}	69.1^{b}	47.8^{a}	60.1^{b}	81.5^{c}	0.000	0.000	0.000	15.3
FPL yield	g/d	L	161.3^{a}	150.7^{a}	209.1^{b}	157.0^{a}	190.4^{b}	132.8^{a}	165.1^{b}	223.2^{c}	0.000	0.000	0.000	40.2
Energy yield	MJ/d	L	4.30^{b}	3.91^{a}	5.45^{c}	4.12^{a}	4.99^{b}	3.51^{a}	4.33^{b}	5.82^{c}	0.000	0.000	0.000	1.05
Milk yield/kg $LM^{0.75}$	g/d	L	39.1^{a}	43.8^{b}	102.3^{c}	57.1^{a}	66.4^{b}	47.4^{a}	60.4^{b}	77.5^{c}	0.000	0.000	0.000	14.5
FPL yield/kg $LM^{0.75}$	g/d	L	6.38^{a}	6.48^{a}	10.55^{b}	7.20^{a}	8.41^{b}	6.06^{a}	7.57^{b}	9.79^{c}	0.000	0.000	0.000	1.81
Energy yield/kg $LM^{0.75}$	kJ/d	L	170.3^{a}	168.0^{a}	275.0^{b}	188.4^{a}	220.5^{b}	159.8^{a}	198.2^{b}	255.4^{c}	0.000	0.000	0.000	48.4
Milk yield actual	kg/LI	T	142.8^{a}	227.8^{b}	492.2^{c}	256.3^{a}	319.0^{b}	201.3^{a}	276.1^{b}	385.4^{c}	0.000	0.000	0.000	74.8
FPL yield	kg/LI	T	23.49^{a}	33.56^{b}	50.75^{c}	31.89^{a}	39.98^{b}	25.16^{a}	34.20^{b}	48.44^{c}	0.000	0.000	0.000	9.21
Energy yield	MJ/LI	T	627^{a}	869^{b}	1322^{c}	833^{a}	1045^{b}	662^{a}	894^{b}	1262^{c}	0.000	0.000	0.000	242
Milk yield actual	kg/year	Y	213.1^{a}	227.4^{a}	501.3^{b}	278.6^{a}	349.2^{b}	222.3^{a}	299.4^{b}	420.1^{c}	0.000	0.000	0.000	88.2
FPL yield	kg/year	Y	34.87^{a}	33.53^{a}	51.70^{b}	35.35^{a}	44.72^{b}	28.56^{a}	37.75^{b}	53.80^{c}	0.000	0.000	0.000	11.56
Energy yield	MJ/year	Y	931^{a}	868^{a}	1347^{b}	925^{a}	1172^{b}	754^{a}	988^{b}	1404^{c}	0.000	0.000	0.000	306
ME per milk actual (day)	MJ/kg	L	22.34^{a}	20.73^{b}	10.49^{c}	18.74^{a}	16.97^{b}	17.61	18.18	17.78	0.000	0.003	0.706	4.34
ME per milk FPL (day)	MJ/kg	L	134.8^{a}	139.2^{a}	102.4^{b}	131.3^{a}	119.6^{b}	126.4	127.3	122.7	0.000	0.001	0.516	25.7
ME per milk energy (day)	MJ/MJ	L	5.05^{a}	5.35^{a}	3.94^{b}	4.99^{a}	4.57^{b}	4.80	4.84	4.70	0.000	0.001	0.655	0.96
ME per milk actual (LI)	MJ/kg	T	37.05^{a}	35.20^{a}	14.61^{b}	32.05^{a}	25.86^{b}	34.09^{a}	28.63^{b}	24.14^{c}	0.000	0.000	0.000	12.26
ME per milk FPL (LI)	MJ/g	T	222.5^{a}	235.8^{a}	142.7^{b}	220.4^{a}	180.2^{b}	238.5^{a}	196.8^{b}	165.7^{c}	0.000	0.000	0.000	70.5
ME per milk energy LI)	MJ/MJ	T	8.32^{a}	9.04^{a}	5.50^{b}	8.37^{a}	6.87^{b}	9.04^{a}	7.48^{b}	6.35^{c}	0.000	0.000	0.000	2.63

Phase: L = lactation, D = dry period, T = total period (lactation and dry period), Y = year, LI = Lambing intervall, FPL = fat + protein + lactose

Table 6: Live weight and milking performance (Interaction Species/Breed × Concentrate level)

Parameter	Unit	Phase	Austrian Mountain Sheep			East-Friesian Milk Sheep			German Dairy Goat			P values		
			C 05	C 25	C 50	C 05	C 25	C 50	C 05	C 25	C 50	S/B × C	S/B × F	C × F
Number of observations	n	T	33	33	34	22	23	22	22	22	24			
Number of lactations	n	L	3.85	3.85	3.92	3.54	3.52	3.54	3.52	3.54	3.50	0.982	0.911	0.372
Weeks of lactation	n	L	19.7	20.9	21.3	26.0	31.4	34.6	34.1	34.6	34.9	0.000	0.002	0.001
Weeks of dry period	n	D	16.8	17.6	15.6	26.6	21.1	17.3	18.2	16.4	16.2	0.058	0.668	0.224
Weeks of lambing interval	n	T	36.5	38.5	36.9	52.6	52.4	51.9	52.3	51.0	51.1	0.852	0.698	0.473
Live weight	kg	L	72.0	73.8	79.4	62.9	64.2	70.0	52.6	52.8	55.9	0.686	0.297	0.985
	kg	D	77.9	81.8	89.9	69.3	71.3	77.7	58.8	58.6	64.4	0.323	0.602	0.982
	kg	T	74.4	77.0	83.1	66.2	67.0	72.6	54.7	54.6	58.5	0.590	0.363	0.987
Fat content	%	L	6.27	6.07	5.82	5.08	4.98	4.76	2.88	2.83	3.09	0.054	0.006	0.970
Protein content	%	L	5.25	5.60	5.71	4.82	4.98	5.08	2.84	2.88	2.99	0.120	0.251	0.592
Lactose content	%	L	4.86	4.92	4.99	4.97	4.94	4.99	4.47	4.41	4.46	0.080	0.028	0.815
FPL content	%	L	16.38	16.59	16.52	14.86	14.90	14.84	10.18	10.12	10.54	0.563	0.005	0.866
Energy content	MJ/kg	L	4.44	4.43	4.37	3.89	3.89	3.83	2.64	2.63	2.75	0.356	0.012	0.888
Milk yield actual	g/d	L	855	943	1150	794	970	1301	1402	1946	2736	0.000	0.261	0.787
Fat yield	g/d	L	53.4	56.4	66.9	40.0	47.2	60.7	39.9	55.1	85.0	0.000	0.751	0.840
Protein yield	g/d	L	44.1	52.4	65.4	38.3	47.9	65.6	39.4	56.1	81.6	0.001	0.798	0.939
Lactose yield	g/d	L	41.6	46.4	57.5	39.4	48.2	65.0	62.5	85.8	122.0	0.000	0.539	0.825
FPL yield	g/d	L	139.0	155.1	189.8	117.7	143.3	191.2	141.8	197.0	288.7	0.000	0.971	0.868
Energy yield	MJ/d	L	3.77	4.14	5.01	3.08	3.72	4.92	3.68	5.12	7.54	0.000	0.985	0.853
Milk yield/kg $LM^{0.75}$	g/d	L	35.1	38.1	44.2	35.3	42.6	53.5	71.7	100.4	134.7	0.000	0.207	0.846
FPL yield/kg $LM^{0.75}$	g/d	L	5.66	6.23	7.26	5.25	6.31	7.88	7.27	10.16	14.22	0.000	0.728	0.912
Energy yield/kg $LM^{0.75}$	kJ/d	L	153.4	166.1	191.5	137.3	164.0	202.7	188.6	264.5	372.0	0.000	0.776	0.892
Milk yield actual	kg/LI	T	119.7	137.4	171.4	149.3	218.2	316.1	335.0	472.7	668.8	0.000	0.029	0.964
FPL yield	kg/LI	T	19.47	22.66	28.34	22.10	32.14	46.44	33.91	47.79	70.55	0.000	0.197	0.898
Energy yield	MJ/LI	T	528	605	748	578	834	1194	879	1242	1844	0.000	0.247	0.892
Milk yield actual	kg/year	Y	185.6	197.1	256.7	148.1	217.1	316.9	333.3	483.9	686.8	0.000	0.317	0.980
FPL yield	kg/year	Y	29.98	32.33	42.31	21.96	32.02	46.62	33.74	48.92	72.46	0.000	0.968	0.949
Energy yield	MJ/year	Y	813	862	1118	574	831	1199	874	1271	1894	0.000	0.995	0.959
ME per milk actual (day)	MJ/kg	L	19.78	23.20	24.05	21.07	21.14	19.98	11.97	10.21	9.30	0.001	0.154	0.627
ME per milk FPL (day)	MJ/kg	L	119.7	139.2	145.4	141.9	141.4	134.3	117.4	101.2	88.5	0.000	0.073	0.589
ME per milk energy (day)	MJ/MJ	L	4.43	5.21	5.50	5.43	5.42	5.21	4.54	3.90	3.40	0.000	0.072	0.578
ME per milk actual (LI)	MJ/kg	T	39.26	37.62	34.28	45.06	34.43	26.12	17.96	13.84	12.04	0.043	0.064	0.181
ME per milk FPL (LI)	MJ/g	T	235.4	225.3	206.7	303.6	228.0	175.7	176.4	137.3	114.5	0.010	0.052	0.125
ME per milk energy LI)	MJ/MJ	T	8.70	8.44	7.82	11.61	8.71	6.81	6.82	5.29	4.40	0.005	0.055	0.124

Phase: L = lactation, D = dry period, T = total period (lactation and dry period), Y = year, LI = Lambing intervall, FPL = fat + protein + lactose

3.7 Nutrient supply in relation to calculated requirements

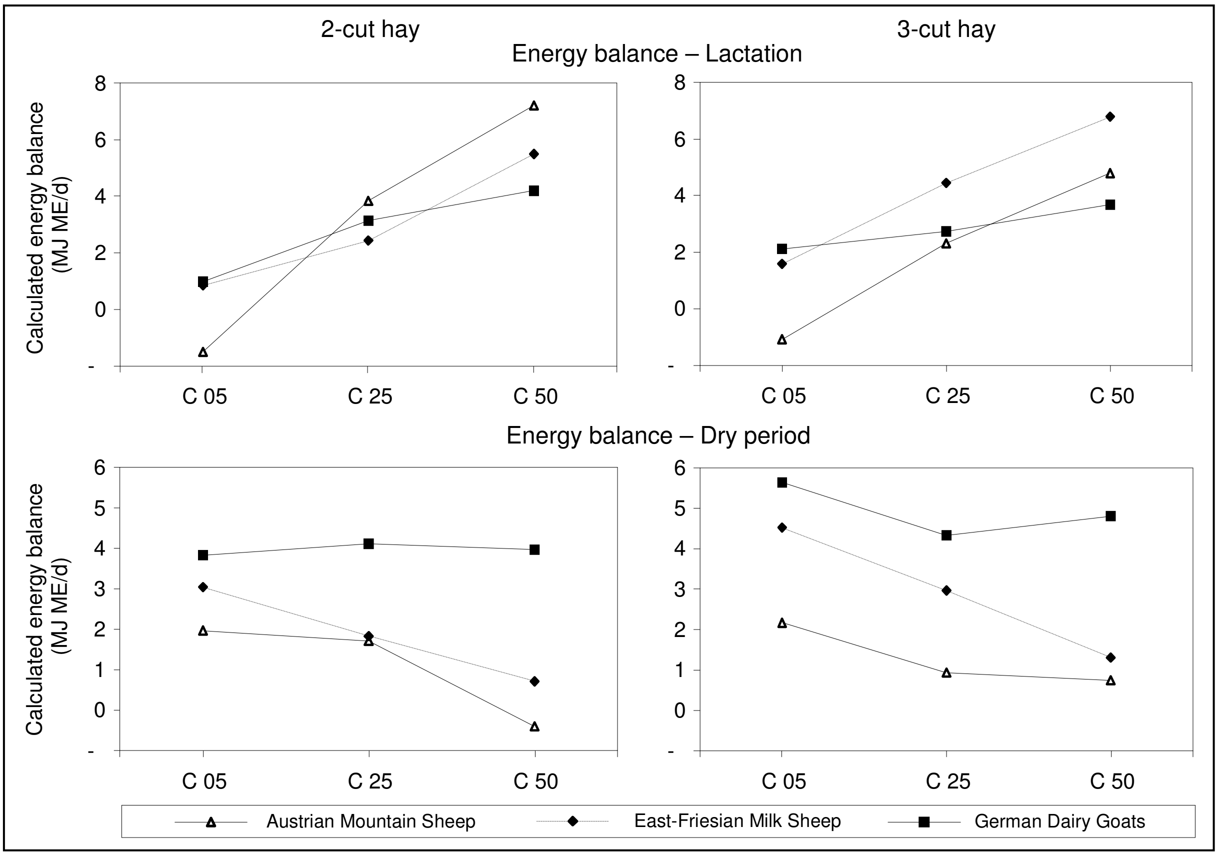
Supply of energy, protein and minerals in relation to calculated requirements is presented in Table 7 (main effects) and 8 (interactions). As calculated according to GfE (1996) for sheep and GfE (2003) for goats (see section 2.7), average energy intake in lactation was above requirements in all animals. Energy surplus was higher in Milk sheep than Mountain sheep and dairy goats (2.6, 3.6 and 2.8 MJ ME for AMS, EMS and GDG). Forage quality did not affect the calculated energy balance (3.0 and 3.0 MJ ME in F 2 and F 3). As expected, the level of concentrate exerted the most significant influence on energy balance (0.5, 3.1 and 5.4 MJ ME for concentrate groups C 05, C 25 and C 50, as a mean of lactation). This corresponds well with recorded live weight change in the respective animals (-75, 133 and 329 g/day). Animals responded to low energy intake during lactation with elevated feed consumption (above their calculated requirements) in the dry period (3.5, 2.6, 1.8 ME MJ in C 05, C 25 and C 50). The extent of compensation was different for the three breed. As dairy goats yielded higher amounts of milk than sheep in lactation, excess in feed intake during dry period was higher in goats than sheep (1.2, 2.4 and 4.4 MJ ME for AMS, EMS and GDG). With regard to the whole lambing interval, animals fed high amounts of concentrate showed higher energy excess than others, as time in milk was longer than dry period (1.7, 2.9 and 4.1 MJ ME in C 05, C 25 and C 50).

Since crude protein and minerals are positively correlated with the energy content of grass, (Gruber et al., 1994), the protein and mineral supply in hay follows the same trends as outlined for the ME supply of the experimental groups (Table 7 and 8).

For the lactation period, significant interactions were analysed for species/breed and concentrate level as well as for species/breed and forage quality for all parameters shown (Table 8). In Fig. 9 the impact of concentrate level on the calculated energy balance is demonstrated for species/breeds and forage quality, both for lactation and dry period. When fed on low concentrate diets (C 05), Mountain sheep exhibited the greatest negative ME balance in both forage groups. However, when offered higher amounts of concentrates, they sooner passed on to positive energy balances than the goats, indicating that they were not able to divert additional energy to milk production to the same extent as goats. Apparently, an increasing part of ME was diverted towards retention of body mass, which agrees well with data for LWC (197, 134, 57 g/day for AMS, EMS and GDG). Results for Milk sheep were similar to that of Mountain sheep, showing that their capacity for milk production was lower than that of dairy goats, too.

In the dry period, species/breeds maintained higher ME balances with better forage quality at all concentrate levels, showing that there was no absolute regulation of feed intake by energy balance. On the other hand, animals fed high quality forage tended to reduce energy balance to a greater extent with increasing concentrate levels compared to animals fed low quality forage. Furthermore, response to concentrate administration during lactation differed between species/breeds in the dry period (P = 0.062). With increasing concentrate levels, both sheep breeds decreased energy balance in the dry period, whereas no alteration was observed in dairy goats (Fig. 9).

Fig. 9. Mean calculated energy balance as influenced by species/breed, concentrate level and forage quality



The evolution of energy balance during lactation is illustrated in Fig. 10. Whereas all species/breeds suffered from intense negative energy balances at the low concentrate level, animals fed the 50% concentrate diet never lapsed into negative energy balance. Period of time in negative energy balance differed for species/breeds (10, 5 and 7 weeks for AMS, EMS and GDG at C 05). With concentrate level C 25, negative energy balance was observed only in the first 2 to 3 weeks. The animals maintained positive energy balances for a long period of time and approached energy equilibrium at the end of the dry period. Extent of energy surplus depended on concentrate level.

Fig. 10. Development of calculated energy balance during lambing interval depending on species/breed and concentrate level

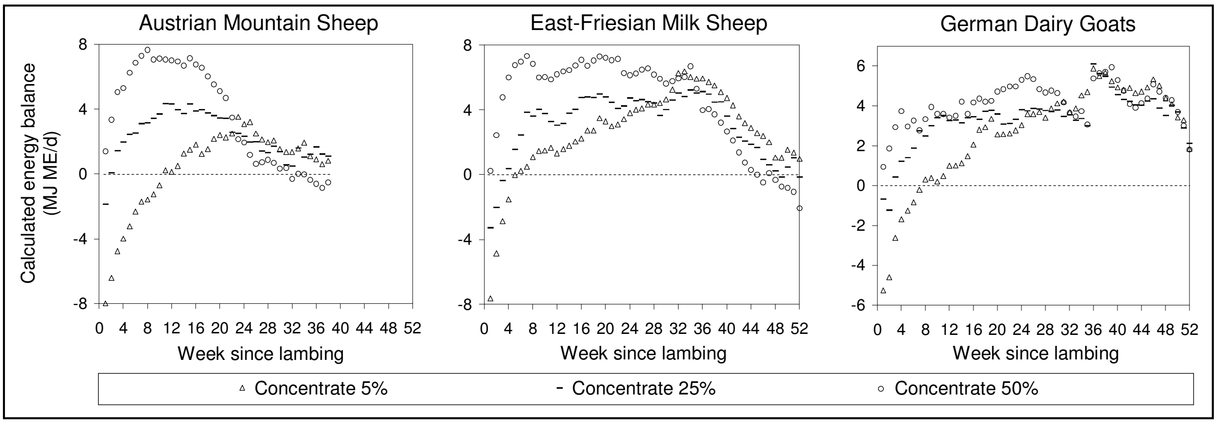


Table 7: Live weight change and nutrient supply (Main effects)

Parameter	Unit	Phase	Species/Breed (S/B)			Forage quality (F)		Concentrate level (C)			P values			RSD
			AMS	EMS	GDG	2 cuts	3 cuts	C 05	C 25	C 50	S/B	F	C	
Number of observations	n	T	100	67	68	116	119	77	78	80				
Live weight change	g/d	L	197^{a}	134^{a}	57^{b}	109	150	-75^{a}	133^{b}	329^{c}	0.000	0.128	0.000	200
	g/d	D	988^{a}	701^{b}	887^{a}	820	897	891	844	841	0.000	0.085	0.594	335
	g/d	T	496^{a}	369^{b}	325^{b}	381	412	308^{a}	389^{b}	493^{c}	0.000	0.138	0.000	154
Covering of	MJ/d	L	2.6^{a}	3.6^{b}	2.8^{a}	3.0	3.0	0.5^{a}	3.1^{b}	5.4^{c}	0.006	0.887	0.000	2.0
ME requirement	MJ/d	D	1.2^{a}	2.4^{b}	4.4^{c}	2.3^{a}	3.0^{b}	3.5^{a}	2.6^{b}	1.8^{c}	0.000	0.012	0.000	2.1
	MJ/d	T	2.0^{a}	3.3^{b}	3.3^{b}	2.8	3.0	1.7^{a}	2.9^{b}	4.1^{c}	0.000	0.320	0.000	1.7
Covering of	g/d	L	47	51	43	49	45	22^{a}	48^{b}	71^{c}	0.154	0.132	0.000	24
uCP requirement	g/d	D	5^{a}	4^{a}	2^{b}	4	3	4	3	3	0.000	0.263	0.614	4
	g/d	T	30	33	30	32	30	15^{a}	31^{b}	47^{c}	0.441	0.366	0.000	16
Covering of	g/d	L	12.1^{a}	11.2^{b}	9.2^{c}	10.5^{a}	11.1^{b}	6.6^{a}	10.5^{b}	15.4^{c}	0.000	0.027	0.000	1.9
Ca requirement	g/d	D	7.0	7.1	7.2	6.8^{a}	7.4^{b}	7.2	7.1	7.0	0.774	0.009	0.601	1.5
	g/d	T	10.0^{a}	9.8^{a}	8.6^{b}	9.2^{a}	9.8^{b}	6.8^{a}	9.1^{b}	12.4^{c}	0.000	0.005	0.000	1.6
Covering of	g/d	L	4.1^{a}	4.0^{a}	2.9^{b}	3.5^{a}	3.9^{b}	2.3^{a}	3.5^{b}	5.2^{c}	0.000	0.000	0.000	0.6
P requirement	g/d	D	2.6	2.5	2.5	2.3^{a}	2.8^{b}	2.6	2.5	2.5	0.375	0.000	0.242	0.6
	g/d	T	3.5^{a}	3.5^{a}	2.8^{b}	3.1^{a}	3.5^{b}	2.4^{a}	3.1^{b}	4.2^{c}	0.000	0.000	0.000	0.5
Covering of	g/d	L	1.33^{a}	1.15^{b}	0.72^{c}	1.13^{a}	0.99^{b}	-0.09^{a}	0.96^{b}	2.32^{c}	0.000	0.000	0.000	0.29
Na requirement	g/d	D	0.35^{a}	0.20^{b}	0.34^{a}	0.34^{a}	0.25^{b}	0.28	0.31	0.29	0.001	0.004	0.816	0.26
	g/d	T	0.93^{a}	0.82^{b}	0.61^{c}	0.85^{a}	0.73^{b}	0.05^{a}	0.70^{b}	1.61^{c}	0.000	0.001	0.000	0.28

Phase: L = lactation, D = dry period, T = total period (lactation and dry period)

Table 8: Live weight change and nutrient supply (Interaction Species/Breed × Concentrate level)

Parameter	Unit	Phase	Austrian Mountain Sheep			East-Friesian Milk Sheep			German Dairy Goat			P values		
			C 05	C 25	C 50	C 05	C 25	C 50	C 05	C 25	C 50	S/B × C	S/B × F	C × F
Number of observations	n	T	33	33	34	22	23	22	22	22	24			
Live weight change	g/d	L	-174	230	534	20	117	265	-69	52	189	0.000	0.799	0.164
	g/d	D	1108	950	905	666	707	730	899	875	888	0.281	0.428	0.802
	g/d	T	323	508	657	339	349	420	263	309	403	0.000	0.645	0.718
Covering of	MJ/d	L	-1.3	3.1	6.0	1.3	3.4	6.1	1.6	2.9	3.9	0.000	0.000	0.056
ME requirement	MJ/d	D	2.1	1.3	0.2	3.8	2.4	1.0	4.7	4.2	4.4	0.062	0.189	0.302
	MJ/d	T	0.1	2.3	3.8	2.5	3.0	4.4	2.6	3.3	4.1	0.004	0.000	0.145
Covering of	g/d	L	6	51	84	28	49	75	33	43	53	0.000	0.006	0.100
uCP requirement	g/d	D	4	5	4	5	4	3	2	1	2	0.446	0.072	0.865
	g/d	T	5	32	54	16	31	52	23	29	37	0.000	0.009	0.027
Covering of	g/d	L	6.8	12.0	17.4	7.2	10.7	15.8	5.9	8.8	12.9	0.000	0.014	0.163
Ca requirement	g/d	D	7.1	7.1	6.8	7.5	7.0	6.8	7.1	7.0	7.4	0.585	0.999	0.716
	g/d	T	6.9	9.9	13.3	7.3	9.2	12.8	6.3	8.2	11.2	0.090	0.104	0.188
Covering of	g/d	L	2.3	4.0	6.0	2.7	3.8	5.6	1.9	2.8	4.0	0.000	0.066	0.069
P requirement	g/d	D	2.6	2.6	2.5	2.7	2.5	2.4	2.5	2.4	2.5	0.463	0.938	0.485
	g/d	T	2.4	3.4	4.7	2.7	3.3	4.5	2.1	2.6	3.5	0.002	0.147	0.121
Covering of	g/d	L	0.0	1.2	2.7	0.0	1.0	2.4	-0.3	0.6	1.8	0.000	0.091	0.550
Na requirement	g/d	D	0.33	0.36	0.36	0.21	0.20	0.19	0.31	0.37	0.34	0.980	0.780	0.747
	g/d	T	0.12	0.86	1.81	0.10	0.70	1.67	-0.07	0.53	1.35	0.122	0.440	0.252

Phase: L = lactation, D = dry period, T = total period (lactation and dry period)

4. Discussion

4.1 Milk composition

Effect of species/breeds

Milk composition did not only differ between goats and sheep but also between the two sheep breeds. Horstick et al. (2001) reported an average fat content of 5.4% and a protein content of 4.9% for East-Friesian Milk Sheep. Whereas protein content in our study corresponds well to their results, with 4.96%, fat percentage was markedly lower in the present experiment (4.94%). Milk composition in AMS considerably differed from that of EMS. Protein concentration was only 0.5% points higher but fat content exceeded that of EMS by 1.1% points. Lactose percentage was very similar in AMS and EMS (4.92% and 4.97%) which goes back to the osmotic effectiveness of lactose and its subsequent correlation with milk yield (Peaker, 1977).

Observed average fat content in goats (2.93%) was low compared to values given in the literature. GfE (2003) assumes an average content 3.6% of fat for Saanen Goats. Protein content (2.90%) was in line with the value of 2.8% given by McDonald et al. (2002a) but lower than 3.2% as supposed by GfE (2003). Lactose concentration corresponded well to values given for Saanen goats (4.5% reported by McDonald et al. (2002a) and GfE (2003)). According to IDF (1986), lactose content is usually higher in goat milk than in sheep milk. Our results, however, show that lactose percentage did not differ between AMS and EMS, but was significantly lower in goats. However, differences in lactose content (although statistically significant) were not important compared to differences in the other constituents, as proposed by Hadjipanayiotou (1995).

Influence of nutrition

Quality of forage and amount of concentrate supplementation showed marked influence on milk composition. Whereas feeding hay of elevated quality induced a rise in fat content in AMS, in EMS the expected decrease in fat content was observed. Typically, fat percentage is positively correlated with NDF concentration of the diet, as fibre is metabolized to acetate (the precursor of fatty acids) in the rumen. Our findings are in line with results of Goodchild et al. (1999) who, in their study on Awassi ewes, also found that ewes fed high fibre diets displayed higher fat percentages than those fed diets with low fibre content. Decreased milk fat percentage with better forage quality is also a result of dilution – elevated energy intakes with forage of high quality promote milk yield and consequently decrease fat content per kg milk yield (Nudda et al., 2004). With better nutrient provision from hay, milk yield in AMS improved only little, whereas fat percentage was elevated. This response might be a breed characteristic.

Tessman et al. (1991) summarized the influence of higher grain diets as promoting milk protein percentage and decreasing fat percentage in cows. These results are also found here for all three breeds, only C 55 treatment in goats led to a significant increase in fat percentage. Milk protein content was increased by a reduction of forage proportion in the diet in all three breeds. Murphy and O'Mara (1993) suggested that, in dairy cows, an increase in starch in the diet leads to an increase in the ratio of propionate to acetate in the rumen which, in turn, increases milk protein and decreases milk fat. In an experiment by El-Gallad et al. (1988) Nubian Goats reacted to an increase in energy intake with significantly elevated milk protein percentage. In our study, higher energy uptake resulted in higher milk protein content in all breeds. However, this increase was not significant at all stages. The increased milk protein content is mainly due to higher microbial protein synthesis in the rumen resulting from enhanced intake of fermentable organic matter associated with highly digestible diets.

A reduction in NDF content of the diet due to decreased percentage of roughage leads to a decrease in the proportion of acetate and butyrate, the principal precursors of fat synthesis in the mammary gland and by this, induce a decrease in milk fat percentage (El-Gallad et al., 1988). This was observed in AMS and EMS, but GDG reacted with an increase in milk fat concentration with C 50 treatments which is difficult to explain.

However, the tendency for higher milk fat content in AMS in C 05 treatments could not only be a result of high fibre content of the diet but also derive from lipid mobilization from adipose tissues. This was also proposed by Schmidely et al. (1999) for goats that were fed at a low DM intake. The observed live weight loss for C 05 treatments confirms this assumption.

Impact of stage of lactation

In contrast to findings by Horstick et al. (2001) for sheep, milk fat and protein content did not increase continuously over the course of lactation, but showed a decrease to the middle of lactation and a rather steep increase before drying off. A clear increase in concentration of milk components with advancement of lactation, as was observed by Casoli et al. (1989) with Massese sheep, was only registered in AMS in our study, whereas milk components decreased to the middle of lactation in EMS. A decrease to the peak of lactation and a subsequent increase is described by Treacher and Caja (2002). They depict the negative relationship between milk yield and the contents of fat and protein as a general phenomenon. Dairy goats in our experiment reached minimum of milk fat already in the beginning of the 3rd month post partum as compared to the fourth month reported by McDonald et al. (2002a).

Whereas fat content as a mean of lactation did not significantly differ between the concentrate treatments, it did so in the first weeks after parturition. Milk fat content was negatively correlated with concentrate level during the first 12 weeks of lactation (4.78, 4.60 and 4.46% in C 05, C 25 and C 50). This probably does not only go back to the decreased NDF content of diets with higher concentrate portions but also to mobilization of body fat and the dilution effect, as milk yield was highest in the first weeks of lactation. Snell (1996) reported that milk fat content decreased profoundly from day 4 to 24 of lactation in goats, whereas the reduction of fat percentage was small afterwards. This is in line with our findings, as average milk fat content decreased from 4.3 to 3.2% in the first four weeks post partum, compared to only small changes in the remainder of lactation. In line with results of our study, increasing energy intake resulted in significant increases in milk protein percent in the study by El-Gallad et al. (1988). Differences in milk protein content between concentrate levels were more pronounced in the middle of lactation than at onset or the close of lactation. During the first 26 weeks of lactation, significant differences in protein content with elevated concentrate supply were observed.

4.1 Milk yield

Effect of species/breeds

According to Treacher and Caja (2002), in sheep, variation in milk yield between and within breeds is very large. With 228 kg in EMS in our study, average milking performance was rather low compared to results by Horstick et al. (2001), who reported the total lactation yield of East-Friesian Milk Sheep to be 500 – 700 kg of milk. No comparable data were available for Mountain sheep. However, meat type breeds like Suffolk sheep suckling twins produce about 145 kg of milk in 12 weeks of lactation (McDonald et al., 2002b). In their 20.6 weeks of lactation, AMS yielded only about 143 kg. Total lactation milk yield was 492 kg in GDG, which is low compared to values given by McDonald et al. (2002a) and AFRC (1998) for Saanen Goats. However, the 904 kg for Saanen and 970 kg for British Saanen reported by McDonald et al. were obtained in a lactation of about 10 months (i.e. 43.5 weeks), whereas milking period in our study was only 34.5 weeks. Still, with an average daily milk yield of 2.74 kg when fed 50% concentrate, goats in our study cannot be regarded as particularly productive.

Influence of nutrition

Daily milk yield per kg metabolic LW was significantly influenced by quality of roughage in EMS and GDG. Not only did the 3-cut hay have a higher energy content but, due to its lower

NDF content, ingestibility was elevated through faster breakdown of feed and accelerated rate of passage (Dulphy and Demarquilly, 1994). This led to higher energy intakes with the 3-cut hay and, as a consequence, improved milk production. Milk sheep increased daily milk production by 265 g when fed the 3-cut hay and GDG produced on average 326 g more milk compared to animals which received the low quality forage. In AMS, the rise in milk yield was only 165 g. However, daily milk energy output per kg $LW^{0.75}$ did not significantly differ between EMS and AMS whether fed the 2-cut or the 3-cut hay, even though EMS improved actual milk yield with better forage quality to a somewhat higher degree ($P = 0.261$).

Concentrate administration significantly influenced milk production. As reported by DePeters and Cant (1992) as well as Murphy and O'Mara (1993) forage to concentrate ratio effects are dependent of energy concentrations. As the proportion of concentrate in the ration is elevated, an increase in energy density of the diet is obtained, which normally leads to elevated milk production and increased protein percentage.

Animals in C 25 produced on average 269 g more milk per day than animals in C 05. Feeding rations with 50% concentrate induced a rise in milk yield by 712 g compared to C 05. This is equivalent to a rise in milk production by 26.5% and 70.0%. Elevation in milk yield was highest in goats, as DGD produced almost twice as much milk in C 50 compared to C 05 (95.2%). In EMS the rise was only 63.9% and the augmentation in AMS was not higher than 34.4%. While milk production of AMS exceeded that of EMS in C 05, there was a tendency for EMS to surpass AMS with higher concentrate levels.

The positive correlation between energy intake and milk production was also reported by Morand-Fehr (1980) for goats. The influence of ME intake on milk yield was highest in goats and smallest in AMS. Goodchild et al. (1999) reported, that as ME intake was increased by 1 MJ, ewes responded with an additional production of 40 ml milk. The corresponding results were 43 g for AMS, 74 g for EMS and 106 g for GDG in our study. As milk content of Awassi ewes was similar to that of AMS ewes, it is comprehensible that a change in ME intake resulted in comparable increases in milk yield.

Response in milk yield to elevated energy intake was more intense in goats than in sheep breeds. It is possible that EMS did not have the genetic potential to increase milk yield to the same extent as the goats. An abated responsiveness to changes in energy intake in low productive animals has already been reported by Sachdeva et al. (1974) for goats.

With higher concentrate administration goats also showed the highest elevation of energy output in milk. Whereas goats and AMS produced the same amount of milk energy in C 05 (3.7 MJ LE), goats improved their milk energy performance with higher concentrate levels to a much greater extent than AMS (7.5 vs. 5.0 MJ LE in C 55). However, rise in protein content of milk with elevated concentrate feeding was highest in AMS so that daily milk energy output in this breed was as high as in EMS even though milk yield in Mountain sheep did not improve to the same extent as in Milk sheep.

Milk performance is one of the most important factors determining feed intake. Daccord and Kessler (1994) proposed an additional intake of 300 – 400 g of feed per kg milk. In our study, goats consumed about 490 g more as milk yield increased by 1 kg. As sheep reacted not so much with improved milk yield but rather with a change in milk content, in AMS extra feed intake per kg milk was as high as 679 g, and even 844 g in EMS.

Hadjipanayiotou and Photiou (1995) reported that reduction in energy supply below requirements will considerably decrease milk yield and that undernourished goats will direct extra feed allowance mainly towards weight gain. The same was observed in our experiment, as AMS and goat dams, that were in negative energy balance, significantly improved ME intake when offered high forage quality (at the low concentrate level) but did not elevate milk production to the extent possible based on increase in ME uptake. Furthermore, negative live weight change was by far smaller in forage group F 3 compared to F 2. As animals passed on to positive energy balances in C 25 treatments, further increase in feed intake was mainly directed towards milk production.

Impact of stage of lactation

McDonald et al. (2002a) as well as Sutton and Mowlem (1991) reported that goats reach peak milk production at about the sixth week post partum and milk yield declines slowly in the succeeding months. This is in line with results of our study, because highest milk yield in GDG was recorded in the 5th week of lactation, after which milk yield decreased. In contrast, milk yield in sheep decreases immediately after the onset of lactation and declines gradually over the course of lactation (Fuertes et al., 1998; Horstick et al., 2001) as was also observed in our study.

El-Gallad et al. (1988) reported that Egyptian Nubian Goats fed a low roughage diet (20% energy from roughage) at a rate of 100% of NRC recommendations, exhibited peak milk production already in the first week of lactation, whereas goats fed on a high energy level (125% of NRC recommendations) peaked in the third week post partum. Results of our study show that the lower the energy supply, the sooner the peak in milk production occurs. Hussain et al. (1996) suggested that high milk yield in late lactation can only be maintained by increasing energy supply to goats, as energy is primarily diverted to rebuilding of body reserves at the end of lactation. This is confirmed by our results, as goats in C 50, contrary to goats of the other treatments, still produced respectable amounts of milk at the end of lactation.

4.3 Feed conversion

In milk sheep and dairy goats, differences in feed conversion (MJ ME/MJ LE) between the different concentrate levels increased with advancement of lactation. This was also described by Goetsch et al. (2001) for dairy goats. Differences in feed conversion may have resulted from body tissue mobilization in early lactation, whereas in late lactation, considerable amounts of nutrients will have been used for replenishment of body reserves. Better feed efficiency with higher forage quality might go back to higher energy intakes per kg DM with the 3-cut forage. Highest value for feed efficiency was attained in week one in C 05 treatments. This indicates that, when only small amounts of concentrates were fed, degradation of body tissue was very intense at the onset of lactation.

Results demonstrate that all three species/breeds showed equal feed intakes at the three concentrate levels investigated. However, feed intake related to metabolic LW was lowest in AMS and highest in GDG, the discrepancy increasing with higher concentrate levels. As a consequence, actual milk yield (per day) was by far highest in dairy goats, while Mountain and Milk sheep showed similar milk yields. High feeding levels, e.g. high concentrate proportions of the diet and relation of milk yield to metabolic LW, underlines the outstanding milk production potential of this breed. Per year, Mountain sheep yielded slightly more actual milk and LE than Milk sheep on a low concentrate diet, whereas Milk sheep were somewhat superior when offered diets with high concentrate portions. Milk yield in goats was by far highest. Regarding feed conversion, goats were more effective than sheep in terms of gross ME expenditure per milk energy, since their maintenance requirements are relatively lower as a result of their higher feed intake capacity. In order to evaluate the effective energy cost for milk production, the different length of dry period must be considered as well. Milk Sheep showed extended dry periods and therefore an unfavourable feed conversion, especially when offered low concentrate diets.

However, for final evaluation of economics of the species/breeds investigated in this study, the fattening performance of the progeny has to be taken into account as well (3^{rd} communication, by Pöckl et al.).

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CHAPTER IV

Production of sheep and goat milk depending on breed, forage quality and concentrate level
III. Fattening performance and carcass quality of male crossbred progeny

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Abstract

This study examines the differences in fattening and carcass characteristics of two lamb and one kid crossbreeds. Thirty-five Mountain sheep × Suffolk lambs (AM × S), 21 East-Friesian Milk Sheep × Suffolk lambs (EM × S), and 24 German Dairy Goat × Boer kids (GD × B) – all male – were fed milk from their mothers, and, after weaning, concentrate for *ad libitum* consumption and either 2- or 3-cut hay until they reached slaughter weight (42 kg for lambs, 30 kg for kids). EM × S lambs took significantly shorter ($P<0.01$) to attain slaughter weight than the other two crossbreeds. Average daily gains (ADG) and feed efficiency were significantly highest in EM × S lambs ($P<0.001$). Dressing percentage did not differ between the breeds. Carcass fat content was highest in AM × S lambs, whereas EM × S lambs and GD × S kids showed similar fat and lean contents. Due to the low forage intake, hay quality did not exert an influence on fattening characteristics.

High daily gains and feed efficiency made fattening of EM × S lambs more profitable than that of AM × S lambs, and the low carcass fat content of Milk sheep progeny corresponds more to the consumers' demand for lean meat. Efficiency of kid fattening exceeded that of AM × S lambs, and, additionally, carcass composition of kids may be more acceptable than that of Mountain sheep crossbreeds.

Keywords: lambs, kids, diet, fattening, carcass composition

1. Introduction

Profitability of sheep and goat fattening mainly depends on duration of fattening, feed consumption until slaughtering, carcass dressing percentage and composition, as well as revenues for the meat. Considering these aspects, breed differences may be of great importance. In an extensive study focusing on productivity of goat and sheep keeping (Gruber *et al.*; Pöckl *et al.*, in preparation) we did not only analyse milking performance of two sheep breeds and one goat breed but also fattening and carcass characteristics of their crossbred progeny. Milk sheep and Mountain sheep were bred to a Suffolk ram to improve fattening performance. German Dairy goats were mated to a Boer bock, as Boer goats are meat-type goats with high average daily gains, distinct meat yield potential and a high carcass yield (van Niekerk and Casey, 1988).

Dependent on management system, different methods of lamb and kid fattening are practised. If milk from dams is marketed, the progeny usually is fed on milk replacer until weaning. Thereafter, lambs and kids are either fattened in drylot or on pasture. With intensive rearing on concentrate-based diets highest daily gains and optimal feed conversion efficiency are achieved, so that this system is practised most frequently (Bellof *et al.*, 2003). However, high energy intake does not only lead to high growth rates but also to greater retention of body fat in goats and sheep (Morand-Fehr *et al.*, 1991; McClure *et al.*, 1994), which, especially in sheep, is not always regarded as favourable. When fed on concentrate-based diets, adequate intake of fibre is essential for sound rumen functioning. However, due to its fibre content, rumen retention time of hay is prolonged, thus limiting intake, especially in young ruminants with comparatively small volume of digestion organs. Therefore it is highly relevant whether forage with low fibre content and high digestibility or hay rich in indigestible fibre is fed. Duration of fattening depends on feed quality, feed intake, feed conversion efficiency and growth potential of the animals. Sheep show higher growth rates compared to goats (van Niekerk and Casey, 1988), and feed input in sheep fattening until attainment of a certain live weight is lower than in goat fattening (Hadjipanayiotou *et al.*, 1991). However, comparison of daily gains between sheep and goats is difficult, because the two species differ in composition of retained tissues as well as in proportion of cuts. Goats are late maturing and deposit substantial amounts of fat only at high live weights so that at a constant age goats and sheep are at different stages of maturity (Owen *et al.*, 1987).

Average daily gains in goats are between 100 – 250 g (Snell, 1996), whereas sheep show daily gains of over 300 g. Reared on a concentrate-based diet after weaning up to a slaughter weight of 30 kg, Saanen × Buren kids exhibit daily gains of about 140 g (Dhanda *et al.*, 1999). With average daily gains of about 280 g, Mountain sheep are inferior to Suffolk in fattening performance, as male Suffolk lambs achieve daily gains of more than 440 g. This suggests that crossbreeding with Suffolk rams improves performance of lambs profoundly (Ringdorfer, 2003, Mendel and Zindath, 2005). Milk sheep show daily gains of 330 g until slaughtering at 40 kg (Mendel and Zindath, 2005).

Ad libitum feed intake relative to body weight is frequently higher in goats than in sheep (Agricultural and Food Research Council, 1998). Lu and Potchoiba (1990) suggest that this goes back to the higher physical activity demonstrated by kids compared to lambs. The resulting lower feed conversion efficiency in kids compared to lambs is confirmed by many studies (Hadjipanayiotou *et al.*, 1991).

At a constant live weight, goats and sheep produce carcasses of the same weight but of different composition. Proportion of lean and bone is higher in goats (Morand-Fehr *et al.*, 1991). In contrast, percentage of fat in the carcass is lower as goats deposit comparably more fat as visceral fat, whereas development of subcutaneous fat is slow (Chilliard *et al.*, 1981; Warmington and Kirton, 1990). The proportion of primal cuts in lamb carcasses makes up for nearly 60%, while goats deposit relatively more tissue in the less valuable forequarters (Hale and Griffin, 1992; Cameron *et al.*, 2001).

The relation of fat to protein deposition increases with age so that carcass fatness is highly dependent on slaughter weight. Due to decreased bone percentage, carcass dressing percentage increases with slaughter weight (Bellof *et al.*, 2003). Besides, dressing percentage is frequently higher in sheep than in goats (Dhanda *et al.*, 1999; Cameron *et al.*, 2001; Klumpp *et al.*, 2004).

2. Material and Methods

Animals and Diets

Fifty-six lambs (35 Mountain sheep × Suffolk, 21 Milk sheep × Suffolk) and 24 kids (German Dairy goats × Boer) were chosen for the experiment. Only male animals were selected.

Lambs and kids were separated from their mother immediately after birth and provided with colostrum. They were kept in group pens and received milk from ewes and goats of the respective breed for *ad libitum* consumption until weaning at a live weight of about 20 kg. Additionally, they received hay from either two or three cuttings for unrestrained intake from the 2nd week onwards. The composition of milk, hay and concentrate is shown in Table 1 and 2. Individual feed dry matter intake (DMI) of this period was calculated as overall feed intake divided by the number of animals. Individual live weight was recorded once a week.

Table 1: *Chemical composition of milk fed to the three different crossbreeds (means ± standard deviations)*

	AM × S lambs	**EM × S lambs**	**GD × B kids**
CP (g/kg DM)	313 ± 8.3	316 ± 2.6	259 ± 6.5
CL (g/kg DM)	338 ± 16.7	330 ± 8.0	272 ±5.4
NFE (g/kg DM)	298 ±20.2	302 ± 6.4	398 ± 6.6
Ash (g/kg DM)	51.2 ± 3.0	51.8 ± 0.8	70.8 ± 0.7

CP = crude protein, CL = crude lipids, NFE = N-free extracts

Table 2: *Chemical composition of hay and concentrate (means ± standard deviations)*

		2-cut hay	3-cut hay	concentrate
dOM	% of DM	55.2 ± 2.4	58.8 ± 1.3	87.4 ± 1.14
CP	g/kg DM	119 ± 4.8	121 ± 11.8	205 ± 13.8
EE	g/kg DM	15 ± 2.0	18 ± 2.2	11 ± 0.9
NFE	g/kg DM	469 ± 12.2	485 ± 13.6	616 ± 21.6
CF	g/kg DM	337 ± 15.9	313 ± 9.0	90 ± 7.5
NDF	g/kg DM	632 ± 19.2	602 ± 10.7	265 ± 2.9
ADF	g/kg DM	384 ± 13.1	362 ±7.4	117 ± 1.0
Ash	g/kg DM	60 ± 6.8	64 ± 4.1	77 ± 7.7
ME	MJ/kg DM	7.76 ± 0.32	8.25 ± 0.21	12.35 ± 0.08

dOM = digestibility of organic matter, EE = ether extract, CF = crude fibre

At weaning lambs and kids were put in individual pens and were fed *ad libitum* with 2- or 3-cut hay and concentrate. Refusals of feed were weighed. Slaughter weight was targeted at 42 kg for lambs and 30 kg for kids. Pre-weaning average daily gains were calculated as weight at weaning minus birth weight, divided by the number of days, whereas post-weaning weight gain was slaughter weight minus weaning weight, divided by the number of days.
The determination of feed value by chemical analysis and *in vivo* digestibility is described in Gruber *et al*. (in preparation).

Carcass Traits

Before slaughtering, animals were fasted for 24 hours. Lambs and kids were weighed immediately before slaughter. Dressing percentage was based on fasted live weight. The carcasses were then chilled for 24 hours before dissection. Warm and cold carcass weight was determined. Decline of ph was measured 1 hour and 24 hours after slaughtering. Carcasses were separated into right and left halves. The left side of each carcass was physically separated into wholesale cuts. Weight of wholesale cuts was evaluated and cuts were dissected into lean, fat and bone portions. Furthermore, weight of kidneys and kidney fat was weighed and length of body and leg measured.

Statistical Analysis

Data were analyzed by multifactor analysis of variance procedures, the main effects being breed and forage quality, together with their two-way interaction, using the statistical package of Harvey (1987). Multiple comparisons were carried out to identify statistically significant differences among means, applying the test of Student-Newman-Keuls ($P \leq 0.05$) of Statgraphics (2000). Significant differences between means are indicated by different superscripts in the tables of results. The values in the tables are least squares-means, RSD is the pooled standard deviation within treatment groups (root mean square of remainder).

3. Results

Growth and feed intake

Lambs were slaughtered at a live weight of 43 kg. Average weight of kids at slaughter was 31 kg. While AM × S lambs and GD × B kids required 99 days to reach slaughter weight, with only 91 days, it took EM × S lambs significantly shorter (see Table 3).

Average daily gains (ADG) for the whole experimental period were 379 g for AM × S lamb, 404 g for EM × S lambs and 254 g for GD × B kids, and differed significantly for all three breeds (compare Table 3). Though not significant, there was a tendency for pre-weaning daily gains to be higher in AM × S lambs compared to EM × S lambs (see Table 4). Pre-weaning ADG in kids were significantly lower than in the two lamb crossbreeds. After weaning, average daily gains were 392 g for AM × S lambs, 420 g for EM × S lambs and 264 g for GD × B kids. The difference was significant for all three breeds. Compared to pre-weaning gains, post-weaning ADG were 6% higher in EM × S lambs and GD × B kids, but only 4% in AM × S lambs. Daily gains in kids were 27% lower than in EM × S lambs (pre-weaning as well as post-weaning), but only 5% and 7% lower than in AM × S lambs.

Daily DM intake (DMI) was highest in AM × S lambs, followed by EM × S lambs and GD × B kids with a statistically significant difference for all three breeds (see Table 3 and 4). In kids, post-weaning average daily feed intake increased by 176% compared to pre-weaning intake. The corresponding values were 160% in EM × S lambs but only 124% in AM × S lambs.

For the whole fattening period average daily DMI was 7% lower in EM × S lambs compared to AM × S lambs, while intake was 34% lower in kids. Differences in intake were higher in the milk-feeding period (18% for EM × S lambs and 45% for GD × B kids, respectively), and diminished to 5% and 32% after weaning.

Expressed as DMI $kgLM^{-1}$, differences weakened. Average daily DMI was only 10% lower in EM × S lambs and 18% in GD × B kids compared to AM × S lambs. Interestingly, compared to pre-weaning intake, post-weaning intake per kg LW decreased in AM × S by 9%, whereas it increased by 6% in EM × S lambs and by even 25% in GD × B kids.

Average milk DMI was highest in AM × S lambs and lowest in kids when expressed as absolute values in g, but also when related to kg LW. AM × S lambs exceeded the other two crossbreeds in respect to forage intake in the pre-weaning period, too. However, post-weaning hay intake per kg LW was highest in kids and lowest in EM × S lambs.

Regarding pre-weaning daily concentrate intake, AM × S lambs surpassed EM × S lambs by 2.5 times and kids by even 10 times. These differences, expressed as intake per kg LW, diminished to 2.6 times compared to EM × S lambs and 8 times in relation to kids. Disparities shrunk after weaning. Even though intake was still highest in AM × S lambs, this was no longer significant in comparison to EM × S lambs. Still, concentrate uptake was nonetheless significantly lowest in kids, whether expressed as absolute values or per kg LW.

Average daily energy intake (ME) was the same for the two sheep crossbreeds but significantly lower in kids (see Table 3). Forage quality did not influence ME intake in any of the three breeds. Average daily intake of CP did not differ for AM × S and EM × S lambs, while it was significantly lower in GD × B kids.

Feed efficiency was greatest in EM × S lambs. Results for ADG:DMI are presented in Table 3. While pre-weaning ratio of ADG to DMI was higher for kids than for AM × S lambs, there was no difference in daily gains per kg DMI in AM × S lambs and kids for the post-weaning period and the whole experimental phase (see Table 4). Weight gain per kg crude protein (CP) intake was significantly higher in EM × S kids and GD × B kids for the whole experimental period than in AM × S lambs (see Table 3). Pre-weaning ratio of gain to CP intake was highest in kids and lowest in AM × S lambs, while EM × S lambs ranged in the middle (compare Table 4). Weight gain per kg CP intake decreased profoundly after weaning. It was reduced by more than 60% in the two sheep crossbreeds and by almost 50% in the kids.

Table 3: *Growth performance and feed intake for the whole experimental period as influenced by breed and forage quality*

Item	Unit	Breed			Forage		P values			RSD
		AM × S	EM × S	GD × B	2 cuts	3 cuts	B	F	B × F	
inital weight	kg	5.8	6.3	5.6	5.9	5.9	0.162	0.735	0.114	1.1
final body weight	kg	42.8 [a]	42.7 [a]	30.8 [b]	38.8	38.7	0.000	0.728	0.419	1.1
duration of fattening	d	99 [a]	91 [b]	99 [a]	97	95	0.007	0.384	0.245	9.8
ADG	g/d	379 [a]	404 [b]	254 [c]	343	349	0.000	0.430	0.438	32.0
daily DMI	g	831 [a]	777 [b]	545 [c]	716	720	0.000	0.793	0.729	62.2
	g/kg LW	36.0 [a]	32.3 [b]	29.5 [c]	32.5	32.7	0.000	0.726	0.946	2.8
ME intake	MJ ME/d	15.20 [a]	13.82 [b]	9.48 [c]	12.80	12.87	0.000	0.696	0.815	0.84
CP intake	g/d	190 [a]	177 [b]	115 [c]	160	161	0.000	0.857	0.897	17.0
ADG:DMI	g/kg	457.4 [a]	521.8 [b]	469.4 [a]	480.6	485.1	0.000	0.691	0.420	49.3
ADG:ME	g/MJ ME	25.06 [a]	29.94 [b]	27.56 [c]	480.62	485.12	0.000	0.528	0.248	2.25
ADG:CP	g/kg	2003 [a]	2300 [b]	2232 [b]	2167	2190	0.000	0.667	0.382	232.1

Table 4: *Pre- and post-weaning growth performance and feed intake as influenced by breed and forage quality*

Item	Unit	Breed			Forage		P values			RSD
		AM × S	EM × S	GD × B	2 cuts	3 cuts	B	F	B × F	
pre-weaning										
Initial weight	kg	5.8	6.3	5.6	5.9	5.9	0.162	0.735	0.114	1.1
final body weight	kg	23.8 ^{a}	22.4 ^{b}	17.1 ^{c}	21.2	21.1	0.000	0.810	0.677	1.7
duration of fattening	d	50 ^{a}	42 ^{b}	47 ^{c}	47	45	0.000	0.242	0.293	5.5
ADG	g/d	378 ^{a}	397 ^{a}	249 ^{b}	337	346	0.000	0.183	0.740	38.4
DMI	g/d	505 ^{a}	412 ^{b}	279 ^{c}	396	401	0.000	0.608	0.389	44.0
	g/kg LW	37.4 ^{a}	30.8 ^{b}	25.8 ^{c}	58.2	58.5	0.000	0.858	0.439	3.3
forage intake	g/d	24 ^{a}	14 ^{b}	13 ^{b}	17	17	0.000	0.816	0.754	6.7
concentrate intake	g/d	83 ^{a}	32 ^{b}	7 ^{b}	38	44	0.000	0.655	0.824	50.0
milk intake (DM)	g/d	398 ^{a}	366 ^{b}	258 ^{c}	341	341	0.000	0.968	0.444	32.8
ME intake	MJ ME/d	16.57 ^{a}	14.48 ^{a}	9.62 ^{b}	13.49	13.63	0.000	0.601	0.274	1.18
CP intake	g/d	145 ^{a}	124 ^{b}	70 ^{c}	112	114	0.000	0.449	0.698	11.4
ADG:DMI	g/kg	752 ^{a}	966 ^{b}	896 ^{c}	868	874	0.000	0.608	0.538	95.3
ADG:ME	g/MJ ME	22.8 ^{a}	27.5 ^{b}	26.0 ^{c}	25.3	25.6	0.000	0.389	0.204	2.6
ADG:CP	g/kg	2603 ^{a}	3216 ^{b}	3575 ^{c}	3112	3151	0.000	0.606	0.274	325.5
post-weaning										
Initial weight	kg	23.8 ^{a}	22.4 ^{b}	17.1 ^{c}	21.2	21.1	0.000	0.804	0.690	1.7
final body weight	kg	42.8 ^{a}	42.7 ^{a}	30.8 ^{b}	38.8	38.7	0.000	0.728	0.419	1.1
duration of fattening	d	49 ^{a}	49 ^{a}	53 ^{a}	50	50	0.201	0.798	0.544	8.0
ADG	g/d	392 ^{a}	420 ^{b}	265 ^{c}	357	361	0.000	0.756	0.402	49.7
DMI	g/d	1132 ^{a}	1073 ^{b}	770 ^{c}	992	991	0.000	0.936	0.329	100.0
	g/kg LW	34.0	32.8	32.2	33.1	33.2	0.166	0.878	0.293	3.3
forage intake	g/d	74 ^{a}	55 ^{b}	70 ^{a}	57 ^{a}	75 ^{b}	0.047	0.005	0.253	26.1
concentrate intake	g/d	1057 ^{a}	1018 ^{a}	700 ^{b}	935	916	0.000	0.442	0.202	109.3
ME intake	MJ ME/d	13.64 ^{a}	13.03 ^{b}	9.21 ^{c}	12.00	11.93	0.000	0.806	0.276	1.26
CP intake	g/d	229 ^{a}	218 ^{a}	153 ^{b}	201	199	0.000	0.838	0.540	26.7
ADG:DMI	g/kg	346 ^{a}	391 ^{b}	344 ^{a}	359	362	0.000	0.796	0.834	41.9
ADG:ME	g/MJ ME	28.8 ^{a}	32.4 ^{b}	28.8 ^{a}	29.8	30.1	0.001	0.680	0.893	3.5
ADG:CP	g/kg	1715 ^{a}	1945 ^{b}	1750 ^{a}	1790	1817	0.003	0.612	0.789	225.3

Development of ADG

In AM × S lambs, ADG did not change considerably over the course of the experimental period (compare Fig.1). Highest gains were recorded in week 13, while lowest gains were observed around weaning. However, weaning did not show a remarkable effect on ADG in this crossbreed. Development of ADG in EM × S lambs was characterized by a constant decrease towards weaning and a steady, but even steeper, increase towards slaughtering. Highest daily gains recorded in Milk sheep progeny were 517 g in week 13 compared to only 336 g in week 6. Shape of curve for GD × B kids was similar to that of EM × S lambs but decrease to weaning and increase afterwards were not as steep.

DMI developed in the same fashion in all three crossbreeds. Intake slowly increased from birth to weaning when intakes suffered a setback that was most intense in GD × B kids (see Fig. 2). However, DMI augmented quickly in the weeks following weaning.

Development of ADG:DMI is presented in Fig. 3. Ratio of gain to feed intake decreased continuously from week 1 to slaughtering in all three crossbreeds. The quotient was most advantageous in EM × S lambs, followed by GD × B kids and lowest AM × S lambs, but differences diminished after weaning. ADG:DMI was still highest in EM × S lambs, but lowest in GD × B kids, while AM × S lambs ranged in the middle. The abrupt reduction in feed intake around weaning in kids lead to a more favourable ADG:DMI ratio.

Fig. 1. *Development of average daily gains (ADG) for the whole experimental period*

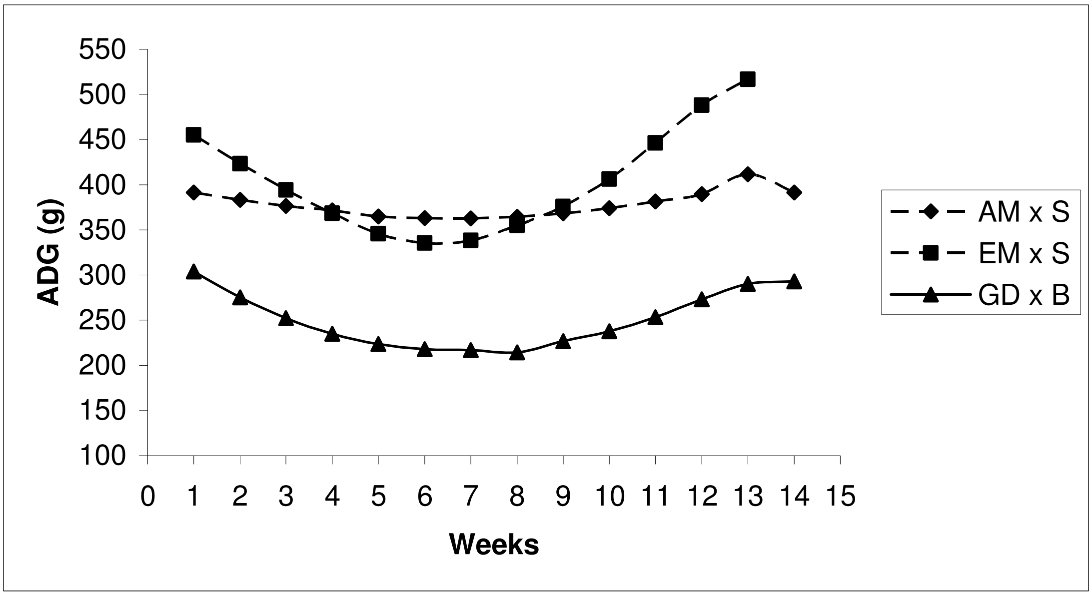


Fig. 2. *Development of daily dry matter intake (DMI) for the whole experimental period*

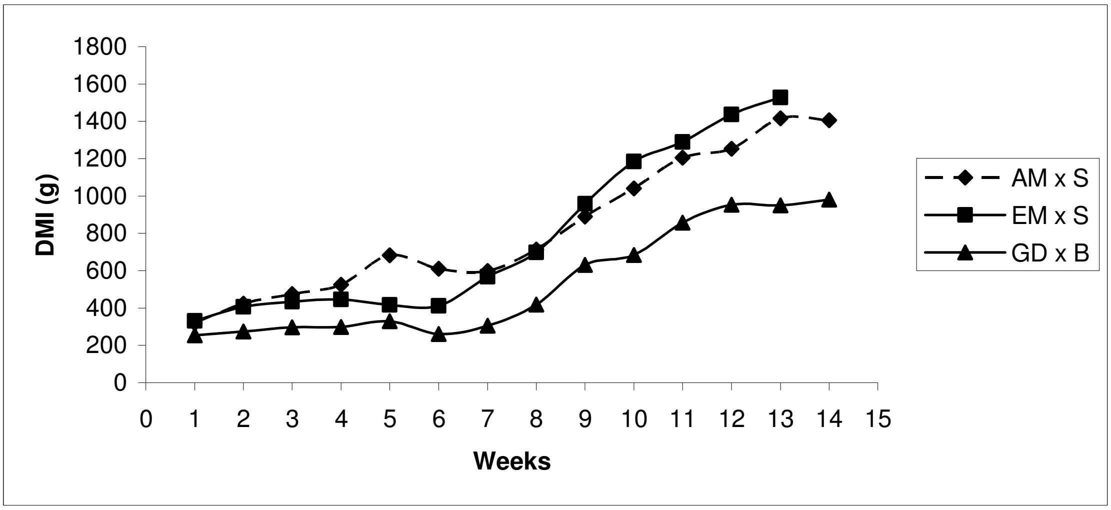
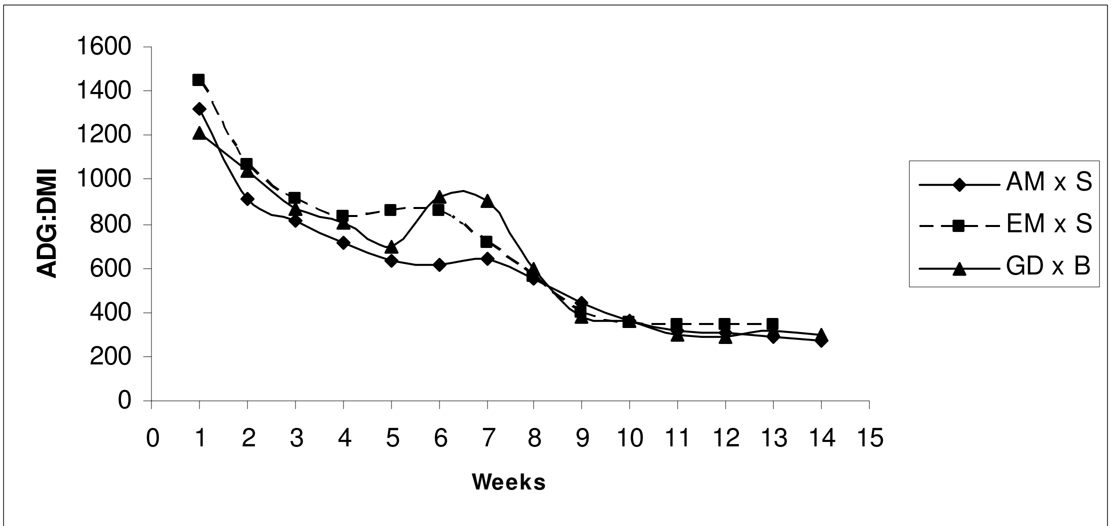


Fig. 3. *Development of gain-to-feed-ratio (ADG:DMI) for the whole experimental period*



As forage intake accounted for less than 10% of feed intake, quality of hay did not influence overall feed intake, nor fattening period or average daily gains. Forage quality showed significant influence only on overall forage intake and on forage intake in the post-weaning period. Animals fed on the 3-cut hay displayed significantly higher hay intakes than those that were fed the 2-cut hay. Elevated intakes in the whole fattening period resulted from higher uptake in the post-weaning phase, since lambs and kids ate similar amounts of forage irrespective of forage quality during the pre-weaning period (compare Table 4 and 8).

Energy, protein and mineral supply

Average daily intake (ADI) of energy and protein for the whole experimental period as well as for the pre- and post-weaning phase and the percentage of demand that is met - according to NRC (1985) and GfE (2003) - is presented in Table 5. Table 5 also shows average daily intakes of major and trace elements or their concentration in feed, respectively.

Table 5: *Energy, protein and mineral intake and percentage of recommended requirements for the three crossbreeds*

Item		AM × S	EM × S	GD × B
Intake				
ME	ADI (MJME)	15.20	13.82	9.48
	pre-weaning ADI (MJME)	16.57	14.48	9.62
	post-weaning ADI (MJME)	13.64	13.03	9.21
CP	ADI (g)	190	178	115
	pre-weaning ADI (g)	145	124	70
	post-weaning ADI (g)	229	218	153
Ca	intake (g)	8.06	6.61	4.47
P	intake (g)	4.71	4.31	2.86
Mg	intake (g)	2.53	2.12	1.49
Na	intake (g)	2.17	2.23	1.62
K	intake (g)	10.91	10.25	8.12
Cl	intake (g)	1.43	1.24	1.33
Mn	mg/kg feed	65.9	66.1	68.5
Cu	intake (mg)	7.99	8.57	8.42
Percentage of requirements				
ME	% (whole period)	104.1	89.5	92.3
	% (pre-weaning)	130.2	109.1	125.5
	% (post-weaning)	82.9	75.8	73.7
CP	% (whole period)	92.3	81.6	169.5
	% (pre-weaning)	79.2	63.9	102.4
	% (post-weaning)	103.1	92.9	
Ca	%	86.9	65.6	102.5
P	%	84.4	73.2	110.0
Mg	%	190.2	144.5	196.0
Na	%	227.8	239.7	388.4
K	%	691.1	649.2	752.8
Cl	%	234.9	195.1	322.7
Mn	mg/kg (recommended)	20	20	60-80
Zn	mg/kg (recommended)	> 20	> 20	50-80
Cu	mg/kg (recommended)	8-10	8-10	10-15

Carcass characteristics

Results for carcass characteristics are presented in Table 6. Percentage of live weight loss during fasting was significantly higher in AM × S lambs than in GD × B kids, while EM × S lambs ranged in the middle. Cooling losses in AM × S lambs were greater than in the other two breeds. Dressing percentage did not differ between the three breeds. With 6.56, the pH value one our after slaughtering was significantly higher in AM × S lambs compared to 6.37 in kids. Decline of pH decline was strongest in AM × S lambs so that pH 24 was highest in kids and lowest in AM × S lambs.

There was no statistically significant difference in percentage of weight of cuts between the two lamb crossbreeds. Proportional weight of neck, chuck, shoulder and breast was higher in kids than in lambs, but percentage of flank and leg was lower. Proportion of rack was similar for all three breeds.

Proportion of lean, fat and bone for the whole carcass as well as the primal cuts is shown in Table 7. Composition of cuts in EM × S lambs resembled that of kids, while it was very different from that of AM × S lambs. Overall fat percentage was profoundly higher in AM × S lambs whereas proportion of lean was lower than in the other two crossbreeds. Percentage of lean in kids was superior to that of lambs in all cuts except for leg. Proportion of fat in AM × S lambs was considerably higher in all wholesale cuts than in the other two crossbreeds.

There was no influence of forage quality on carcass characteristics except fasting losses and percentage of neck and flank. Weight losses due to fasting were significantly higher in animals fed the 3-cut hay, so that fasted live weight was lower in this group compared to animals that received the 2-cut hay. However, breed × forage interaction showed that elevated fasting losses with the 3-cut hay were only observed in the two lamb crossbreeds, whereas losses in kids decreased with the high quality forage. Percentage of neck was significantly decreased with the 3-cut forage while proportion of flank was increased.

The relation of kg carcass yield per kg feed intake was most favourable in EM × S lambs (see Table 8). Yield was only 5% lower in GD × B kids but 15% poorer in AM × S lambs. Overall feed intake for the whole experimental period was highest in AM × S lambs, followed by EM × S lambs and lowest in GD × B kids. DMI was 1.5 times higher in AM × S lambs and 1.3 times higher in EM × S lambs than in kids.

Table 6: *Slaughtering characteristics and weight percentage of wholesale cuts as influenced by breed and forage quality*

Item	Unit	Breed			Forage		P values			RSD
		AM × S	EM × S	GD × B	2 cuts	3 cuts	B	F	B × F	
live weight	kg	42.8 [a]	42.7 [a]	30.8 [b]	38.8	38.7	0.000	0.728	0.419	1.1
fasted live weight	kg	39.6 [a]	39.9 [a]	29.1 [b]	36.5 [a]	35.8 [b]	0.000	0.308	0.384	1.3
fasting losses	%	7.46 [a]	6.57 [ab]	5.41 [b]	5.80 [a]	7.15 [b]	0.013	0.012	0.035	2.29
hot carcass weight	kg	19.9 [a]	20.0 [a]	14.6 [b]	18.2	18.0	0.000	0.333	0.900	0.9
cold carcass weight	kg	19.1 [a]	19.6 [a]	14.3 [b]	17.6	17.7	0.000	0.784	0.516	2.4
dressing percentage	%	50.3	50.1	50.1	50.0	50.3	0.938	0.552	0.245	2.0
pH 1		6.56 [a]	6.48 [ab]	6.37 [b]	6.47	6.47	0.036	0.983	0.057	0.25
pH 24		5.66	5.74	5.76	5.71	5.73	0.218	0.521	0.998	0.19
back length	cm	47.71 [a]	48.97 [b]	43.46 [c]	46.98	46.44	0.000	0.149	0.296	1.60
leg length	cm	48.3 [a]	47.7 [ab]	47.3 [b]	47.7	47.7	0.024	0.462	0.452	1.2
kidney	g	144.5 [a]	160.0 [a]	113.2 [b]	140.8	137.7	0.001	0.751	0.209	0.04
kidney fat	g	322.9 [ab]	272.4 [a]	344.3 [b]	323.0	303.4	0.049	0.384	0.990	0.1
half carcass weight (left)		9.54 [a]	9.56 [a]	6.88 [b]	8.70	8.62	0.000	0.350	0.022	0.43
neck	%	7.83 [a]	7.57 [a]	8.76 [b]	8.26 [a]	7.85 [b]	0.000	0.037	0.464	0.84
shoulder	%	17.22 [a]	17.79 [a]	19.28 [b]	18.09	18.12	0.000	0.931	0.957	0.84
neck end	%	5.54 [a]	5.56 [a]	5.99 [b]	5.77	5.62	0.002	0.164	0.155	0.48
loin	%	8.57 [a]	8.67 [a]	7.51 [b]	8.04 [a]	8.46 [b]	0.000	0.013	0.994	0.72
rack	%	8.74	8.34	8.32	8.32	8.61	0.061	0.056	0.909	0.64
breast	%	18.38 [a]	18.46 [a]	19.35 [b]	18.95	18.51	0.010	0.108	0.109	1.17
leg	%	33.63 [a]	33.61 [a]	30.68 [b]	32.53	32.75	0.000	0.277	0.768	0.99

Table 7: Carcass c*omposition of the three crossbreeds*

Item	AM × S	EM × S	GD × B
whole carcass			
lean (%)	52.41 [a]	60.04 [b]	61.25 [b]
fat (%)	26.55 [a]	17.54 [b]	17.09 [b]
bone (%)	20.70 [a]	22.18 [b]	21.91 [b]
lean:bone ratio	2.5 [a]	2.7 [b]	2.8 [b]
wholesale cuts			
neck (kg)	0.748	0.725	0.609
lean (%)	50.73	57.4	62.83
fat (%)	20.51	14.45	18.09
bone (%)	28.70	27.96	25.49
shoulder (kg)	1.644	1.704	1.339
lean (%)	56.87	62.06	63.54
fat (%)	21.93	16.73	15.32
bone (%)	20.93	21.10	20.98
neck end (kg)	0.529	0.533	0.416
lean (%)	50.34	59.64	61.07
fat (%)	21.02	13.88	13.34
bone (%)	28.46	26.44	25.22
loin (kg)	0.816	0.831	0.522
lean (%)	52.02	60.21	61.23
fat (%)	28.26	18.68	17.23
bone (%)	19.57	20.58	21.03
rack	0.832	0.800	0.578
lean (%)	46.04	52.64	56.89
fat (%)	29.91	20.71	18.58
bone (%)	23.68	26.31	24.13
breast	1.762	1.770	1.343
lean (%)	37.46	48.12	50.87
fat (%)	45.05	28.75	27.78
bone (%)	17.09	22.78	20.98
leg	3.208	3.223	2.130
lean (%)	61.05	68.20	67.46
fat (%)	19.68	11.95	11.46
bone (%)	19.08	19.67	20.96

Table 8: *Overall feed and nutrient intake from birth until slaughtering as well as carcass yield per feed intake*

Item	**Unit**	**Breed**			**Forage**		**P values**			**RSD**
		AM × S	**EM × S**	**GD × B**	**2 cuts**	**3 cuts**	**B**	**F**	**B × F**	
DMI	kg	81.39 [a]	70.39 [b]	54.10 [c]	69.01	68.24	0.000	0.687	0.543	2.61
concentrate	kg	57.28 [a]	51.85 [b]	37.87 [c]	49.66	48.34	0.000	0.504	0.951	2.70
hay	kg	4.83 [a]	3.20 [b]	4.23 [a]	3.68 [a]	4.49 [b]	0.000	0.016	0.200	1.42
milk	kg DM	19.28 [a]	15.35 [b]	12.00 [c]	15.67	15.42	0.000	0.643	0.033	2.34
ME	MJ ME	1488.47 [a]	1252.08 [b]	939.64 [c]	15.42	15.24	0.000	0.639	0.089	121.27
CP	kg	18.52 [a]	16.01 [b]	11.46 [c]	15.22	15.24	0.000	0.666	0.309	1.88
carcass yield per DMI	kg/kg	0.237 [a]	0.280 [b]	0.267 [c]	0.260	0.263	0.004	0.713	0.801	0.04

4. Discussion

Growth and feed intake

Average daily gains in lambs in our study were higher than in the study by McClure *et al.* (1995) on weaned Targhee × Hampshire lambs fed an all-concentrate diet. Bellof *et al.* (2003) report ADG of about 340 g for Merino lambs, which is only slightly lower than our results for AM × S lambs. ADG in kids were much higher than the 154 g reported by Cameron *et al.* (2001) for postweaning growth of Boer × Spanish goats. Dhanda *et al.* (1999) give daily gains of 140 g for Boer × Spanish kids slaughtered at 30–35 kg. However, Warmington and Kirton (1990) summarize that progeny of goat breeds of large mature size, like Saanen and Boer goats, exhibit growth rates beyond 200 g/day. In a study by Fehr and Sauvant (1976), male Alpine kids slaughtered at an age of about 110 days grew at 214 g per day, which is only little below values from our study. In line with results by El Khidir *et al.* (1998) on desert goats and sheep, ADG in lambs were significantly greater than in kids.

Growth rates in our study were partly substantially higher than in the experiments quoted above which is probably due to the elevated feed intake observed in our study. The high DM intake might go back to the superior protein content of the ration. The effect of protein level on feed intake was already observed by Lu and Potchoiba (1990).

The ratio of ADG to DMI was generally very high compared to values found in the literature, presumably going back to the high feeding intensity, where concentrate accounted for more than 90% of feed intake. McClure *et al.* (1995) found a gain to feed ratio of 230 g/kg for weaned Targhee × Hampshire lambs, which is low compared to post-weaning values of 346 g/kg (AM × S lambs) and 391 g/kg (EM × S lambs) as found in our study. However, it has to be noted that fattening period in their experiment was from 27 to 47 kg. Manso *et al.* (1998) report gains of 275 g/kg DM intake for Merino lambs slaughtered at 30 kg, which is still much lower than values resulting from our study. Gain to feed ratio was 177 g/kg for Mutton synthetic lambs slaughtered at a weight of 25 kg in a study by Karim and Santra (2000). For crossbred Boer × Spanish goats, Prieto *et al.* (2000) report a value of not more than 153 g gain/kg DM.

Average daily gain to DMI ratio was significantly higher in Milk sheep crossbreeds than in the other two crossbreeds. It is astonishing, that the ratio did not differ for Mountain sheep progeny and kids. In general, feed efficiency is low in goats compared to sheep, as goats grow more slowly and divert more energy to physical activity (Lu and Potchoiba, 1990). In line with this claim are results by El Khidir *et al.* (1998), who found lower feed efficiency in goats than in sheep (112 g gain/kg DMI vs. 135 g gain/kg DMI). They assign the reduced efficiency of goats to their higher activity and lower concentrate intake compared to lambs. However, Sormunen-Cristian and Kangasmäki (2000) report a gain to feed ratio of 205 g/kg for kids and 181 g/kg for lambs in the period from 12 to 37 kg and 23 to 43 kg, respectively. They ascribe the improved feed utilization for meat production of goats compared to sheep to the lower feed intake in kids.

In our study, efficiency in terms of ME intake per kg gain in Milksheep crossbreeds was superior to that reported for Merino sheep by Bellof *et al.* (2003). They give ME intakes of 34.0 and 41.9 MJ per kg weight gain in sheep slaughtered at 30 kg and 45 kg, respectively. With a slaughter weight of 43 kg, lambs in our study displayed intakes of 40.8 MJ (AM × S) and only 34.1 MJ (EM × S) per kg weight gain. This shows that while Mountain sheep crossbreeds show similar values to Merino sheep, Milk sheep require 16% less energy per kg weight gain. Efficiency of goats ranged between that of the two lamb crossbreeds but was by far higher than the 55.8 MJ ME/kg as reported for weaned Finnish Landrace kids by Sormunen-Cristian and Kangasmäki (2000).

Primarily, the intensive feeding allowed for high daily gains and thereby reduced number of feeding days compared to other studies. This positively influences feed efficiency, as it decreased feeding for maintenance.

Influence of forage quality

The small effect of forage quality on feed and energy intake as well as growth and carcass characteristics goes back to the very low forage consumption. Hay intake accounted for only 6.2% of DMI in AM × S lambs, 4.6% in EM × S lambs and 7.8% in GD × B kids. However, post-weaning increase in hay intake and the resulting development of the forestomach lead to a marked influence of forage quality on hay intake. Compared with lambs, kids seemed to take longer until they were able to consume larger amounts of hay. However, after weaning, they showed a preference for higher percentages of forage in the ration than lambs.

Energy, protein and mineral supply

As energy and protein intake in AM × S lambs is close to what is recommended by NRC (1985) for sheep with corresponding ADG, it can be concluded that recommendations of NRC can very well be applied to this crossbreed and that composition of the ration is adequate for the given growth rate.

According to values given by NRC (1985), ME and CP intake would not be appropriate for EM × S lambs with their high growth rates. It has to be assumed that either maintenance requirements or requirements for growth for this breed were actually lower. The fact that fat content of the carcass was 50% higher in AM × S lambs compared to EM × S lambs leads to the conclusion that composition of gain is very different for the two breeds so that energy and protein requirement for growth is varying.
Compared with recommendations given by the Society of Nutrition Physiology (GfE, 2003), ME content of the ration in kids was slightly below requirements, whereas CP concentration was too high. However, uCP concentration only accounted for 61% of needs as given by GfE.
Compared to recommendations given by Jeroch *et al.* (1999) for sheep, intake of calcium was below requirements, resulting from a deficit in the first weeks post-weaning. Similarly, according to recommendations established by GfE (2003), Ca intake in goats did not meet requirements in this period. In the last weeks prior to slaughtering reduced gain-to-feed ratio led to sufficient uptake of Ca. Phosphorus requirements were higher than intake for the whole post-weaning period in both sheep crossbreeds, whereas intake exceeded needs in kids at the end of fattening. Magnesium intake proved to be sufficient, with even a small surplus in the weeks before slaughtering in sheep. In contrast, intake did not meet requirements in kids in the first weeks post-weaning, but exceeded them in the last weeks. Uptake of sodium was above requirements for the whole post-weaning period, the surplus expanding with advancement of fattening. The NRC (1985) proposes that requirements for potassium are met in growing lambs with concentrations of 0.5% of DM, whereas a K content of about 3% is toxic. K concentration in sheep rations in our study was above 0.5%, but well below the toxic level. In kids, potassium intake was sufficient in the first weeks and far beyond requirements in the last weeks of post-weaning fattening.
The NRC (1985) recommends that, for manganese, 20 mg/kg DM is sufficient for sheep. With values not below 82 mg/kg DM, intake of manganese therefore, was certainly adequate. In kids, manganese recommendations (60 to 80 mg/kg DM) were exceeded slightly for the whole post-weaning period. Concerning zinc intake, the NRC (1985) suggests a minimum concentration of 20 mg/kg DM for growing sheep. Zinc content of the ration was far beyond this value. With values beyond 140 mg/kg DM, intake of zinc was 75% above the proposed 50-80 mg/kg DM in ruminant goats. Copper intake in sheep was in the range of 8 to 10 mg/kg DM recommended by NRC (1985) for growing sheep. With an intake of about 11 mg/kg DM, uptake in kids corresponded to the proposals of 10-15 mg/kg DM given by GfE (2003).

It seems, therefore, that special care has to be taken on Ca and P levels in feed and, with high daily gains, the risk of undersupply has to be born in mind.

Carcass characteristics

According to McGeehin *et al.* (2001) rate of pH decline after slaughter, a result of glycolysis, is not only influenced by stress, chilling temperature, sex, species, breed and season, but also by carcass weight, age and ambient temperature. In their study on goat meat quality, Dhanda *et al.* (1999) report the ultimate pH to be in the range of 5.6–5.8, which corresponds well to the value of 5.76 measured in our study for the kid crossbreeds. As stated by Priolo *et al.* (2002), ultimate pH tends to be higher in carcasses of lambs having developed at high growth levels. This tendency is also observed in our study as pH 24 of EM × S lambs is higher than that of AM × S lambs. For ultimate pH, Vergara and Gallego (1999) give a mean of 5.7 for male Manchega lambs, which is perfectly in line with the measured value in our study.
When comparing dressing percentages given in different studies, attention has to be paid to whether dressing percentage is based on live weight, fasted live weight or empty body weight. Vergara *et al.* (1999) found a dressing proportion of 49% for male Manchega sheep at a slaughter weight of 28 kg. Based on a final live weight of 43 kg, Sormunen-Cristian and Kangasmäki (2000) observed a dressing percentage of 42.6% in Finnish Landrace lambs. For different Merino crossbreeds, Kleemann *et al.* (1990) found dressing proportions between 40 and 48% based on fasted live weight. Dhanda *et al.* (1999) give dressing percentages of 50 to 55% for kids when based on empty body weight. Colomer-Rocher *et al.* (1992) report dressing percentages of about 45.5% based on starved live weight. For male Criollo kids, Gallo *et al.* (1996) give a dressing proportion of 45% (based on LW). Higher dressing percentage in goats in our study compared to the studies quoted above might be the result of higher fat content associated with the higher feeding intensity. Increased carcass weight and dressing percentage was already reported by Shahjalal *et al.* (1992) with high-energy diets in Angora goats. Hadjipanayiotou and Koumas (1994) report dressing percentages of 51.6 and 51.1% for Chios lambs and Damascus kids, respectively based on fasted live weight of 39.3 and 37.0 kg, which is very close to results from our study.
While El Khidir *et al.* (1998) report that dressing percentage was significantly higher for goats than sheep, there was no difference in our study for the two species and breeds.
Carcass tissue composition in AM × S lambs was significantly different from that of EM × S lambs and GD × B kids. It is interesting to note that composition of Milk sheep crossbreeds resembled that of kids while it was totally different from that of Mountain sheep crossbreeds.

Accretion of fat was much higher in AM × S lambs than in EM × S lambs and kids, while proportion of lean was much lower. This aspect of carcass composition might be of great importance regarding sales potential and price, as meat with low fat content is usually preferred by consumers. Although significant, the difference in bone proportion was comparatively small.

Proportion of lean in the carcass is higher, while proportion of fat is lower in lambs in our study compared to values given by McClure *et al.* (1995) for Targhee × Hampshire lambs. They report fat percentages of 36.1% for lambs fed an all-concentrate diet, which is very high compared to 26.6% as observed in AM × S lambs. Lean percentage in their study was only 43.4% as opposed to 52.4% in Mountain Sheep progeny in our study. For Sudanese desert goats, weighing 33.6 kg, El Khidir *et al.* (1998) give a lean percentage of 61.9 and fat content of 12.2%. Johnson and McGowan (1998) report similar values for carcass composition of intensively fed Florida native kids, slaughtered at a weight of 27 kg. With 67.5%, lean content was 6% points higher than in our study whereas with 12.5%, fat percentage was 4.5% points lower. It seems that carcass composition of different goat breeds slaughtered at similar live weight does not vary to a similar extent as that of lambs.

Gallego (1999) found that high growth rates correspond with considerable development of adipose tissue. Likewise, McClure *et al.* (1995) conclude that high ADG and feed efficiency do not correspond with maximizing muscle accretion and minimizing fat accretion. While results from EM × S lambs with their high daily gains, high feed efficiency and high accretion of lean, contradict McClure's outcome, results from AM × S lambs and kids support their findings. With low daily gains in kids, but no difference in feed efficiency compared to AM × S lambs, kids exceed in accretion of lean while AM × S lambs divert more energy to fat deposition. The genetic disposition of the particular breed seems to exert considerable influence on whether uptaken energy is diverted to fat or protein accretion.

It is interesting to note that while proportion of wholesale cuts in relation to the carcass was the same for the two sheep crossbreeds while being significantly different for the kids, tissue composition of the cuts was the same for EM × S lambs and GD × B kids but significantly different for AM × S lambs. Colomer-Rocher *et al.* (1992) found that leg, shoulder and neck were the joints with highest muscle content in New Zealand Saanen goats, results which also apply to our study.

In line with results by Gallo *et al.* (1996), the breast was the joint with highest fat content in goats. Increased development of visceral fat in goats compared to sheep, as was proposed by Warmington and Kirton (1990), is reflected by the greater weight of kidney fat.

Regarding feed intake, average daily gain, feed conversion efficiency and carcass characteristics, fattening of EM × S lambs is more profitable than that of AM × S lambs. Efficiency of kid fattening ranges not far behind that of Milk sheep progeny and exceeds that of Mountain sheep crossbreeds. It can be concluded that proportional weight of cuts is a species characteristic, but differences in growth characteristics and composition of cuts between breeds may be greater than between species.

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CHAPTER V

SUMMARY

A great deal of research has been done on goat and sheep milk production as influenced by forage quality and concentrate administration in Mediterranean regions, South America and Africa (El-Gallad et al., 1988; Casoli et al., 1989; Kawas et al., 1991; Dulphy and Demarquilly, 1994; Wahome et al., 1994; Sanz Sampelayo et al., 1998). However, few data are available that are applicable to Alpine regions. This study wants to close this gap. Two sheep breeds – Austrian Mountain Sheep (AMS) and East Friesian Milk Sheep (EMS) – as well as one goat breed – German Dairy Goats (DGD) were chosen for the experiment. A three-factorial experiment was carried out to investigate the impact of species/breed, forage quality and concentrate level on feed intake and milk production of dams as well as on fattening characteristics of male progeny. Two levels of forage quality were received by cutting an alpine permanent grassland two or three times a year (F 2 and F 3). Concentrate levels were 5, 25 and 50% of DM intake. Every new lactation, animals were allocated to a different concentrate level (but not forage quality), according to a Latin square design.

Mean live weight for the three breeds was 75, 66 and 54 kg (AMS, EMS and GDG). Whereas absolute values for dry matter intake (DMI) did not significantly differ between species/breeds, DMI related to $LW^{0.75}$ revealed significant differences between the breeds (78, 85 and 100 g/ kg $LW^{0.75}$), showing that animals of higher milk yield potential display a higher feed intake capacity. Increasing the concentrate proportion from 5 to 25 and 50% significantly promoted DMI (1.88, 2.14 and 2.46 kg/d, during lactation). Substitution rate, determined by linear regression, was on average 0.38. With high quality forage, the value increased (0.32 vs. 0.44 in F 2 and F 3). Feeding 3-cut forage instead of 2-cut forage enhanced DMI from 1.97 to 2.09 kg/d. Contrary to expectations, diet selection was more intense with milk sheep (EMS) than with dairy goats (GDG).

Results show that all of the three factors investigated exerted a significant impact on feed intake of lactating and dry sheep and goats. In general, feed intake was determined either by ruminal fill (high milk yield – low diet energy concentration) or by energy balance (low energy requirement – high energy concentration). This principally supports the feed intake model established by Mertens (1994), although, in the present study, the animals consumed an amount of more than 12.5 g NDF per kg LW (upper limit for ruminal fill).

Regarding milking performance, goats were superior to both sheep breeds. AMS, EMS and GDG yielded 983, 1022 and 2028 g actual milk, equivalent to 4.3, 3.9 and 5.5 MJ milk energy (LE) per day. Mean milk fat content was 6.1, 4.9 and 2.9% for AMS, EMS and GDG, respectively, as well as 4.74, 4.63 and 4.56% for concentrate levels 5, 25 and 50% (C 05, C 25, C 50). Corresponding values for milk protein were 5.5, 5.0 and 2.9% (AMS, EMS, GDG) and 4.3, 4.5 and 4.6% (C 05, C 25, C 50). Due to their lower live weight (LW), superiority of goats was even more obvious when LE output was related to $LW^{0.75}$ (160, 198, 255 kJ/d). Efficiency of concentrate feeding was significantly higher for GDG than EMS and AMS (0.30, 0.55 and 1.31 kg milk per kg concentrate DM in AMS, EMS and GDG). Actual milk yield per lactation was 143, 228 and 492 kg in AMS, EMS and GDG as well as 201, 276 and 385 kg in concentrate levels C 05, C 25 and C 50. Per year, Mountain sheep yielded slightly more actual milk and LE than Milk Sheep on a low concentrate diet, whereas Milk sheep were somewhat superior when offered diets with high concentrate portions. Milk yield in goats was by far highest. Gross ME utilisation for LE production was 8.3, 9.0 and 5.5 MJ ME per MJ LE for species/breeds AMS, EMS and GDG, and 9.0, 7.5 and 6.4 for concentrate levels C 05, C 25 and C 50. Regarding feed conversion, goats were more effective than sheep in terms of gross ME expenditure per milk energy, since their maintenance requirements are relatively lower as a result of their higher feed intake capacity. High feeding levels, e.g. high concentrate proportions of the diet, and the relation of milk yield to metabolic LW underline the outstanding milk production potential of dairy goats. For the evaluation of effective energy costs for milk production the different length of dry period must be considered as well. Milk sheep show extended dry periods and therefore an unfavourable feed conversion.

In a milk production business, marketing of meat from progeny has to be considered and may be an important factor of income. Goat and sheep breeds differ in feed intake, daily gains, feed efficiency and carcass composition, which makes choice of species and breed an important aspect (Kleemann et al., 1990; Hadjipanayiotou and Koumas, 1994; El Khidir et al., 1998; Sormunen-Cristian and Kangasmäki, 2000). Data from this study show that Milk sheep crossbreeds reached slaughter weight in significantly less time than Mountain sheep and dairy goat crossbreeds. While feed intake was highest in AM × S lambs and lowest in GD × B kids, average daily gains were significantly highest in EM × S lambs and lowest in GD × B kids. This improved feed conversion efficiency in EM × S lambs compared to the other two crossbreeds. Accretion of fat was significantly higher in Mountain Sheep progeny, while the proportion of lean was lower than in the other two breeds. Dressing percentage did not differ between the three breeds. Proportion of wholesale cuts in relation to carcass was the same for the two sheep crossbreeds but significantly different for the kids, whereas tissue composition of the cuts was the same for EM × S lamb and GD × B kids but different for AM × S lambs. This leads to the conclusion that fattening of EM × S lambs is more profitable than that of AM × S lambs, whereas efficiency of GD × B fattening does not range far behind that of EM × S lambs.

Results show that forage quality, concentrate level and species/breed exert significant influence on feed intake, milk production and fattening characteristics and thereby, economic profitability of small ruminant husbandry. High concentrate feeding is useless with animals of low productivity as they are not able to convert the digested nutrients into milk. The feeding of high quality forage shows favourable effects on feed intake and milk production in all breeds, although to different extents. For choice of breed for fattening, it is important to consider consumers' preferences concerning carcass composition.

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CHAPTER VI

GENERAL DISCUSSION

The results of the project underline the assumption that producing forage of high quality is one of the most important aspects of ruminant nutrition. Forage of high energy and protein content can replace concentrate supplementation to a certain extent without a severe reduction in milk yield. With oil and transportation costs rising, prices of concentrates will increase. Therefore, forage will move more and more towards the centre of attention, especially in Alpine regions where no grain is produced. What is more, high concentrate administration is always a risk to the animal's health, as it easily leads to metabolic disorders. High protein diets frequently induce diarrhoea (Cannas, 2004), while feed with high content of ruminally degradable carbohydrates leads to acidosis (Morgante, 2004). Additionally, nutritional imbalances aggravate worm infections and predispose the animal to bacterial infections like enterotoxaemia. Ensuing expenses for veterinarians and an additional amount of time spent on medical treatment may easily outweigh the rise in income for the additional milk produced. This, again, underlines the importance of feeding very high quality forage. Ruminants spending the vegetation period on pasture will be provided with high quality forage. The high protein content of the grass in spring also reduces the employment of concentrate without having a detrimental effect on milk yield. At any rate, before recommendations for feeding high concentrate diets can be given to farmers, long-term effects of the diet on metabolism and body condition have yet to be studied. In cattle, high concentrate diets showed to be unfavourable to the animal's health in many situations and it can be assumed that the same applies to small ruminants. Over-feeding in connection with high concentrate diets (which is especially dangerous with low productive animals) may induce fatty liver syndrome with serious symptoms in early lactation (AFRC, 1993).

On the other hand, apart from reducing milk production, long-term underfeeding is a risk to the animal's health as well. Energy deficiency induces ketosis, or, less acute, persisting weight loss predisposes the animal to illnesses.

The study also illustrates that feeding of hay and concentrate must be adjusted to the respective needs of the animal, depending on its productivity. Moreover, the importance of using only sheep and goats with the genetic potential to produce larger amounts of milk was confirmed. With animals of low productivity feeding of high concentrate rations is of no use

because they are not able to convert the ingested energy and protein into milk. In general, it seems that goats are more apt to divert additional nutrients to milk production than sheep.
The use of Austrian Mountain sheep for milk production may be considered by farmers, especially in regions of higher altitude, to which Mountain sheep are better adapted than Milk sheep and where animals are fed mainly on forage. Further breeding of Mountain sheep towards higher milk production might lead to widespread use of this breed as dairy sheep.

Fattening of Milk Sheep proved to be preferable to the fattening of Mountain sheep because of higher daily gains and feed efficiency. Additionally, it is Milk sheep carcass composition which meets consumers' demands rather than that of Mountain sheep. The production of goat meat is not more cost intensive than that of Mountain sheep and carcass composition may be better received due to its low fat and high lean content. Depending on the management system, it should be considered to reduce the use of concentrate and to extend fattening period instead. Feeding animals high quality forage or raising them on pasture, might reduce feeding costs and increase overall income without detrimental effect on the carcass.

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