Arch. Tierz., Dummerstorf **48** (2005) 5, 417-427

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Rearing diet effects on body condition and milk performance in first lactating dairy cows – A longitudinal study

Dedicated to Prof. Dr. Peter Horst on the occasion of his 75th birthday

Abstract

Fourteen pairs of identical female Holstein twins were used for a feeding trial during a period between 3rd and 21st month. One in two sibling was reared continuously at a medium (M) and the other one at a high (H) feeding intensity. Lasting diet effects of body weight (BW), back fat thickness (BFT), and milk performance (M-kg) were analyzed for the subsequent lactation.

A lasting diet effect was verifiable for BFT, whereas BW don't differ between groups. BFT indicated the changes from negative to positive energy balance 7 and 10 weeks later than BW, for M and H group, respectively. Besides, BFT showed, that the duration and dimension of negative energy balance was longer in H group than in M group. BFT difference became smaller according day of lactation and resulted in about zero at day 305 of lactation. If the groups were compared only by feeding intensity, the daily milk yield was 1.7 kg higher in M than in H group, but the difference didn't show any significance (p=0.22). However, the tendency of superiority was completely absorbed after the addition of the covariate age at first calving (AFC) in the model. Presented date in identical twins give no indications for lasting feeding effects per se on milk performance.

Key Words: heifers, feed intensity, body weight, back fat thickness, milk performance

Zusammenfassung

Titel der Arbeit: **Effekte der Fütterung während der Aufzucht auf Körperkondition und Milchleistung von Jungkühen – Eine Langzeitstudie**

Innerhalb eines Abschnittes zwischen dem dritten und 21. Lebensmonat wurden 14 Paare genetisch identischer, weiblicher Zwillinge der Rasse Holstein Friesian einem Fütterungsversuch unterzogen. Während ein Zwillingspartner kontinuierlich einer mittleren (M) Ernährungsintensität ausgesetzt war, wurde der andere Zwillingspartner kontinuierlich intensiv (H) ernährt. Nachwirkende Fütterungseffekte in der Laktation wurden für die Merkmale Körpergewicht (KG), Rückenfettdicke (RFD) und Milchleistung (M-kg) analysiert. Während die RFD zwischen den Gruppen auch noch zum Zeitpunkt der Laktation differierte, traf das auf Körpergewicht nicht zu. Die RFD zeigte den Wechsel von der negativen in die positive Energiebilanz 7 (M) bzw. 10 (H) Wochen später an als das Körpergewicht. Darüber hinaus signalisierte sie, dass Dauer und Ausmaß der negativen Energiebilanz in der H-Gruppe größer als in der M-Gruppe waren. Die RFD beider Gruppen näherten sich im Verlaufe der Laktation an, so dass zum Zeitpunkt des 305. Laktationstages auch für dieses Merkmal kaum noch Unterschiede vorhanden waren. Sofern die Gruppen nur hinsichtlich der vorangegangenen Fütterungsintensität miteinander verglichen wurden, war die M- der H-Gruppe um 1,7 kg Milch/Tier und Tag überlegen. Diese Differenz war statistisch jedoch nicht zu sichern (p=0,22). Nachdem das Erstkalbealter (EKA) zusätzlich in die Analyse einbezogen wurde, verschwand der Unterschied aber vollkommen. Die vorgestellten Ergebnisse weisen nicht darauf hin, dass die Fütterungsintensität während der Aufzucht per se die Milchleistung beeinflusst.

Schlüsselwörter: Jungrinder, Aufzucht, Fütterungsintensität, Rückenfettdicke, Milchleistung

Introduction

Feeding during rearing period does not only influence the growth rates of calves and heifers. Some researchers also reported evidences for lasting effects on performance in lactating dairy cows, especially, when the feeding concerned the prepubertal period of development (SJERSEN and PURUP, 1997; VAN AMBURGH et al., 1998). In these investigations a moderate feeding level was beneficially for lactational performance. Although the physiological reasons of feeding effects on milk performance are not well defined, there are evidences suggest that the composition of the mammary gland and differences in hormonal patterns could be involved (SJERSEN and PURUP, 1997; SJERSEN et al., 2000). On the other hand, other researches found no differences in milk production, when heifers were fed at a moderate or high feeding level (ABENI et al., 2000; ABENI et al., 2003) and results of CAPUCO et al. (1995) did not show an influence of udder composition on milk performance. According results of LACASSE et al. (1993), MÄNTYSAARI et al. (1999), and MÄNTYSAARI et al. (2002), the responsiveness of milk performance according to feeding after puberty and during gestation seems to be anymore inconsistently.

Possible reasons for this contrariness could be the varieties of investigation conditions like diet, ontogentic location and length of the treatment period. Additionally, also the use of animals, which have different genetic potential for yield or for responsiveness after feeding stimuli, could be induce inconsistent results, especially in small samples. Differences in body condition and changes of body condition also could lead to varieties in milk yield and animals health, even when body weight is the same. Like shown by VAN AMBURGH et al. (1998) heifers, fed diet formulated to an high average daily gain during rearing, can have a lower postcalving body weight and simultaneously a higher BCS then heifers fed less intensively. This seems paradoxical, because a positive correlation between both body weight and body condition is known (FOX et al., 1999). In analyses of SILVA et al. (2002) prepubertal body weight gain did not account for any of the variation in mammary development, whereas BCS was the only significant covariate for milk production.

The purpose of this paper aimed to the question, whether differences in feeding intensity during a longitudinal period of development may have lasting effects on body weight, back fat thickness, and yield during the first lactation. In opposite to others we used continuous high vs. moderate feeding systems, because these are the most frequently methods in rearing practice, but our knowledge about its effects during lactation is not well founded yet.

Materials and methods

Animals

Fifteen female twin pairs of Holstein Friesian, born within a period of four months between 1999 and 2000, were used for the investigations of growth parameters in two separated feeding groups. Seven of these pairs, resulting from embryo splitting, were born in the research farm. Eight additionally purchased pairs from other farms were involved later, at an age of 4 - 5 months. Subsequently, these animals were adapted to the new rearing and feeding conditions during the following 2 – 3 weeks. All over the time both feeding groups were housed in protective open barns with one open wall and space to run about outside. Heifers were inseminated after reaching a body weight of 400 kg. Because of a calving loss, only 14 pairs were used for investigations of body traits and milk performance during lactation.

Feeding

Treatment started at an age of 13 weeks and ended eight weeks before calving or if animals reached an age of 29 months. For the purchased animals treatment started at the time of availability. Animals were fed ad libitum. Diets differed by compositions and aimed at an daily gain of approximately 600 g and 850 g for medium (M) and high intensity group (H), respectively. Dry matter intake and requirements were calculated according to the DLG-recommendations for dairy heifers (DEUTSCHE LANDWIRTSCHAFTS-GESELLSCHAFT, 1997). The supposed growth parameters and dry matter intake resulted in requirements of energy concentrations of about 9.5 to 10.5 MJ ME/ kg DM and 10.5 to 11.5 MJ ME/ DM in M and H group, respectively. For prevention of undesirable responses, resulting from changes in feed composition, the feeding stuffs were long termed and changes were hold at a minimum. In the case of the M-group, grass silage, hey, and straw were fed. Additionally, Minerals and 450 g of concentrate were added just until the 9th month. Later no concentrates were provided. Animals of the H-group were fed maize silage, hey, minerals and about 800 g of concentrates per day all over the time, including an amount of 900 g/d at the beginning and 500 g/d at the end of treatment. Table 1 shows the mean nutrient concentration during treatment period.

Table 1
Mean nutrient content of diets within treatment period (calculated from 124 samples in total) (Mittlerer Nährstoffgehalt der Rationen innerhalb des Fütterungsabschnittes (berechnet aus insgesamt 124 Proben))

	ME (MJ/kg DM)		CP (g/kg DM)		CF (g/kg DM)	
Age (mo)	H	M	H	M	H	M
3-6	11.5	10.6	128	141	129	163
6-9	11.0	9.6	132	146	203	303
9-12	10.9	9.7	138	145	208	293
12-15	10.9	9.9	130	147	209	274
15-18	11.1	9.7	135	149	198	262
18-21	11.1	9,8	136	153	195	258

ME= metabolizable energy, CP= crude protein, CF= crude fibre, DM= dry matter

Table 2
Mean nutrient content of diets fed in lactation (calculated from 90 samples in total) (Mittlerer Nährstoffgehalt der Rationen in der Laktation (berechnet aus insgesamt 90 Proben))

Stage of lactation	NEL (MJ/kg DM)		CP (g/kg DM)		CF (g/kg DM)	
	H	M	H	M	H	M
week 6 to day 11 a.p.	6.77	6.04	143	166	190	243
day 10 to day 1 a.p.	6.59		160		196	
month 1 to month 4 p.p.	7.25		161		191	
month 5 p.p. to month 10 p.p.	7.00		157		191	

NEL= net energy for lactation, CP= crude protein, CF= crude fibre, DM= dry matter

Heifers were removed from the dietary treatment groups about 6 weeks before calving. Dietary treatments were then discontinued. Afterwards all animals were housed as a group and were fed according to Table 2. During the first lactation, heifers were housed in a pen stall, fed a diet contained an ad libitum mixture of maize-, and grass

silage, concentrate, and hey. In the late stage of lactation maize silage and concentrate were reduced.
Nutrient compositions were determined according to the methods of NAUMANN and BASLER (1997).

Measurements

After the treatment period body weight (BW) and back fat thickness (BFT) were collected together once before and five times after calving about at the same stage of lactation. The analysis of measurements was confined to the period from partus until week 41 of lactation. All body measurements were taken around week 1, 5, 16, 32 and 41. BFT was measured by ultrasound, using a portable device (AMI Ultrascan II®) with a 5.0-MHz-Linearscanner. The scanner was located over the area between the hook and the pinbone. More details about BFT measurement are described by SCHRÖDER and STAUFENBIEL (2002) and STAUFENBIEL et al. (2003).
Individual milk production data (yields, fat and protein concentration) were determined monthly from Landeskontrollverband Brandenburg e.V. Milk Recording Organization.

Table 3
Means and standard deviations of all measurements for a period of 305 d of lactation (Mittelwerte und Standardabweichungen für die Messwerte der 305-Tage Laktation)

	N	$\bar{x}$	SD
BW (kg)			
Total	122	566	52
M	59	565	43
H	63	568	58
BFT (mm)			
Total	125	14.9	5.5
M	62	13.5	4.6
H	76	16.3	6.0
Milk (kg/d)			
Total	229	29.5	5.3
M	117	30.2	5.6
H	112	28.9	5.0

Results of age at first calving (AFC), services per conception (SPC) and mastitis frequency were shown only as raw data.

Statistical Analysis

All data were analyzed using the SAS procedure MIXED, repeated measurement ANOVA (SAS INSTITUTE 2000, LITTELL et al., 2002). In all models the effect of feeding intensity during rearing (H or M) was considered fixed. In order to analyze the lasting effect of feeding intensity over the time of lactation, variables were fitted as a function of time of lactation including the time in the model as a covariant up to three polynomial degrees. AFC was also used as a covariate. Additionally, interactions between feeding intensity and covariates in linear and exponential terms were considered in the model statement. Only significant effects were used in the final models, with exception of such ones were non significantly as simple main effects but significantly in polynomial degrees or interactions. Spatial structures of covariance were assumed to fit a time-series type covariance structure in which the correlations decline as a function of time for each animal. If an animal dropped out before reaching the 305th d of lactation the corresponding sibling also was excluded from the analysis at the same day.

Results

Results of analysis of variance and the corresponding regressions during lactation are given in Table 4 and Figure 1, respectively.

Differences in feeding intensity and AFC did not result in significant effects on BW during lactation, whereas BFT was affected by lasting treatment effects. At the beginning H animals had a significant higher BFT than M animals, although BW was the same. Later BFT differences became lower and tended to be zero at the end of lactation. The nadir of the BW curve was detected at week 12, whereas BFT was decreased until week 19 and 22, in moderate and intensive fed animals, respectively (Figure 1). H animals mobilized about 2 mm BFT more than M animals.

Table 4
Estimates and *P*-values for fixed effects during lactation (Schätzwerte und P-Werte für die fixen Effekte während der Laktation)

Effect	BW (kg)	*p*	BFT (mm)	*p*	Milk	*p*
1) Diet			-5.069 ± 1.19	0.0024		
2) AFC					0.018 ± 0.008	0.0400
2) Week of lactation	-10.005 ± 1.48	<0.0001	-1.745 ± 0.15	<0.0001	1.095 ± 0.256	0.0006
2) Week of lactation ²	0.539 ± 0.08	<0.0001	0.060 ± 0.009	<0.0001	-0.056 ± 0.013	0.0037
2) Week of lactation ³	-0.007 ± 0.001	<0.0001	-6.2^{-4} ± 1.3^{-4}	<0.0001	-7.2^{-4} ± 1.9^{-4}	0.0002
1) Interaktion Week *diet			0.111 ± 0.043	0.0121		

1) estimates were calculated on the base M minus H 2) estimates of covariates
1) Die Schätzwerte wurden berechnet auf der Basis M minus H 2) Schätzer für Kovariate)

Figure 2 shows the relationship between BFT and BW. The vortex of the graph indicates that BFT at the time of least BW differed by 3 mm.

Milk performance was not affected by diet in the full model (Table 4, Figure 1). The peak of daily milk yield was arrived around week 13 of lactation, either for H and M group.

Because of the main interest of this investigation was the analyses of lasting diet effects on milk performance, and M group showed a clear tendency for superiority according row data, we additionally tested the sole effect of diet (model 1) and the effects of both, diet and AFC, (model 2) on milk performance in two reduced models. Results are given in Table 5. If feeding groups were compared by diet only, the daily milk yield was 1.7 kg higher in M than in H group. This superiority was absorbed after including AFC in the model, indicating identical twins had about the same milk performance.

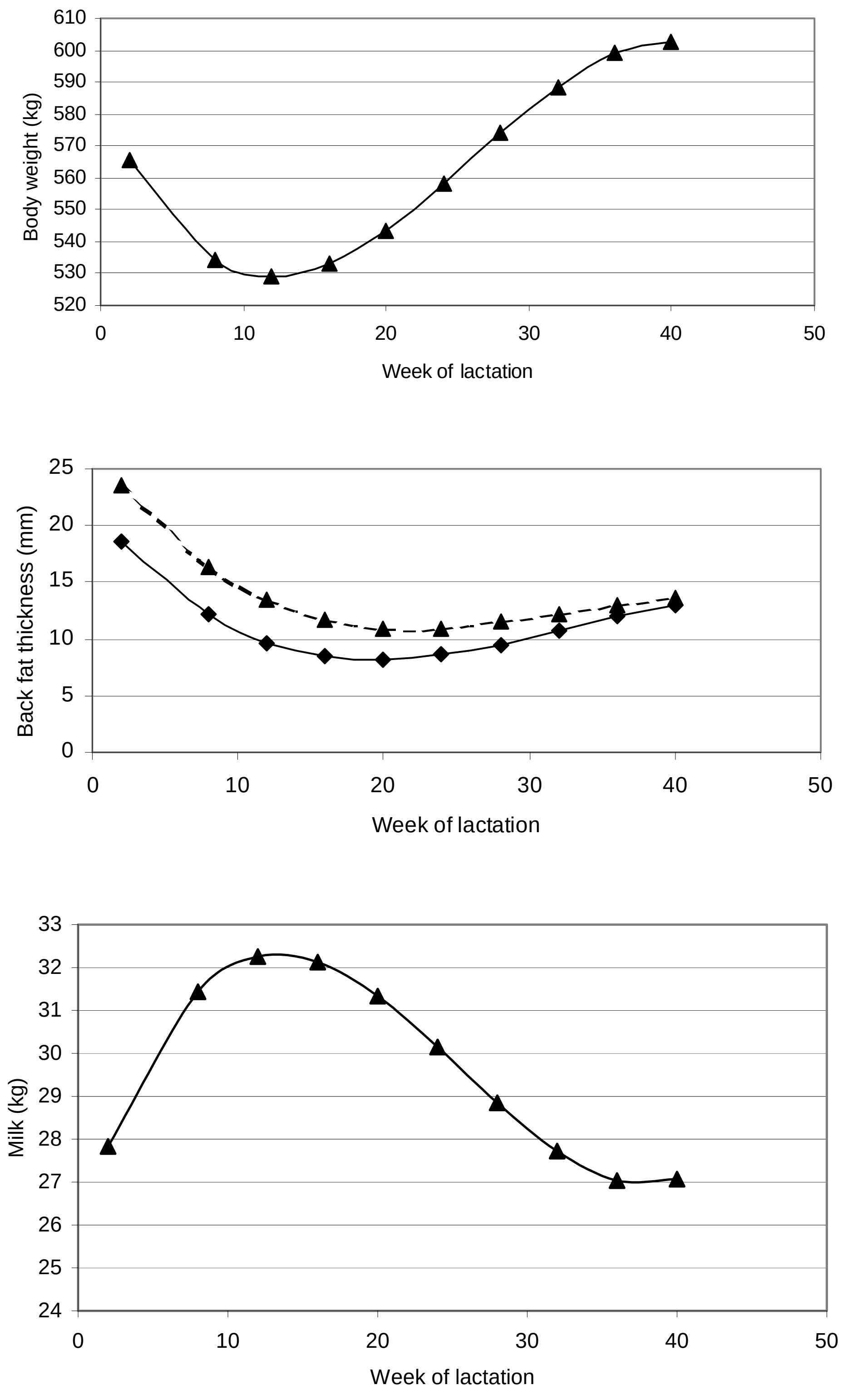

Fig. 1: Regressions of body weight, back fat thickness, and milk performance on week of lactation (Regressionskurven für Körpergewicht, Rückenfettdicke und Milchleistung auf die Laktationswoche)
H: broken line, triangle; M: continuous line, quadrates; H+M: continuous line, triangle (H: unterbrochene Linie, Dreiecke; M: durchgehende Linie, Quadrate; H+M: durchgehende Linie, Dreiecke)

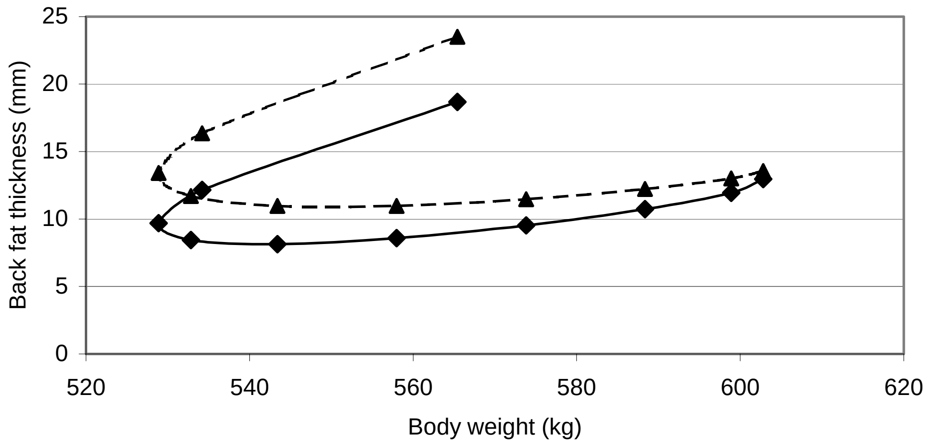

Fig. 2: The relationship between body weight and back fat thickness in lactating heifers (Die Beziehung zwischen Körpergewicht und Rückenfettdicke bei Jungkühen)
H: broken line, triangle; M: continuous line, quadrates (H: unterbrochene Linie, Dreiecke; M: durchgehende Linie, Quadrate)

Table 5
Contrasts (M minus H) of milk performance (kg/d) basing on reduced models (Kontraste (M minus H) für die Milchleistung (kg/d) auf der Basis reduzierter Modellansätze)

Model 1	Model 2
Diet (*P*=0.22)	Diet (*P*=0.98) AFC (*P*=0.04)
1.7	-0.02

Results for reproduction and health, giving in Table 6, are basing on raw data. The tests do not show differences between the groups with exception of AFC. Only full data sets of siblings were used for calculations of paired T-Tests (SPC-Rearing, AFC, SPC-Lactation) and McNeamers-test (mastitis).The absence of significance is due to small amount of data.

Table 6
Characteristics of reproduction and health (Kriterien der Reproduktion und der Tiergesundheit)

	M	H	*P* (paired T-test, McNeamers-Test)
SPC (rearing)	1.4 ±0.8 (n=15)	1.7 ±1.0 (n=15)	0.313 (N_{Pairs}=15)
AFC (mo)	28.6 ±2.2 (n=15)	25.6 ±2.0 (n=15)	0.001 (N_{Pair}=15)
SPC (lactation)	2.0 ±1.3 (n=13)	2.5 ±1.5 (n=11)	0.503 (N_{Pair}=10)
Mastitis frequency (%)*	43 ±5.1 (n=14)	53 ±5.2 (n= 15)	0.781 (N_{Pair}=14)

AFC = age at first calving, SPC = services per conception
* % of animals treated at least once per lactation
(AFC = Erstkalbealter, SPC = Besamungsindex, * % Tiere, die wenigstens einmal wegen Mastitis behandelt wurden)

Discussion

The chosen twin design had the advantage that the absence of genetic differences between feeding groups reduced total variance and therefore, it enabled investigations also in small samples.

In the current study the estimated nadir of BW in both groups was reached at week 12 and the nadir of BFT at week 19 in moderate group and at week 22 in the intensive group. Peak of lactation was obtained at week 13 for both groups. SØNDERGARD et al. (2002) also found that the minimum BW is reached earlier than peak in milk, but the difference was greater in this case averaged about 4 weeks. Maybe the use of animals of three breeds over three lactations in SØNDERGARDs work could give an explanation for the discrepancy to the own data. In the work on hand only Holstein heifers were used. Additionally, the level of milk performance was higher in the own than in SØNDERGARDs herd.

COFFEY et al. (2002) and EBENDORF et al. (1995) argue that cumulative body energy loss in first lactation is fully recovered at around day 200 of lactation. Data on hand show, that this statement may be case by using BW as an indicator of energy state. As shown in BFT none of both feeding groups recovered the adipose loss until day 305. Probably, skeleton mass, masses of muscles, rumen fill and body water are raising more independently from energy balance than body fat, especially in growing animals. Therefore, the correlation between BW and BFT shows only a small amount of common variation (r= 0.21; p= 0.02; n=121) and a non-lineare relationship (Figure 2) during lactation. Similar results were observed by SCHMIDT and SCHÖNMUTH (1997). From these findings we have to conclude, that BW does not indicate the true changes of actual or cumulative energy balance.

BFT was considerably higher in H than in M group at the beginning of lactation and about the same in both groups at the end (Figure 1). About 2 mm BFT were mobilized more in H than in M animals during the period from week 2 of lactation until the nadirs. In opposite to this, BW does not show differences between the groups at any time of lactation. A longer period of fat mobilization in the intensive than in moderate group, indicates, that intensively reared animals had to undergo a longer negative energy balance than moderately fed animals, although the yield in this group tended to be lower (EBENDORF et al., 1995). A higher amount of mobilized body fat, a longer time of fat mobilization and a tendency for lower milk yield point to the assumption that heifers reared at a high plan of nutrition had a lower feed intake during lactation than moderate fed heifers. This hypothesis is relating to the fact, that AFC was favorable correlated with yield (Table 4 and 5). Like known from GRINGS et al. (1996) and GREENWOOD et al. (1997) there is a positive relationship between age and feed intake in growing cattle. In data on hand, lactating M animals were 3 months older than H animals and had about the same BW. But there is a lack of well founded information about this relationships independent on BW. However, BUSKIRK et al. (1996) have show, that animals, get a moderate density ration eat more than such get a high density ration. Maybe, high feed intake was hold up until lactation. This assumption is basing on results of WALDOW et al. (1998), where animals fed moderately before lactation had a marginally higher feed intake during lactation than animals fed intensively.

Similarly treatment responses regarding milk yield were found in studies of AMIN et al. (1996) and ETTEMA and SANTOS (2004), where cows at a high AFC produced more milk than cows calved early. WALDOW et al. (1998) detected positive relationships between AFC and milk production and also between BW after calving and milk production. ABENI et al. (2000) compared two diets in trials before and after puberty and found, that rearing diet has not affected milk production, but early calving influenced milk yield negatively. VAN AMBURGH et al. (1998) reported that heifers with a growth rate of 0.6 kg had a significant increased yield compared to heifers with a growth rate of 1.0 kg. After covariate analysis using BW as covariate yield was about the same for both groups. Our own data did not show a relationship between milk production and BW of the feeding groups, because BW did not differ at any time of lactation. LACASSE et al. (1993) could not verify any effects of plan of nutrition on milk production. Similarly to the presented results the authors found no evidences for a relationship between BW at calving and milk yield.

Summing up we can say that a reduced rearing intensity can lead to higher AFC and to lower energy depots, but, because of continued growth and development, not to differences in BW of lactating heifers. Additionally, a moderate feeding intensity during rearing maybe leads to a slightly higher feed intake during lactation and a tendency for better milk yield.

Reproduction and health (Table 6) were not affected by feeding intensity during rearing, although fertility tend to be better in moderate fed animals than in intensive. However, the small amount of data in the current study severely limited a well-founded discussion of these results. Besides, in a larger sample ETTEMA and SANTOS (2004) observed that the number of artificial inseminations per cow was least within an span of AFC of 701 to 750 d. Higher as well as lower AFC were unfavorable for reproductive performance (PLATEN et al., 1999). LACASSE et al. (1993) found, that a high plan of nutrition, especially during from 1st yr of age until 3 mo of gestation, was negatively associated with reproduction and health, whereas VAN AMBURGH et al. (1998) and ABENI et al. (2000) did not find any relationships.

Conclusions

Feeding intensity during rearing per se does not determine lasting differences in milk yield during subsequent lactation, but there is a positive relationship between AFC and production. It seems possible, that a higher AFC, due to lower gain during rearing, leads to a slightly higher feed intake during lactation. Animals, which reared at a high feeding level, use more adipose tissue for milk synthesis then such reared at a medium level, but they have the same or a marginally lower milk performance. Therefore, from the view of lactational physiology an AFC of 28 months seems to be better than that one of 25 months. This evidence does not aim at an economical evaluation of rearing intensity. Besides, results above 28 months may be differ from these findings. Work is required to identify the lactational responsiveness causing by interactions of feeding intensity with BW at insemination.

Acknowledgement

The authors thank the H. Wilhelm Schaumann Stiftung for supporting this project. Our appreciation is extended to family Paries (GRUEPA-Hof Klein Mutz) for their permanent help in animal care. Furthermore, we thank Prof. G. Leuthold for his support at the time of preparation of the trial. We thank Dr. Barbara Schröder, Jürgen Weber, Sabine Betzin, and Theresa Skibbe for their help in taking measurements.

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Received: 2005-08-31

Accepted: 2005-09-23

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