FEED INTAKE AND ENERGY UTILIZATION IN DAIRY COWS OF DIFFERENT BREEDS

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J.K. Oldenbroek

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Proefschrift
ter verkrijging van de graad van
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op gezag van de rector magnificus,
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(Voeropname en energiebenutting bij melkkoeien van verschillende rassen)

STELLINGEN:

1. Bij ad libitum voedering van melkkoeien met een compleet gemengd rantsoen zijn de verschillen in voeropname tussen rassen en tussen koeien gerelateerd aan de verschillen in voerbehoefte voor melkproduktie en onderhoud.
   Dit proefschrift

2. De melkproduktie per kilogram lichaamsgewicht is een betere maat voor de biologische efficiëntie van de melkproduktie dan de melkproduktie per koe.
   Dit proefschrift

3. Onder goede voedingsomstandigheden is voeropname van melkkoeien meer het gevolg van de melkproduktie-aanleg, dan dat melkproduktie het gevolg is van het voeropnamevermogen.
   Dit proefschrift

4. Selectie op voeropname is in de rundveehouderij alleen zinvol wanneer het leidt tot een betere benutting van ruwvoeders van het eigen bedrijf.
   Dit proefschrift

5. Een mogelijke interactie tussen de erfelijke aanleg voor melkproduktie en de respons op een behandeling met bovine somatotropine verdient nader onderzoek.
   Dit proefschrift

6. De beperking van de produktie van melkvet per bedrijf dient plaats te vinden door een quotering van de hoeveelheid melkvet en niet door een quotering van de hoeveelheid melk met een bevriezing van het vetgehalte.

7. De zuiverheid van de afstammingsindex van proefstieren neemt toe wanneer ook de afstamming van moedersvader geverifieerd is met behulp van bloedgroepenonderzoek.

8. De Nederlandse rundvleesproducenten zouden jaarlijks minstens tien miljoen gulden aan kosten kunnen uitsparen wanneer de fokkerij-organisaties de erfelijke aanleg voor de vleesproduktie van de melkveestapel niet zouden verwaarlozen.

9. Voor de meeste melkveehouders is het fokken van mooie koeien een dure hobby.

10. Het huidige mond- en klauwzeervaccin voor rundvee dient uit overwegingen van dierlijk welzijn sterk verbeterd te worden.

11. Een proefdierverzorger doet veel meer dan het verzorgen van proefdieren.

12. Jonge boeren kunnen gemakkelijker een levenspartner vinden wanneer hun interesses verder reiken dan de eigen agrarische wereld.

13. Groepshuisvesting van vleeskalveren betekent geen verbetering van hun welzijn.

14. Wanneer Hervormden en Gereformeerden samen in een kerk zitten, betekent dit nog niet dat ze "Samen op Weg" zijn.

15. Het instellen van de Directie Wetenschap en Technologie naast de Dienst Landbouwkundig Onderzoek betekent het onder voogdij plaatsen van het landbouwkundig onderzoek en staat een werkelijke verzelfstandiging in de weg.

16. De komst van de melkrobot zal, in het weideseizoen, afbreuk doen aan de stoffering van het Nederlandse landschap.

Proefschrift van J.K. Oldenbroek.
Feed intake and energy utilization in dairy cows of different breeds.
Wageningen, 24 februari 1988.

aan: Riet,

Gerwin, Bertjan en Alien

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Voorwoord

Bij het presenteren van onderzoeksresultaten, zeker in de vorm van een proefschrift, wordt gemakkelijk de indruk gewekt dat het uitgevoerde onderzoek het werk van één persoon is. Dit is beslist niet het geval wanneer het experimenteel onderzoek met rundvee betreft. Dit proefschrift is gebaseerd op onderzoek dat in 1979 gestart is op het proefbedrijf "'t Gen" van het Instituut voor Veeteeltkundig Onderzoek "Schoonoord". In de afgelopen 8 jaar zijn zeer velen binnen en buiten het instituut bij het onderzoek betrokken geweest. Aan het begin van dit proefschrift wil ik hen allen bedanken voor hun hulp. In dit verband wil ik een aantal personen en groepen met name noemen.

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CONTENTS

CHAPTER 1. INTRODUCTION

FEED INTAKE AND ENERGY UTILIZATION IN DAIRY COWS OF DIFFERENT BREEDS

INTRODUCTION

Feed costs determine the greatest part of costs in dairy production. Nutrition and breeding of dairy cattle aim to improve the efficiency of milk production: to increase the ratio between milk yield and feed intake or to increase the difference between returns from milk and feed costs. In these biological and economic definitions of efficiency, the relationship between feed intake and milk production plays a major role. Little knowledge is available about genetic differences in feed intake and its relation with the efficiency of milk production (Freeman, 1975 and Korver, 1987).

In a simple approach feed and milk consist of energy of which part is protein. For these components the efficiency can be established. In rations for dairy cows approximately 15-20 per cent of the dry matter is crude protein. The dry matter part of the milk contains 25 - 30 per cent protein. The energy level of the ration has a great impact on protein production (e.g. Tamminga, 1981). Quantitatively, energy in feed and milk is more important than protein. Our studies about differences in feed intake and energy utilization between breeds will be restricted to a description of the use of Net Energy for the production of milk energy, maintenance and gain.

Improvement in the efficiency of the dairy cow may be obtained by changes in digestion and nutrient absorption, changes in maintenance requirements, changes in the utilization of metabolizable energy for production or changes in the partition of energy between milk production, maintenance and body weight gain (changes in the homeorhetic control of energy partitioning, Bauman et al., 1984). Digestibility can be greatly enhanced by manipulation of the diet. Relatively little variation exists among cows, fed similar rations, in maintenance requirements per kg metabolic weight and in the utilization of metabolizable energy for milk production (Freeman, 1975 and Bauman et al., 1984). In these reviews it was concluded that individual cows show a large variation in feed intake and in the partition of energy. In the dairy cow energy is partitioned between maintenance, milk production, body weight gain (which might occasionally be negative) and eventually gain of the foetus.

Genetic differences among animals may be reflected in differences among breeds, which are developed through different breeding goals. Dual purpose breeds like the Dutch Friesian (DF) and the Dutch Red and White (DRW) were used in Western Europe to produce milk and beef. In other parts of the world specialised dairy breeds like the Holstein Friesian (HF) and the Jersey produce a great part of cow's milk. These breeds differ genetically in milk yield, milk composition, body weight and body composition (De Rooy, 1980; Oldenbroek, 1984). Through those differences they might also be different in feed intake and in utilization of Net Energy for maintenance, for milk production and for gain. In the respective home countries of these breeds differences exist among feeding rations (concentrates, feed crops, grass and grass products) as well as among breeding goals (fluid milk, butter and cheese). So, breeds do not only differ in production traits but maybe differ also in adaptation to their local diets, which might result in a breed x diet interaction for feed intake and milk production.

In modern Dutch dairy farming cows are kept in groups and, they are fed, apart from a considerable amount of concentrates, ad libitum with high quality roughages. Former, present and maybe also future conditions plead for comparing breeds on a concentrates based diet. However, it is also imaginable that more roughage will be offered to dairy cows in the future. The restriction of milk production on farm level within the EEC decreases herd size. At farms, where alternative agricultural activities are limited, more roughage will be available for dairy production. Therefore at least two diets, which differ in the amount of concentrates, should be used when comparing breeds for feed intake and partition of Net Energy.

Different feeding systems can be used to study feed intake and energy utilization of dairy breeds. It is possible to feed roughage ad libitum to all animals and to supply concentrates individually according to milk yield. This system is less appropriate for breed comparisons because of concentrates intake is totally confounded with milk yield. A second system is feeding a basic amount of concentrates and to supply roughage ad libitum. However, for breeds which differ largely in body weight and milk production traits, it is difficult to choose the optimal concentrates level for all breeds. A third possibility, for which is opted, is to feed complete diets with a different concentrates to roughage ratio ad libitum. In this way milk production of the breeds depends on their feed intake capacity and on the energy concentration of the rations. From several reviews in the literature (Rickaby, 1978 and Gill, 1979) it can be concluded that complete diets have more advantages to measure voluntary feed intake of cows, e.g. selection between diet components is impossible. The mixing of the diet components has a slight positive effect on intake and production. In early lactation cows should be fed a relatively high amount of concentrates in the complete diet and a lower amount in a later part of lactation to produce efficiently. However, changes in the composition of the complete diets always result in a change in feed intake and in milk production. Therefore we have decided to keep the composition of the supplied complete diets constant during lactation.

Among and within breeds differences exist in maturity (Bergström, 1978), which may influence feed intake capacity at a fixed age. Differences in age are related to differences in body weight and milk yield, but these differences do not fully explain the differences in feed intake among age groups (Kristenson and Ingvartson, 1985). Therefore differences between breeds in feed intake within a parity can not be used for predicting differences between breeds in feed intake within another parity. So, feed intake studies to establish differences in energy intake and energy utilization among breeds should be carried out with cows of different parity classes.

The partition of energy in the dairy cow is, among others, controlled by the concentration of somatotropin in blood (Hart, 1983). Besides somatotropin, thyroxin and insulin play a role in this partitioning. Therefore in studies on differences in Net Energy utilization among dairy breeds, it is worthwhile to establish possible differences in blood levels of hormones involved in partitioning and differences in metabolites in blood, which may reflect aspects of partitioning.

At the moment bovine somatotropin (BST) can be produced with recombinant DNA techniques. Injections of exogenous bovine somatotropin (BST) gives an increase in milk production (e.g. Bauman et al., 1984). So far, most experiments were carried out with Black and Whites. It is questionable whether BST injections in dairy cows of other breeds, with a different genetic ability for milk production, will give similar results. In an experiment to establish the optimum dosage of exogenous somatotropin, Black and Whites, Dutch Red and Whites and Jerseys were involved to obtain an impression of a possible breed-dosage interaction and its consequences for feed intake and for the utilization of Net Energy for milk production, maintenance and gain.

The aim of this thesis is to describe differences between dairy breeds in feed intake and partition of energy between milk production, maintenance and gain in different circumstances: different parities, different parts of lactation, feeding ad libitum complete diets which differ in roughage content and treatment with different dosages of BST. Relationships between feed intake and milk production, maintenance and gain will be presented in the different circumstances. Possibilities to manipulate feed intake and feed utilization in dairy cattle will be outlined.

This thesis is based on four studies which describe differences between different dairy breeds in feed intake, milk production and body weight within parities and fed ad libitum a complete diet with only roughage or a complete diet of the same mixture of roughage and 50 per cent concentrates on a dry matter basis. In each study the course of feed intake, milk production and body weight during lactation is outlined, correlations between these traits are given and the partition of Net Energy intake between milk yield, maintenance and gain is calculated. The chapters two to five summarize successively:

- A study with HF, DRW and DF heifers from 2 months before first calving until 10 months after calving.
- A study with HF, DRW and DF second calved cows from 2 months before the second calving until 10 months after the second calving. These animals had participated in the former study as a heifer on the same diets.
- A study with Jersey, HF, DRW and DF heifers from calving until 39 weeks of lactation.
- A study with Jersey, HF, DRW and DF third calved cows from calving until 39 weeks of lactation. These cows had already participated in the former study in first lactation on the same diets.

In chapter six these four studies are summarized. Special attention is paid to the effect of parity on the measured traits. The multiple relationship between Net Energy intake and milk production, maintenance and body weight gain is used to study differences between breeds in the utilization of Net Energy for the different processes.

Chapter seven is a description of a somatotropin dosage trial with Black and White, DRW and Jersey cows fed ad libitum with a complete diet containing 50 per cent concentrates from calving until 36 weeks of lactation. Special attention is given to the increase in efficiency of milk production after BST administration in the different breeds and to differences between breeds and treatments in blood levels of metabolites and hormones involved in nutrient partitioning.

The general discussion outlines the four main subjects of this thesis: differences between and within breeds in feed intake, differences between and within breeds in feed efficiency, relationships between feed efficiency and feed intake, milk production and body weight and possibilities to manipulate feed intake and feed efficiency.

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CHAPTER 2

HOLSTEIN FRIESIANS, DUTCH FRIESIANS AND DUTCH RED AND WHITES ON TWO COMPLETE DIETS WITH A DIFFERENT AMOUNT OF ROUGHAGE: PERFORMANCE IN FIRST LACTATION

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HOLSTEIN FRIESIANS, DUTCH FRIESIANS AND DUTCH RED AND WHITES ON TWO COMPLETE DIETS WITH A DIFFERENT AMOUNT OF ROUGHAGE: PERFORMANCE IN FIRST LACTATION

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ABSTRACT

Oldenbroek, J.K., 1984. Holstein Friesians, Dutch Friesians and Dutch Red and Whites on two complete diets with a different amount of roughage: performance in first lactation. *Livest. Prod. Sci.*, 11: 401—415.

Groups of 20 Holstein Friesian (HF), 23 Dutch Red and White (DRW) and 20 Dutch Friesian (DF) heifers were fed a complete diet with only roughage (a mixture of grass- and corn-silage) or the same mixture of roughage with 50% concentrates on a dry matter basis, from 2 months before the first calving until 10 months after calving.

No significant breed—feed composition interactions were found for any of the characteristics.

The HF, DRW and DF heifers differed significantly in feed intake and milk production. They consumed 4725, 4432 and 4476 kVEM, respectively, and produced 5331, 4562 and 4660 kg milk, respectively, with 3.96, 4.20 and 4.22% of fat, respectively, and 3.25, 3.49 and 3.40% of protein, respectively.

The concentrates and roughage groups differed significantly in feed intake, milk production, average body weight and gain. The respective mean values for the concentrates and the roughage groups were: 5160 and 3928 kVEM, 5534 and 4168 kg milk, 4.00 and 4.26% fat, 3.52 and 3.24% protein, 542 and 506 kg body weight and 97 and 38 kg gain, respectively.

HF heifers used 51% of their energy intake for milk production (milk energy), DF heifers 49% and DRW heifers 48%. Both feed composition groups used 49% of their energy intake for milk production, but the roughage group used 8% more of the energy intake for maintenance than the concentrates group, as a result of lower energy intake.

INTRODUCTION

The black and white dairy breed in North America, the Holstein Friesian, was founded by imports of black and whites from The Netherlands a century ago. In North America, milk and beef production is much more separated than in Western Europe. The Holstein Friesian has been more selected for dairy production than the European Friesian. There is a much higher percentage of concentrates in the ration of dairy cows in North America than in

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Western Europe, due to a difference in profitability and possibilities of the alternative use of grassland for arable products.

At the moment, Holstein Friesian sires are used extensively in Western Europe. A question is whether animals with breeding values based on progeny fed high concentrate rations, will have comparable breeding values based on their progeny with rations mainly based on roughage. Between Holstein Friesians (HF), Dutch Friesians (DF) and Dutch Red and Whites (DRW), differences in milk yield (Oldenbroek, 1984) and in feed intake (Oldenbroek and van Eldik, 1980) were measured in a feeding system with ad libitum roughage and concentrates according to production.

In this experiment, HF, DF, and DRW heifers were fed either a complete diet of grass- and corn-silage or a complete diet with grass- and corn-silage and 50% concentrates on a dry matter basis. The purpose was to study differences in voluntary intake of roughage and concentrates and its consequences for milk yield and body weight in different dairy breeds. Besides possible breed—feed composition interactions, the differences between breeds and feed composition groups in the biological efficiency of milk production (energy in milk/energy in feed consumed) were studied.

LITERATURE

Differences in feed intake between cattle breeds were reported by Hooven et al. (1971) (between Holsteins and Jerseys), by Dickinson et al. (1969) (between Ayrshires, Brown Swiss and Holstein Friesians), by Monteiro (1975) (between British Friesians and Jerseys) and by Frisch and Vercoe (1977) (between *Bos taurus* and *Bos indicus* crossbred cattle). Korver (1982) found that HF crossbreds consumed 3.0% more energy and produced 7.7% more FCM (4% fat corrected milk) than Dutch Friesians. The differences between breeds in feed intake reported in the literature were accompanied by differences between the breeds in milk yield and body weight.

Oldenbroek and van Eldik (1980) described feed intake experiments, within a breed comparison of HF, DF and DRW, with 20 animals per breed at different stages of lactation and at different ages. In the experiments with dairy cows, animals were offered concentrates individually according to their milk yield. In all experiments, roughage was offered ad libitum. In these trials, the DRW animals consumed less roughage than the DF and HF animals, although they received the lowest amount of concentrates in nearly all experiments, due to their lower milk yield. The HF animals had the highest milk yield and were offered more concentrates than the DF animals, but ate the same amount of roughage.

Feed intake aspects of complete diets are reviewed by Rickaby (1978), Gill (1979) and Ghekiere et al. (1980). From their reviews, it can be concluded that complete diets are very suitable for measuring voluntary feed intake capacity of dairy cows. The mixing of concentrates and roughage has a positive effect on feed intake and milk production. In order to reach a high peak yield in early lactation and to prevent excessive fat deposition in a later phase of lactation, a complete diet should contain a relatively high amount of concentrates in early lactation and a relatively low amount in the later phase of lactation. It is very difficult to determine the optimum moment for change over to a lower proportion of concentrates in a complete diet. It is found in these reviews that a decrease in concentrates content of a complete diet is always accompanied by a decrease in feed intake and milk production.

In review articles, Freeman (1975) and Syrstad (1976) concluded that in general in the developed countries, no genotype—nutrition interaction was detected within and between breeds. Richardson et al. (1971) and Lamb et al. (1977) found interactions between progeny groups and concentrate level of the diet. In both trials, the interaction was due to progeny groups of New Zealand bulls, which produced relatively better on roughage diets. Mao and Burnside (1969) found an interaction between progeny groups and concentrate levels in summer in milk-recorded herds. Both they and Syrstad (1976) concluded that in data of milk-recorded herds' feeding levels are not defined accurately enough to interpret a genotype—nutrition interaction.

MATERIALS AND METHODS

Animals

The HF, DRW and DF heifers used for this experiment calved in May 1979 (Batch 1), in November 1979 (Batch 2) and in May 1980 (Batch 3). Each breed group was divided in a concentrates and a roughage group according to body weight eight weeks before the expected calving date (= Week 0) and sire. The distribution over breeds and feeding groups and the number of sires involved in each breed—feed composition group is given in Table I.

TABLE I

The distribution of the heifers over breeds and feeding groups (the number of sires involved in each group in parentheses)

	Breed			Total
	HF	DF	DRW	
Concentrates group	11 (10)	10 (8)	12 (10)	33
Roughage group	9 (9)	10 (8)	11 (10)	30
Total	20 (13)	20 (11)	23 (12)	63

Complete diets

The concentrates diet (C) consisted of 50% concentrates, 30% grass-silage and 20% corn-silage on a dry matter base. The complete roughage diet (R) consisted of 60% grass-silage and 40% corn-silage. During the trial, the composition of the concentrates used was kept constant. All heifers were offered 1 kg of concentrates daily during milking. Salt, vitamins and minerals were added to the roughage diet in the same amount per kg dry matter as in the concentrates diet. Before calving, the C animals received the roughage diet up to Week 7. In Weeks 8, 9 and 10, they received a diet with 25% concentrates and from Week 11 to Week 52 they received the C diet. The R animals got the R diet from Week 1 to Week 52. On average the heifers calved in the middle of Week 8.

Once a month, the weekly samples of grass- and corn-silage were combined and analysed for dry matter, energy (VEM*, according to the method described by Van Es, 1975) and digestible protein content (dpc). The C and R diets were sampled biweekly and analysed for dry matter content. Refusals of each animal were analysed once a month for dry matter content. In the whole experimental period, the concentrates diet contained on average 955 VEM and 120 g dpc and the roughage diet 896 VEM and 110 g dpc (per kg dry matter).

Treatment of animals

About nine weeks before the expected date of calving, the heifers were placed in a pen. Each animal had access to a single Calan electronic feeding gate, which allows measurement of individual feed intake in a loose-housing system. The experiment started eight weeks before the expected calving date. Twice daily, the heifers were offered a new bucket containing a measured amount of feed, which was a little higher than the expected intake. Refusals were fed again and once a week refusals were weighed and removed. Three times a week, the amount of feed supplied was changed according to the intake of previous days. With this feeding method, an average of only 5% of the feed offered to the animals was refused.

Biweekly after a morning milking, the live weight of the heifers was measured. The gain during the experimental period was calculated as weight in Week 52 minus weight in Week 1. Once a week, individual milk yield was measured at an afternoon and a morning milking and a sample of milk, consisting of equal parts of morning and afternoon milk, was analysed for fat and protein content. The heifers were milked at 12-h intervals. The animals were inseminated from Week 17 onwards.

Statistical analysis

The data concerning feed intake, milk yield and body weight over the whole experimental period were analysed with the following analysis of variance model:

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*1 VEM = 6.9 kJ NE, 1 kVEM = 6.9 MJ NE.

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{(ij)} + e_{ijkl}$$

where:

Y_{ijkl} = observation on animal l from batch k in feed composition group j of breed i;

μ = mean;

α_i = effect of breed i;

β_j = effect of feed composition group j;

γ_k = effect of batch k;

$\alpha\beta_{(ij)}$ = interaction effect of breed i and feed composition group j;

e_{ijkl} = error term.

Preliminary analyses of variance including the interaction terms $\alpha\gamma_{(ik)}$ and $\beta\gamma_{(jk)}$ was carried out. These terms were non-significant and were deleted from the final model.

From the weekly observations of energy intake, body weight, milk yield, fat and protein production of each animal, a "smooth" curve was constructed according to the principles described by Du Chateau et al. (1972). For each animal and characteristic, the average value for a biweekly period was taken from the "smooth" curve. These averages were analysed with the analyses of variance model described previously.

RESULTS

Differences between breeds and between feed composition groups

For none of the traits summarized in Table II was a significant breed—feed composition interaction detected. The probabilities for the interaction term varied from 0.57 for gain to 1.00 for milk yield. Therefore the results are presented in Table III by breed and by feed composition groups. For more detailed information, the results in Table II are presented by breed—feed composition groups.

HF heifers consumed 6% kVEM more than DF heifers and 7% kVEM more than DRW heifers (Table III). Their milk yield was 14 and 17% higher than those of DF and DRW heifers, respectively. Differences for fat percentage were 0.26 and 0.24 lower, respectively, and for protein percentage 0.15 and 0.24 lower, respectively. Differences in body weight between the breeds were rather small.

The concentrates group consumed 23% more dry matter and 31% more energy than the roughage group. The milk production of the concentrates group was 33% higher, fat percentage was 0.26 lower and protein percentage 0.28 higher. These gave differences in fat yield of 24% and in protein yield of 45% in favour of the concentrates group. Due to a 59 kg higher gain, the concentrates group was on average 7% heavier than the roughage group.

TABLE II

Mean values of the breed—feed composition groups for feed intake, milk production and body weight characteristics in Weeks 1—52 (SE is standard error of the means)

		Breed and group					
		HF		DF		DRW	
		C	R	C	R	C	R
Dry matter intake (kg)	Mean	5620	4556	5296	4348	5288	4251
	SE	123	137	132	132	119	125
Energy intake (kVEM)	Mean	5372	4078	5053	3899	5056	3808
	SE	119	132	128	128	115	121
Dig. crude protein intake (kg)	Mean	673	501	632	478	634	469
	SE	15	14	15	16	16	17
Milk yield (kg)	Mean	6014	4649	5352	3969	5238	3887
	SE	219	243	235	235	212	223
% fat	Mean	3.87	4.06	4.04	4.39	4.08	4.32
	SE	0.09	0.10	0.09	0.09	0.08	0.09
% protein	Mean	3.39	3.12	3.53	3.27	3.66	3.33
	SE	0.05	0.06	0.06	0.06	0.05	0.06
Fat yield (kg)	Mean	232	187	216	174	212	167
	SE	8	9	9	9	8	8
Protein yield (kg)	Mean	203	144	188	130	190	129
	SE	6	7	7	7	6	7
Average body weight (kg)	Mean	541	506	525	496	561	516
	SE	11	12	12	12	11	11
Gain (kg)	Mean	88	19	106	43	95	52
	SE	13	14	14	14	12	13
Final weight (kg)	Mean	609	545	600	542	629	564
	SE	14	16	15	15	14	14

Feed intake, milk production and body weight during the trial

From Fig. 1a, it can be seen that differences between the breeds in energy intake were significant only in Weeks 35—37 and 45—51 (S at the bottom of the figures means $P < 0.05$). In those periods, the HF heifers consumed more and the DRW heifers less than the DF heifers. After calving, the energy intake curve of the roughage group was rather flat (Fig. 1b). The highest energy intake of this group was around Week 15 (six weeks after calving). The energy intake curve of the concentrates group shows two peaks: in Week 21 (12 weeks after calving) and in Week 35. The reason for the decline in energy intake of the concentrates group between Week 23 and Week 29 is not clear. During the whole trial, the difference in energy intake between the feed composition groups was significant.

All three breeds reached peak yield (Fig. 1c) in Week 17 (8 weeks after calving). After Week 13, significant differences in milk yield between the breeds were found, which were due to higher milk yields in the HF heifers compared to the DF and DRW heifers. Differences in fat and protein yield

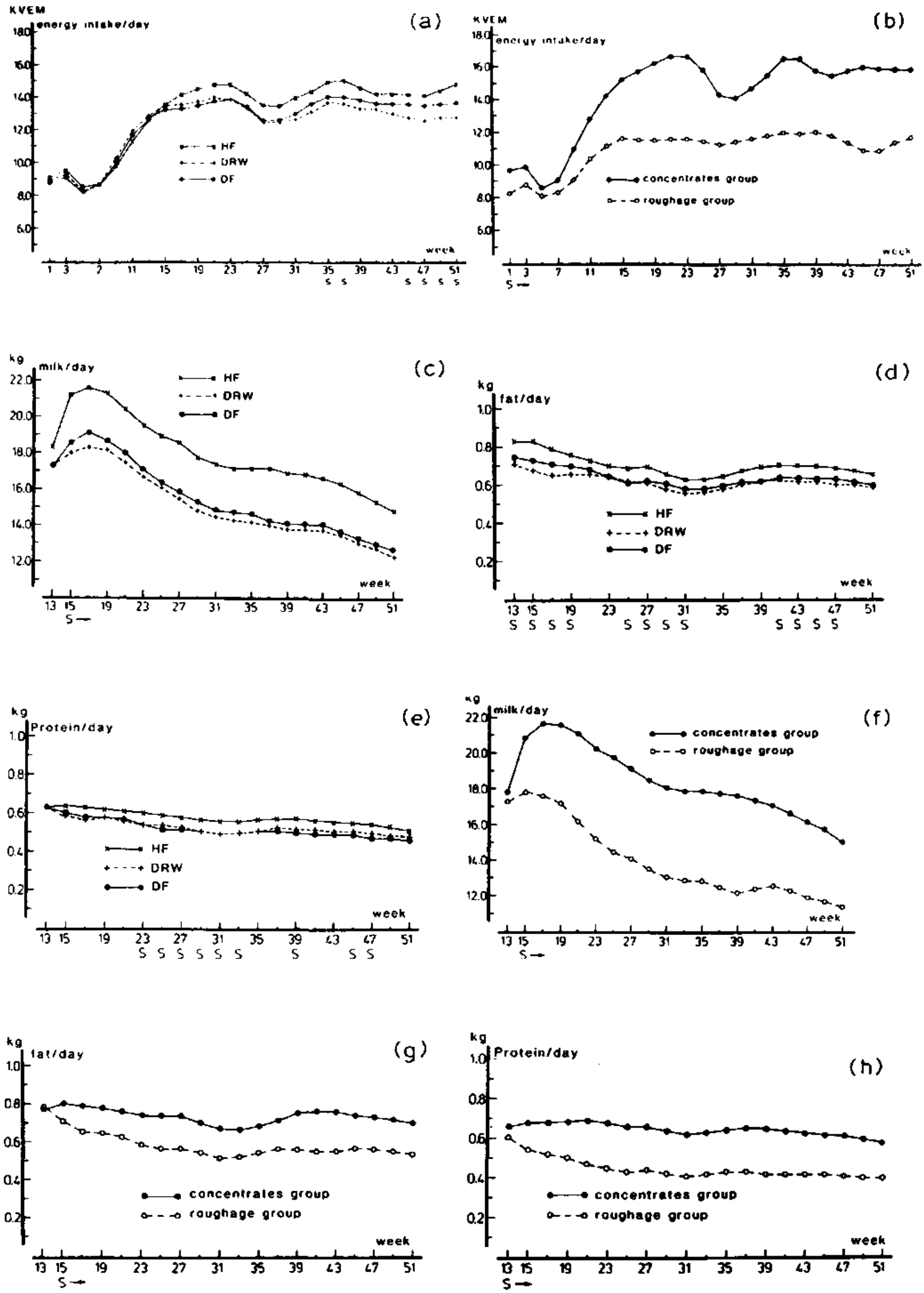
TABLE III

Mean values of the HF, DF and DRW heifers and of the concentrates and roughage group for feed intake, milk production and body weight characteristics in Weeks 1—52

		Breed			Group	
		HF	DF	DRW	C	R
Number of animals		20	20	23	33	30
Dry matter intake (kg)*/**	Mean	5088	4822	4769	5401	4385
	SE	92	88	95	73	78
Energy intake (VEM)*/**	Mean	4725	4476	4432	5160	3928
	SE	89	85	92	71	75
Digestible protein intake (kg)*/**	Mean	587	555	552	647	482
	SE	11	11	12	9	9
Milk yield (kg)*/**	Mean	5331	4660	4562	5534	4168
	SE	164	156	170	130	138
Fat %*/**	Mean	3.96	4.22	4.20	4.00	4.26
	SE	0.06	0.06	0.07	0.05	0.05
Protein %*/**	Mean	3.25	3.40	3.49	3.52	3.24
	SE	0.04	0.04	0.04	0.03	0.03
Fat yield (kg)**	Mean	210	195	189	220	176
	SE	6	6	6	5	5
Protein yield (kg)**	Mean	174	159	159	194	134
	SE	5	5	5	4	4
Average body weight (kg)**	Mean	524	511	538	542	506
	SE	8	8	8	6	7
Gain (kg)**	Mean	54	74	74	97	38
	SE	10	9	10	8	8
Final weight (kg)**	Mean	577	571	597	613	550
	SE	10	10	11	8	9

*Significant differences between breeds, $P < 0.05$.
**Significant differences between feed composition groups, $P < 0.05$.

(Figs. 1d and e) between the breeds were significant or almost significant during lactation. The concentrates group reached peak yield (Fig. 1f) in Week 17 (eight weeks after calving) and the roughage group in Week 15. The difference in milk yield between both feed composition groups was most pronounced between Weeks 25 and 38. From six weeks after calving, the difference in milk yield between both feed composition groups was significant. Shortly after calving, the fat and protein yield (Figs. 1g and h) of the roughage group decreased. Later in lactation, these differences became fairly constant and stayed so.


(a)
KVEM
energy intake/day
HF
DRW
DF
week
(b)
KVEM
energy intake/day
concentrates group
roughage group
week
(c)
kg
milk/day
HF
DRW
DF
week
(d)
kg
fat/day
HF
DRW
DF
week
(e)
kg
Protein/day
HF
DRW
DF
week
(f)
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milk/day
concentrates group
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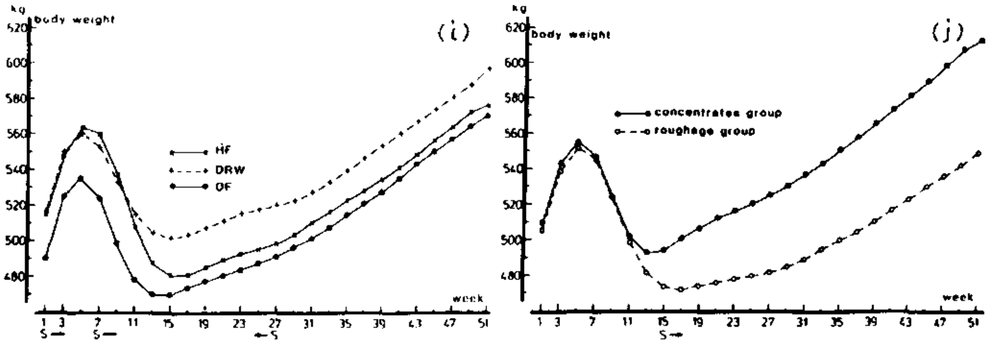

Fig. 1. Energy intake, milk production and body weights for the breeds or the feeding group derived from the smooth curves (see statistical analysis). An "S" at the bottom of a figure means that the differences between the breeds or the feeding groups are significant in those weeks ($P < 0.05$). (a) Energy intake of HF, DRW and DF heifers. (b) Energy intake of the concentrates and the roughage groups. (c) Milk yield of HF, DRW and DF heifers. (d) Fat yield of HF, DRW and DF heifers. (e) Protein yield of HF, DRW and DF heifers. (f) Milk yield of the concentrates and of the roughage groups. (g) Fat yield of the concentrates and of the roughage groups. (h) Protein yield of the concentrates and of the roughage groups. (i) Body weight of HF, DRW and DF heifers. (j) Body weight of the concentrates and of the roughage groups.

At the start of the trial, the breeds differed significantly in body weight: the HF and DRW heifers were heavier than the DF heifers (Fig. 1i). The lowest body weight was reached for all breeds in Week 15 (six weeks after calving). HF heifers decreased more in body weight than DRW heifers. Between Weeks 7 and 27, the differences in body weight between the breeds were significant: the DRW heifers were heavier than the HF and DF heifers. The concentrates group reached its lowest body weight in Week 13 (four weeks after calving) and the roughage group in Week 17 (Fig. 1j). From Week 15 onwards, the concentrates group was significantly heavier than the roughage group as a result of the higher decline in body weight in the roughage group after calving.

Correlations between feed intake, milk yield, body weight and gain

Table IV summarizes the simple residual correlations between characteristics, which were calculated with the model including breeds, feed compositions, batches and breed × feed composition interaction. From Table IV, it can be concluded that heifers with higher milk yield had higher feed intake, gained less during the trial, had lower fat and protein percentages in their milk and had less energy available for gain. Heifers with a higher feed intake produced more milk, were heavier and also had more energy available for gain. The correlation between gain and feed for gain is rather poor (0.51). The error for the feed for gain is high, because it is obtained as a difference between energy intake and energy for maintenance and milk energy. Besides this, feed requirements for gain vary with the composition of the gain.

TABLE IV

Simple residual correlations between feed intake, milk production and body weight characteristics

	2	3	4	5	6	7
1. Energy intake	0.55	−0.03	−0.12	0.47	−0.14	0.58
2. Milk yield (kg)	—	−0.40	−0.53	0.07	−0.70	−0.29
3. Fat (%)		—	0.55	−0.02	0.06	0.10
4. Protein (%)			—	0.02	0.37	0.27
5. Average body-weight (kg)				—	0.27	0.28
6. Gain (kg)					—	0.51
7. Feed for gain						—

TABLE V

The calculated partition of the energy intake (means and percentages) over milk production maintenance and gain per breed and per feed composition group in MJ NE

	Breed						Group			
	HF		DF		DRW		C		R	
	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Intake*/**	32601	100	30884	100	30581	100	35605	100	27105	100
Lactose*/**	4222	13	3691	12	3613	12	4383	12	3301	12
Milk fat**	8014	25	7500	24	7295	24	8476	24	6770	25
Milk protein**	4257	13	3895	13	3906	13	4748	13	3290	12
Milk energy**	16553	51	15086	49	14814	48	17607	49	13361	49
Maintenance**	11668	37	11451	38	11911	40	11980	34	11373	42
Gain**	4380	12	4347	13	3856	12	6018	17	2371	9

*Significant differences between breeds, $P < 0.05$ (means).
**Significant differences between feed composition groups, $P < 0.05$ (means).

The calculated partition of the energy intake over milk yield, maintenance and gain

By definition, 1 kVEM is equal to 6.9 MJ NE. One kg of milk contains on average 48 g lactose, which is equal to 792 kJ NE. One kg of milk fat contains 38.5 MJ NE and one kg of protein 24.5 MJ NE (Kleiber, 1961). One kg metabolic weight needs 293 kJ NE per day for maintenance. From these figures, calculations were made to find out what part of the energy intake (not corrected for feeding level; Van Es, 1975) had to be used for maintenance, what part was represented in the milk and what part was left for gain. Table V gives the partition of the energy intake between milk yield, maintenance and gain by breeds and by feed composition groups. HF heifers used 2% more of their energy intake for milk production than DF heifers and 3% more than DRW heifers. With an equal percentage of energy intake used for milk production and a lower intake level, the roughage group used 8% more of their energy intake for maintenance. Thus, 8% less could be used for gain compared to the concentrates group.

TABLE VI

The calculated partition of the energy intake (in percentages) over milk production, maintenance and gain per breed and per feed composition group in different periods

Partitioned to	Period* (weeks)	Breed			Group	
		HF	DF	DRW	C	R
Maintenance	1–11	53	51	53	50	55
	11–25	35	35	36	30	40
	25–39	34	36	38	32	41
	39–52	34	35	38	31	40
	1–52	37	38	40	34	42
Milk production	1–11	–	–	–	–	–
	11–25	63	59	57	58	61
	25–39	57	54	55	56	54
	39–52	53	49	51	51	51
	1–52	51	49	48	49	49
Gain	1–11	47	49	47	50	45
	11–25	2	6	7	11	–1
	25–39	9	10	7	12	5
	39–52	13	15	11	18	9
	1–52	12	13	12	17	9

*Weeks 1–11: 10 weeks before and around calving. Weeks 11–25: first 98 days of lactation, etc.

Table VI gives the calculated partition of the energy intake in different parts of the experimental period. During lactation the percentage of energy intake used for maintenance was constant within the breeds and within the feed composition groups. The percentage of energy intake used for milk production was highest for HF heifers in Weeks 11–25 and lowest for DF heifers in Weeks 39–52. As a consequence of these facts, the HF heifers used, during lactation, the lowest percentage of energy intake for gain in Weeks 11–25 and the DF heifers the highest percentage in Weeks 39–52. In Weeks 11–25, the roughage group used a higher percentage of energy intake for milk production than the concentrates group, but in Weeks 25–39 it was reversed. The roughage group used body tissues for milk production in Weeks 11–25; the energy intake was less than the sum of the maintenance requirements and the output of milk energy.

DISCUSSION

In this experiment with dairy heifers, no significant breed–feed composition interaction could be found. Significant differences between breeds and between the feed composition groups were found for feed intake and milk production. For all characteristics studied, the ranking of the breeds was the same in both feed composition groups. Differences between the breeds on the concentrates diet were nearly equal to differences on the roughage diet.

In feed intake experiments with dairy cows fed concentrates according to milk yield, Oldenbroek and van Eldik (1980) found a difference in energy intake between HF and DF cows of 6.7% and a difference between DF and DRW cows of 5.4%. In this experiment with heifers fed ad libitum with complete diets, corresponding differences were 5.6% and 1.0%, respectively. Oldenbroek (1984) found that HF heifers fed concentrates according to milk yield produced 10.5% more fat and protein than DF heifers, while DF heifers produced 7.3% more fat than DRW heifers. In the current trial, such differences were 8.5 and 1.4%, respectively. When concentrates were fed according to milk yield, differences in energy intake and milk production seemed to be larger than with ad libitum feeding of complete diets of constant composition during lactation. Korver (1982) found that the differences in milk yield between HF-crossbred and DF cows were larger when concentrates were fed individually according to milk yield as compared to when feeding constant levels of concentrates during different parts of lactation.

From the Fig. 1a, c, d, e, i and from Table VI, it can be concluded that at the start of the lactation the HF and DF heifers produced more milk from body reserves than the DRW heifers. At the end of lactation, the HF and DF heifers had a somewhat higher increase in body weight and had also a higher percentage of energy intake available for gain compared to the DRW heifers. According to Dickerson (1970), the ratio between milk yield and maintenance is the best predictor for the efficiency of milk production. This ratio was highest for the HF heifers and lowest for the DRW heifers. The HF heifers used 51% of their energy intake for milk production and had also the highest energy intake. The DRW and DF heifers used the same amount of the energy intake for milk yield, but the DF heifers had a slightly higher intake.

In the concentrate group, the pH of the rumen was probably more favourable for the synthesis of propionic acid, which led to a lower fat percentage in the milk compared to the roughage group. A high amount of concentrates has a favourable effect on protein percentage in the milk (Tamminga, 1981). The protein percentage in the milk of the roughage group might also have been lower, as a result of underfeeding in early lactation. A dairy cow has a very limited body reserve of protein which can be used for lactation (Tamminga, 1981).

The fall in energy intake in the concentrate group between Weeks 23 and 35 is remarkable and cannot be explained. There was no relationship to the stall temperature, the composition of the concentrates was kept constant and the roughage in the concentrates diet was the same roughage as was offered to the roughage group, which did not show a fall. The fall was seen in all three batches (different year/season).

Another remarkable finding was that an equal proportion of energy intake was used for milk production by both the concentrates group and the roughage group. Due to the lower energy intake level, the roughage group had to use 8% more of the energy intake for maintenance than the concentrates group.

An increase in feed intake level leads to a slightly lower feeding value of the consumed nutrients (Van Es, 1975). Usually, the energy intake (in VEM) has to be corrected by a factor

$$100 - 1.8 \times \frac{\text{VEM intake}}{\text{VEM for maintenance}}$$

It is questionable whether such a correction factor is usable to correct energy intakes of extreme feed composition groups. If this adjustment is applied, the energy intake of the HF, DF and DRW heifers should be 0.7, 0.6 and 0.3% lower, respectively, and for the concentrates and the roughage groups 1.1 and 0.0% lower, respectively. In that case, the HF, DF and DRW heifers used 51, 49 and 49 % of their respective energy intakes for milk yield. The concentrates and the roughage groups would have used 50 and 49%, respectively.

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RESUME

Oldenbroek, J.K., 1984. Holstein Frisonnes, Frisonnes Néerlandaises et Pie Rouges Néerlandaises sur deux rations complètes différant par la proportion de fourragés: performances en première lactation. *Livest. Prod. Sci.*, 11: 401—415 (en anglais).

Des lots de 20 génisses Holstein Frisonnes (HF), 23 Pie Rouges Néerlandaises (DRW) et 20 Frisonnes Néerlandaises (DF) ont reçu une ration complète constituée soit exclusivement de fourrages (mélange d'ensilages d'herbe et de maïs), soit des mêmes fourrages et de concentrés en proportions égales, sur la base de la matière sèche. Cela, de deux mois avant le 1er vêlage jusqu'à 10 mois après.

On n'a pas observé d'interactions significatives entre la race et la composition de la ration pour aucun des caractères.

La consommation d'aliments et la production laitière ont été significativement différentes entre les trois races: 4 725, 4 432 et 4 476 k VEM respectivement pour les HF, DRW et DF; 5 331, 4 562 et 4 660 kg de lait; 3,96; 4,20 et 4,22% de matières grasses, et 3,25; 3,49 et 3,40% de protéines dans le lait.

Il y a eu des différences significatives entre les deux rations de fourrages-concentrés et de fourrages seuls: 5 160 et 3 928 k VEM consommées, 5 534 et 4 168 kg de lait; 4,00 et 4,26% de matières grasses et 3,52 et 3,24% de protéines dans le lait; 5,42 et 5,06 kg de poids vif et 97 et 38 kg de gain de poids respectivement.

Les génisses HF ont utilisé 51% de leur consommation d'énergie pour la production laitière (énergie du lait), les DF 49% et les DRW 48%. Pour les deux rations, 49% de l'énergie consommée ont été utilisés pour la production de lait. En raison de leur consommation d'énergie plus faible, les animaux recevant la ration de fourrages en ont utilisé 8% de plus pour l'entretien que ceux recevant la ration fourrages-concentrés.

KURZFASSUNG

Oldenbroek, J.K., 1984. Untersuchungen zur Erstlaktationsleistung bei Holstein-Friesians, niederländischen Schwarzbunten und niederländischen Rotbunten, die mit zwei Rationen mit unterschiedlichem Raufutteranteil gefüttert wurden. *Livest. Prod. Sci.*, 11: 401—415 (auf englisch).

Drei Gruppen von Färsen, 20 Holstein-Friesians (HF), 23 niederländische Rotbunte (DRW) und 20 niederländische Schwarzbunte (DF), wurden ab dem 2. Monat vor bis zum Ende des 10. Monats nach dem Kalben mit vollwertigen Rationen gefüttert, die einmal nur aus Raufutter (Mischung aus Gras- und Maissilage) bestanden und einmal 50% der Trockensubstanz in Kraftfutter enthielten.

Für keinen der Versuchsparameter wurde zwischen der Rasse und der Futterzusammensetzung eine signifikante Interaktion gefunden.

Die HF-, DRW- und DF-Tiere differierten signifikant zwischen Futteraufnahme und Milchproduktion. Sie verbrachten 4725, 4432 bzw. 4476 kVEM und erzeugten 5331, 4562 bzw. 4660 kg Milch mit 3,96%, 4,20% bzw. 4,22% Fett und 3,25%, 3,49% und 3,40% Protein.

Die Kraftfutter- und Raufuttergruppen differierten signifikant in Futteraufnahme, Milchproduktion, durchschnittlichem Körpergewicht und Zunahmen. Die Mittelwerte für die Kraftfutter- und Raufuttergruppen waren: 5160 und 3928 kVEM, 5534 und 4168 kg Milch, 4,00 und 4,26% Fett, 3,52 und 3,24% Protein, 542 und 506 kg Lebendgewicht sowie 97 und 38 kg Zunahmen.

HF-Färsen verbrauchten 51% ihrer Energieaufnahme für die Milchproduktion (Milchenergie), DF-Färsen 49% und DRW-Färsen 48%. Beide Futtergruppen verbrauchten 49% ihrer Energieaufnahme für Milchproduktion, jedoch brauchte die Raufuttergruppe 8% mehr für die Erhaltung als die Kraftfuttergruppe, als Konsequenz der geringeren Energieaufnahme.

CHAPTER 3

HOLSTEIN FRIESIANS, DUTCH FRIESIANS AND DUTCH RED AND WHITES ON TWO COMPLETE DIETS WITH A DIFFERENT AMOUNT OF ROUGHAGE: PERFORMANCE IN SECOND LACTATION

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HOLSTEIN FRIESIANS, DUTCH FRIESIANS AND DUTCH RED AND WHITES ON TWO COMPLETE DIETS WITH A DIFFERENT AMOUNT OF ROUGHAGE: DIFFERENCES IN PERFORMANCE BETWEEN FIRST AND SECOND LACTATION

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ABSTRACT

Oldenbroek, J.K., 1984. Holstein Friesians, Dutch Friesians and Dutch Red and Whites on two complete diets with a different amount of roughage: differences in performance between first and second lactation. *Livest. Prod. Sci.*, 11: 417–428.

Groups of 11 Holstein Friesian (HF), 11 Dutch Red and White (DRW) and 12 Dutch Friesian (DF) second calved cows were fed a complete diet with only roughage (a mixture of grass- and corn-silage) or the same mixture of roughage with 50% concentrates on a dry matter basis. The animals had participated in the same experiment during their first lactation.

For none of the characteristics was a significant breed—feed composition interaction found. The differences between breeds in feed intake, milk production, body weight and gain were equal with both feed compositions.

The breeds differed significantly in the increase in milk, fat and protein yield from the first to the second lactation. This increase was 902, 194 and 103 kg milk, 46, 16 and 5 kg fat and 27, 1 and 3 kg protein for the HF, DRW and DF animals, respectively. The body weight gain of the concentrates group in the second lactation was much less than in the first lactation.

For the HF animals, 55% of total energy intake was used for milk yield, 37% for maintenance and 8% for gain; corresponding values for the DRW animals were 48, 41 and 11%, respectively, and for the DF animals 44, 37 and 19%, respectively. For the concentrates group, this partition was 51, 36 and 13%, respectively, and for the roughage group 47, 41 and 13%, respectively.

INTRODUCTION

Differences in feeding level do influence milk yield and body weight directly, but effects were also found in later parts of lactation and even in the next lactation (Wiktorsson, 1979). Wiktorsson concluded that feeding levels should be studied long enough (more than one lactation) to assess whether differences in feeding level stabilize.

Holstein Friesian (HF), Dutch Friesian (DF) and Dutch Red and White (DRW) cows, fed ad libitum in their first lactation with a complete diet with

50% concentrates or a complete diet with no concentrates, were also fed these diets in second lactation without a change-over of diet from first to second lactation. Large differences were found between these two feed groups in feed intake, milk yield, body weight gain and final weight in first lactation (Oldenbroek, 1984b). The difference in weight (63 kg) at the end of the first lactation between the concentrates and the roughage group may especially influence feed intake and milk yield in the second lactation.

In this report, the differences in feed intake, milk yield and body weight between the first and the second lactation are described for those animals, which in both lactations were fed either a complete diet with 50% concentrates or a diet with no concentrates. Due to a loss of 29 (out of the 63) animals between first and second lactation, less information is available about breed—feed composition interaction and differences between breeds in the increase in feed intake, milk yield and body weight from first to second lactation. More attention will be paid to these increases from first to second lactation for the concentrates group (C) and the roughage group (R).

LITERATURE

Wiktorsson (1979) concluded that information about feed intake experiments during more than one lactation is very limited. In a study over three lactations with three feeding levels, he found that in the long run, cows regulate their milk production according to feed intake. Differences resulting from different feeding levels arose in first lactation and remained constant through second and third lactations. The difference in body weight after calving between cows at a high or a low feeding level was most pronounced in their first lactation. In later lactations, the ability to mobilize body tissues was very limited for cows at the low feeding level. Broster et al. (1958) concluded that low feeding levels before calving led to a lower milk production after calving due to the cows' limited ability to mobilize body tissues.

In a change-over experiment during two lactations, where cows changed from concentrates levels between lactations, Korver (1982) found that the concentrates level during the first year affected feed intake, milk yield and body weight in the second year. These effects were most pronounced in the first part of the second lactation, and were compensated afterwards.

MATERIALS AND METHODS

The HF, DRW and DF cows calved for the second time in May 1980 (batch 1), in November 1980 (batch 2) and in May 1981 (batch 3). The partition over breeds and feeding groups and the number of sires involved in each breed—feed composition group is given in Table I.

At the end of the first lactation, 28 of the 63 animals, that participated in the experiment during their first lactation, had to leave the experiment. Of these 28 animals, 10 animals were not pregnant (3 HF, 2 DF and 5 DRW)

TABLE I

The distribution of the cows over breeds and feeding groups (number of sires involved in each group in parentheses)

	Breed			Total
	HF	DF	DRW	
Concentrates group	3 (3)	7 (7)	4 (3)	14 (13)
Roughage group	8 (8)	5 (5)	7 (7)	20 (20)
Total	11 (10)	12 (9)	11 (9)	34 (28)

and 18 animals would calve too late (6 HF, 5 DF and 7 DRW) to participate effectively. One DF cow had to be slaughtered after calving due to pelvic paralysis.

On average, the animals calved at the beginning of Week 10. Day 1 is the first day of the dry period prior to the second calving.

The composition of the complete diets was exactly the same as in the first lactation (Oldenbroek, 1984b). The concentrates group received the roughage diet for Weeks 1—8, a diet with 25% concentrates for Weeks 9—11 and from Week 12 onwards, a diet with 50% concentrates. Throughout the experimental period (Weeks 1—52), the concentrates diet contained on average 944 VEM (1 VEM = 6.9 kJ NE) and 121 g dpc and the roughage diet 887 VEM and 108 g dpc (per kg dry matter).

The treatment of the animals in the second year was exactly the same as described by Oldenbroek (1984b) in the first year.

The data from the second lactation and the increases in feed intake, milk production and body weight from first to second lactation were analysed with an analysis of variance model including breeds, feed composition groups, batches and the interaction breed × feed composition group (Oldenbroek, 1984b). Figure 1a—j were constructed in the same way as described in Oldenbroek (1984b).

RESULTS

Differences for the breeds and for the feed composition groups between the second and first lactation

For none of the traits measured in the second lactation was a significant ($P < 0.05$) breed—feed composition interaction detected. Table II summarizes the increases in feed intake, milk production and body weight from first to second lactation for each breed—feed composition group. This detailed information is of little value, because the means have large standard errors. For milk yield, fat yield, protein yield and average body weight the breed—feed composition interaction was significant for the increase from

TABLE II

Mean values of the breed—feed composition groups for the increase in feed intake, milk production and body weight characteristics from first to second lactation (SE is standard error of the means)

		Breed and group					
		HF		DF		DRW	
		C	R	C	R	C	R
Dry matter intake (kg)	Mean	983	637	639	728	−146	586
	SE	342	202	216	274	300	108
Energy intake (kVEM)	Mean	911	542	555	624	−230	466
	SE	336	198	212	269	294	212
Dig. crude protein intake (kg)	Mean	133	63	84	70	−4	50
	SE	39	23	24	31	34	24
Milk yield*	Mean	1510	294	294	−87	−124	512
	SE	320	188	201	256	280	201
Fat yield (kg)*	Mean	70	21	10	0	6	26
	SE	15	9	9	12	13	9
Protein yield (kg)*	Mean	43	12	4	2	−12	15
	SE	12	7	7	9	10	7
Average body weight (kg)*	Mean	103	53	60	73	46	54
	SE	15	9	10	12	13	10
Gain (kg)	Mean	−56	32	−36	16	−81	−18
	SE	31	18	19	24	27	19
Final weight (kg)	Mean	72	60	74	90	30	50
	SE	29	17	18	23	25	18

*Significant interaction breed × feed composition $P < 0.05$.

first to second lactation. Little value should be attached to these interactions, because the number of animals per breed—feed composition group is very low (Table II), and analysis is continued with a study of the principal effects.

Table III summarizes the increase in feed intake, milk production and body weight from first to second lactation per breed and per feed composition group.

The differences between breeds for the increase of feed intake were significant at $P < 0.10$. The increase in feed intake was less for DRW cows than for HF and DF cows. The increase in milk yield was larger for HF than for DF and DRW cows. There was also a tendency for DRW cows to gain less in second lactation than HF and DF cows.

During second lactation, the concentrates group gained 57 kg less than in first lactation, while the roughage group gained 10 kg more in second lacta-

TABLE III

Mean values of the HF, DF and DRW cows and of the concentrates and roughage group for the increase in feed intake, milk production and body weight characteristics from first to second lactation

		Breed			Group	
		HF	DF	DRW	C	R
Number of animals		11	12	11	14	20
Dry matter intake (kg)	Mean	810	684	219	491	650
	SE	196	178	186	166	136
Energy intake (kVEM)	Mean	726	589	118	412	544
	SE	194	174	183	164	134
Dig. crude protein intake (kg)	Mean	89	77	23	71	61
	SE	22	20	21	19	15
Milk yield (kg)*	Mean	902	103	194	560	239
	SE	184	166	174	156	127
Fat yield (kg)*	Mean	46	5	16	28	15
	SE	9	8	8	7	6
Protein yield (kg)*	Mean	27	3	1	11	10
	SE	7	6	6	6	5
Average yield (kg)*	Mean	78	67	50	70	60
	SE	9	8	8	7	6
Gain (kg)**	Mean	−12	−10	−50	−57	10
	SE	18	16	17	15	12
Final weight (kg)	Mean	66	82	40	58	67
	SE	17	15	16	14	12

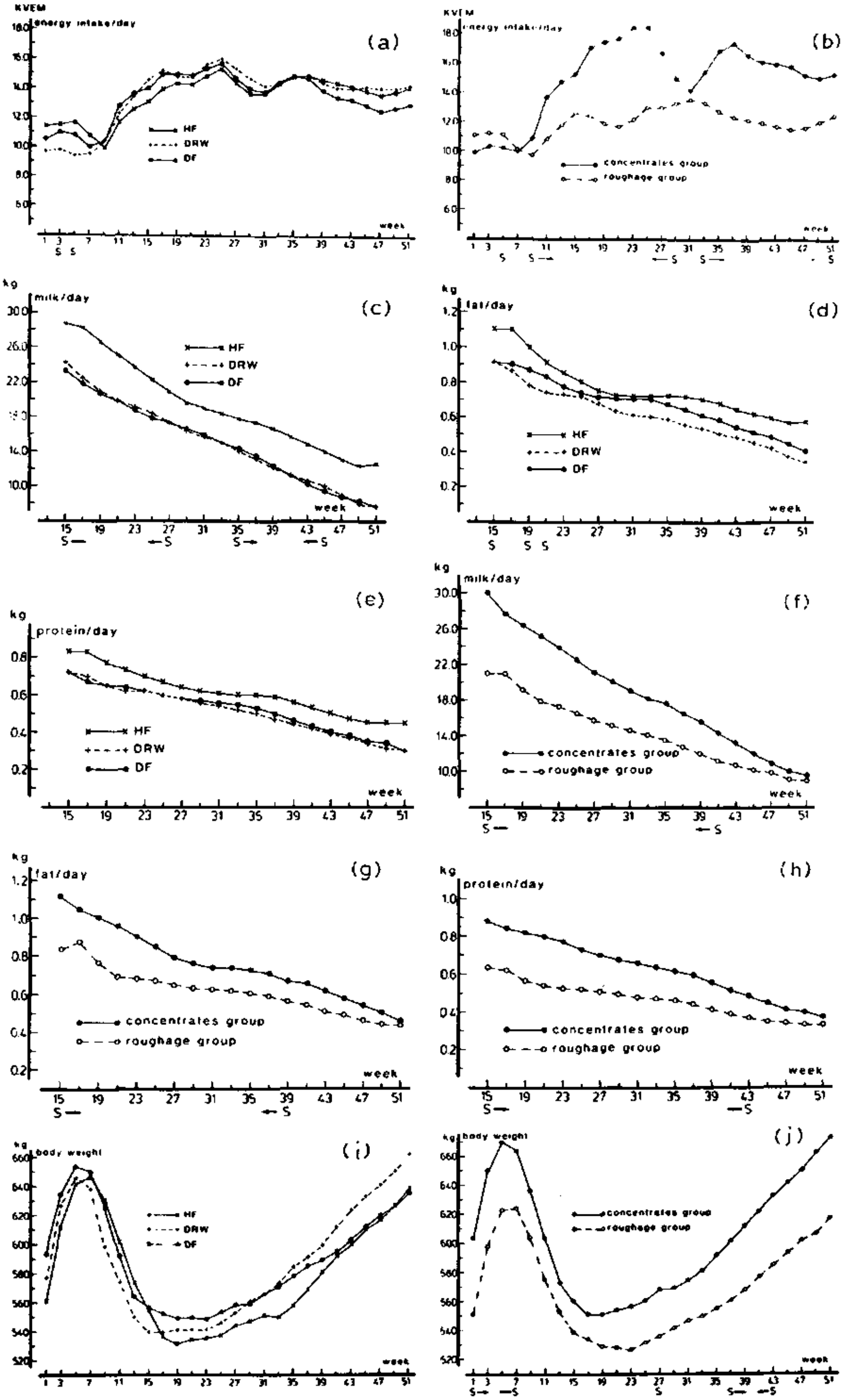
*Significant differences between breeds, $P < 0.05$.
**Significant differences between feed composition groups, $P < 0.05$.

tion than in first lactation. There was a tendency for the increase in feed intake to be larger for the roughage group and for the increase in milk production to be larger for the concentrates group.

Feed intake, milk production and body weight during the second lactation

Figure 1a shows that differences in energy intake between the breeds were significant only in Weeks 3—5 (dry period). (An S at the bottom of the figures means $P < 0.05$.) In these weeks, the HF cows consumed more and the DRW cows less energy than the DF cows. The breeds had the highest intake in Week 25 (15th week of lactation).

The differences between the concentrates and the roughage groups were


(a)
KVEM
energy intake/day
HF
DRW
DF
week
(b)
KVEM
energy intake/day
concentrates group
roughage group
week
(c)
kg
milk/day
HF
DRW
DF
week
(d)
kg
fat/day
HF
DRW
DF
week
(e)
kg
protein/day
HF
DRW
DF
week
(f)
kg
milk/day
concentrates group
roughage group
week
(g)
kg
fat/day
concentrates group
roughage group
week
(h)
kg
protein/day
concentrates group
roughage group
week
(i)
kg
body weight
HF
DRW
DF
week
(j)
kg
body weight
concentrates group
roughage group
week

not significant in Weeks 1, 3, 7 and 31 (Fig. 1b). After calving, the energy intake curve of the roughage group was rather flat. The energy intake of the concentrates group decreased after Week 25 with 4.3 kVEM and increased again in Weeks 31—37.

Figure 1c—h gives milk yield data from Week 15 onwards. In Week 14, the last calving took place. HF cows produced significantly more milk in Weeks 15—27 and 35—45 than DF and DRW cows (Fig. 1c). The breeds differed significantly in fat yield in Weeks 15 and 19—21 (Fig. 1d). During the whole lactation, protein yield (Fig. 1e) for HF cows was slightly (not significantly) higher than protein yield for DF and DRW cows.

The difference in milk yield between the concentrates and the roughage group decreased during lactation (Fig. 1f) and from Week 41 onwards the difference was not significant. From Week 39 onwards, the difference in fat yield (Fig. 1g) was not significant and from Week 43 the difference in protein yield (Fig. 1h) was not significant.

During the whole trial, the difference between breeds in body weight was not significant (Fig. 1i) The difference in body weight between the feeding groups was significant in Weeks 1—7, 27 and 37—43 (Fig. 1j). After calving, the concentrates group increased in body weight earlier (Week 21) than the roughage group (Week 25).

Correlations between feed intake, milk yield, body weight and gain

Within second lactation

Table IV summarizes the simple residual correlations between characteristics, which were calculated with the model including breeds, feed compositions, batches and breed × feed composition interaction. From this table, it can be concluded that cows with a higher feed intake had a higher average body weight and a higher milk yield, but had also more energy available for gain.

Between first and second lactation

Table V gives the simple residual correlations between the first and second lactation in several periods. For feed intake, milk production and body

Fig. 1. Energy intake, milk production and body weights for the breeds or the feeding group derived from the smooth curves (see Oldenbroek, 1984b). An "S" at the bottom of the figure means that the differences between the breeds or the feeding groups are significant in those weeks ($P < 0.05$). (a) Energy intake of HF, DRW and DF second-calved cows. (b) Energy intake of the concentrates and of the roughage groups. (c) Milk yield of the HF, DRW and DF second-calved cows. (d) Fat yield of HF, DRW and DF second calved cows. (e) Protein yield of HF, DRW and DF second-calved cows. (f) Milk yield of the concentrates and of the roughage groups. (g) Fat yield of the concentrates and of the roughage groups. (h) Protein yield of the concentrates and of the roughage groups. (i) Body-weight of HF, DRW and DF second-calved cows. (j) Body weight of the concentrates and of the roughage groups.

TABLE IV

Simple residual correlations between feed intake, milk production and body weight characteristics in second lactation

	2	3	4	5	6	7
1. Energy intake	0.47	0.44	0.53	0.44	0.28	0.83
2. Milk yield (kg)	—	−0.02	0.18	0.17	−0.02	−0.07
3. Fat (%)		—	0.58	0.16	0.19	0.36
4. Protein (%)			—	0.28	0.31	0.41
5. Average body weight (kg)				—	0.53	0.25
6. Gain (kg)					—	0.24
7. Feed for gain						—

TABLE V

Simple residual correlations between first and second lactation in several periods

	Period (weeks)				
	1—52	1—11	11—25	25—39	39—52
Dry matter intake	0.70	0.61	0.39	0.10	0.69
Energy intake	0.67	0.71	0.41	−0.07	0.69
Digestible crude protein intake	0.74	0.60	0.46	−0.03	0.74
Milk yield	0.71	—	0.42	0.73	0.66
Fat yield	0.70	—	0.51	0.47	0.70
Protein yield	0.72	—	0.60	0.71	0.71
Average body weight	0.81	0.62	0.84	0.82	0.82
Gain	0.14	0.48	0.27	0.03	0.57
Final weight	0.71	0.57	0.65	0.73	0.71

weight the correlations were almost equal for the whole experimental period (Weeks 1—52). For milk yield, the correlation was lowest in Weeks 11—25 and for feed intake the correlation was absent in Weeks 25—39.

The calculated partition of the energy intake over milk yield, maintenance and gain

The partition of the energy intake over milk yield, maintenance and gain was calculated in the same way as for the first lactation (Oldenbroek, 1984b). The results are summarized in Table VI. During second lactation, HF cows were most efficient for milk production, while DF cows used the smallest amount of energy intake for milk production. The roughage cows used 4% more of their energy intake for maintenance and 4% less for milk production.

TABLE VI

The calculated partition of the energy intake (means and percentages) over milk production maintenance and gain per breed and per feed composition group in MJ NE

	Breed						Group			
	HF		DF		DRW		C		R	
	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Intake**	35052	100	35182	100	32015	100	37188	100	30978	100
Lactose*/**	4728	14	3800	11	3723	12	4678	13	3490	11
Milk fat*/**	9295	27	7733	22	7905	25	9249	25	7372	24
Milk protein*/**	4676	14	3943	11	3921	12	4859	13	3502	11
Milk energy*/**	18700	55	15475	44	15548	48	18786	51	14363	47
Maintenance**	12648	37	12726	37	12726	41	13026	36	12374	41
Gain	3705	8	6481	19	3740	11	5377	13	4241	13

*Significant differences between breeds, $P < 0.05$ (means).
**Significant differences between feed composition groups, $P < 0.05$ (means).

TABLE VII

The calculated partition of the energy intake (in percentages) over milk production, maintenance and gain per breed and per feed composition group in different periods

		Breed			Group	
Partitioned to	Period* (weeks)	HF	DF	DRW	C	R
Maintenance	1—11	47	49	57	53	49
	11—25	39	36	38	34	41
	25—39	35	34	37	34	37
	39—52	36	36	42	35	41
	1—52	37	37	41	36	41
Milk production	1—11	—	—	—	—	—
	11—25	83	66	68	76	68
	25—39	62	48	54	57	52
	39—52	51	33	42	41	43
	1—52	55	44	48	51	47
Gain	1—11	53	51	43	47	51
	11—25	−22	−2	−6	−10	−10
	25—39	3	18	9	10	11
	39—52	13	31	16	25	16
	1—52	8	19	11	13	13

*Weeks 1—11: 10 weeks before and around calving;
Weeks 11—25: first 98 days of lactation, etc.

In a separate analysis of the differences in efficiency of milk production between first and second lactation, it appeared that HF cows were 2% more efficient, DRW cows 1% more efficient, DF-cows 4% less efficient, C-cows 2% more efficient and R cows 2% less efficient than in first lactation.

Table VII gives the calculated partition of the energy intake in different parts of the experimental period. During lactation, the percentage of energy intake used for maintenance was in general constant for the breeds and for the feed composition groups. The percentage of energy intake used for milk production was highest for HF cows in Weeks 11—25 and lowest for DF cows in Weeks 39—52. As a consequence the HF cows in early lactation used the lowest percentage of energy intake for gain (in fact they mobilized body tissues) in Weeks 11—25 and the DF cows the highest percentage in Weeks 39—52. The decline in the amount of energy intake used for milk production during lactation was sharper for HF and DF cows than for DRW cows. This decline was also sharper for the concentrates group than for the roughage group. During Weeks 11—25 the energy intake of both feeding groups was 10% below the requirements. In Weeks 39—52, the concentrates group had 9% more energy available for gain than the roughage group.

DISCUSSION

In the second lactation, there was no evidence for a breed—feed composition interaction. This agrees with the observations made in the first lactation (Oldenbroek, 1984b). The chances of detecting an interaction during the first lactation were much higher than in the second because of the great loss (29 out of 63) of cows between first and second lactations.

Due to the low number of animals per breed for the second lactation (11—12), the results for the HF, DF and DRW cows are less representative for the respective breeds. For example: in a bigger sample Oldenbroek (1984a) found increases in milk yield for HF, DRW and DF cows from first to second lactation of 777, 561 and 635 kg of milk, respectively. For the DRW and DF cows in this feeding trial especially, these increases were much lower. The increase in feed intake for DRW cows from first to second lactation was less than for HF and DF cows. These facts indicated that HF cows were the most efficient milk producers in second lactation, while DF cows were the least efficient. The lowest efficiency of the DF cows was most affected by the big gap between energy intake and energy requirements in late lactation (Table V). In this context, the efficiency of milk production is the ratio between milk energy output and feed energy intake.

Outside the dry period, the roughage group had to use a larger part of their energy intake for maintenance due to a lower energy intake than the concentrates group. In the first part of the second lactation especially, the efficiency of milk production in the concentrates group was higher than in the roughage group. The C and R groups both had an energy deficiency of 10% in Weeks 11—25, but in absolute terms the C group could mobilize more energy from body tissues. These body tissues seemed to be restored later in lactation (Weeks 39—52).

As in the first lactation (Oldenbroek, 1984b), the intake curve of the roughage group was rather flat. In the same period as in first lactation the concentrates group showed a temporary decrease in energy intake, which cannot be explained.

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RESUME

J.K. Oldenbroek, 1984. Holstein Frisonnes, Frisonnes Néerlandaises et Pie Rouges Néerlandaises sur deux rations complètes différant par la proportion de fourrages: différences entre la première et la deuxième lactation. *Livest. Prod. Sci.*, 11: 417—428 (en anglais).

Des lots de vaches en deuxième lactation, de 11 Holstein Frisonnes (HF), 11 Pie Rouges Néerlandaises (DRW) et 12 Frisonnes Néerlandaises (DF), ont reçu une ration complète constituée soit exclusivement de fourrages (mélange d'ensilages d'herbe et de maïs), soit des mêmes fourrages et de concentrés en proportion égale sur la base de la matière sèche. Les vaches avaient participé à la même expérience au cours de la première lactation.

Aucune interaction entre la race et la composition de la ration n'a été observée. Les différences entre races dans la consommation d'aliments, la production laitière, le poids et le gain de poids ont été les mêmes pour les deux rations.

Il y a eu des différences significatives entre races dans l'augmentation des productions de lait, de matières grasses et de protéines entre la première et la deuxième lactation. Elles ont été de 902, 194 et 103 kg de lait, 46, 16 et 5 kg de matières grasses, 27, 1 et 3 kg de protéines respectivement pour les vaches HF, DRW et DF. Le gain de poids des animaux recevant la ration de fourrages-concentrés a été bien moindre qu'en première lactation.

La répartition de l'énergie ingérée entre la production laitière, l'entretien et le croît au cours de la deuxième lactation a été de 55, 37 et 8% respectivement pour les HF; 48, 41 et 11% pour les DRW et 44, 37 et 19% pour les DF. Cette répartition a été de 51, 36 et 13% et 47, 41 et 13% pour les animaux recevant respectivement la ration de fourrages concentrés et la ration de fourrages.

KURZFASSUNG

Oldenbroek, J.K., 1984. Untersuchungen zu den Leistungsunterschieden zwischen der ersten und zweiten Laktation bei Holstein-Friesians, niederländischen Schwarzbunten und niederländischen Rotbunten, die mit zwei Rationen mit unterschiedlichem Raufutteranteil gefüttert wurden. *Livest. Prod. Sci.*, 11: 417—428. (auf englisch).

Drei Gruppen mit Kühen in der 2. Laktation, 11 Holstein-Friesen (HF), 11 niederländische Rotbunte (DRW) und 12 niederländische Schwarzbunte (DF), wurden mit vollwertigen Rationen gefüttert, die einmal nur aus Raufutter (Mischung aus Gras- und Maissilage) und einmal aus der gleichen Mischung, jedoch mit 50% der Trockensubstanz in Kraftfutter, bestanden. Die Tiere hatten in ihrer 1. Laktation bereits denselben Versuch durchlaufen.

Für keinen Versuchsparameter wurde zwischen der Rasse und der Futterzusammensetzung eine signifikante Interaktion gefunden. Die Unterschiede zwischen den Rassen bezüglich Futteraufnahme, Milchproduktion, Körpergewicht und Zunahmen waren bei beiden Futterzusammensetzungen gleich.

Die Rassen differierten signifikant im Anstieg des Milch-, Fett- und Proteinertrages von der ersten zur zweiten Laktation.

Die Leistung für die HF-, DRW- und DF-Tiere stieg um folgende Werte: Milch: 902 kg, 194 kg bzw. 103 kg; Fett: 46 kg, 16 kg bzw. 5 kg; Protein: 27 kg, 1 kg bzw. 3 kg. Die Gewichtszunahmen der Kraftfuttergruppe waren in der zweiten Laktation viel geringer als in der ersten. Der Energieanteil für Milchleistung, Erhaltung und Zunahmen während der zweiten Laktation betrug für die HF-Tiere 55, 37 bzw. 8%; für die DRW-Tiere 48, 41 bzw. 11% und für die DF-Tiere 44, 37 bzw. 19%. Für die Kraftfuttergruppe betrugen diese Anteile 51, 36 bzw. 13%, und für die Raufuttergruppe 47, 41 bzw. 13%.

CHAPTER 4

THE PERFORMANCE OF JERSEY HEIFERS AND HEIFERS OF LARGER DAIRY BREEDS ON TWO COMPLETE DIETS WITH DIFFERENT ROUGHAGE CONTENTS

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THE PERFORMANCE OF JERSEY HEIFERS AND HEIFERS OF LARGER DAIRY BREEDS ON TWO COMPLETE DIETS WITH DIFFERENT ROUGHAGE CONTENTS

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ABSTRACT

Oldenbroek, J.K., 1986. The performance of Jersey heifers and heifers of larger dairy breeds on two complete diets with different roughage contents. *Livest. Prod. Sci.*, 14: 1—14.

A group of 48 Jersey heifers and a control group of 16 Holstein Friesian (HF), 16 Dutch Friesian (DF) and 16 Dutch Red and White (DRW) heifers were fed ad libitum after calving, a complete diet of roughage (R) or a complete diet of the same roughage with 50% concentrates on a dry matter basis (C). Body weight, milk production and feed intake were recorded in the first 39 weeks of lactation.

For feed intake, milk yield, fat percentage and protein yield a significant breed × diet interaction was found, which was caused by non-equal differences between the breeds on the different diets. Mean differences between the Jersey and the HF + DF + DRW group for the C diet were: -946 kVEM for energy intake; -1791 kg for milk yield; 2.31 for fat percentage; 0.72 for protein percentage; -5 kg for fat yield; and -39 kg for protein yield. The mean differences for the R diet were: -626 kVEM for energy intake; -991 kg for milk yield; 1.84 for fat percentage; 0.56 for protein percentage; 7 kg for fat yield; and -16 kg for protein yield.

Between the Jersey and the HF + DF + DRW group the mean difference in body weight was -164 kg during the trial, and the HF + DF + DRW group had a 38 kg higher body weight gain than the Jersey group.

The biological efficiency for milk production (energy in milk divided by net energy in feed) was 59% for the Jersey group on the C diet, 65% for the Jersey group on the R diet, 55% for the HF + DF + DRW group on the C diet and 56% for the HF + DF + DRW group on the R diet.

INTRODUCTION

In dairy production feed costs determine a great part of production costs. Feed intake should be considered in comparisons of different breeds or genotypes for dairy production (Freeman, 1975). In 1980 a comparison

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of Holstein Friesians (HF), Dutch Friesians (DF) and Dutch Red and Whites (DRW) (Oldenbroek, 1984a) was expanded by buying Jersey cattle in Denmark. A review of the literature (De Rooy, 1980) had pointed out that Jerseys have a low body weight, are efficient producers of butterfat, and due to their lower feed intake it is possible to keep more Jersey animals on a farm than, for example, Friesians. Therefore, in the comparison of Jerseys with the other larger breeds, feed intake experiments with Jerseys were planned.

In reviews of the literature there have been hardly any indications of an interaction between breed or genotype and feeding regimes in dairy cattle: Freeman (1975), Syrstad (1976), Taneja and Rao (1982), Korver (1982) and Oldenbroek (1984b). Only Richardson et al. (1971) found an interaction between progeny group and food ration, in an experiment with 10 Holstein Friesian and 13 Jersey progeny groups, split over a ration of only roughage and a ration of concentrates plus roughage. They found that within the Holstein Friesians the difference between the rations in milk yield was 1400 kg, while this difference within the Jerseys was only 746 kg.

Their findings, and the big difference in body weight and milk composition between the Jerseys and the HF, DF and DRW animals, led to an experiment in which heifers of these breeds were fed ad libitum for the first 39 weeks after calving a complete diet of grass- and corn silage or a complete diet consisting of the same roughage and 50% concentrates on a dry matter basis. A mixed control group of HF + DF + DRW heifers was chosen, because there were not enough animals of one breed available to serve as the control group. The differences in the studied characteristics between HF, DF and DRW heifers (described by Oldenbroek, 1984b) were expected to be relatively small compared to the differences between the Jerseys and these three breeds. In the present study, feed intake, milk production, body weight and efficiency of milk production of the Jersey heifers were compared with those of a mixed control group of HF, DF and DRW heifers on both diets.

MATERIALS AND METHODS

Animals

The heifers used in this experiment calved between October 1981 and March 1982 (Batch 1) and between October 1982 and March 1983 (Batch 2) at an average age of 25 months. After calving the heifers were placed in a pen provided with electronic feeding gates (Calan), which allowed measurement of individual feed intake. The first Tuesday after calving the heifers were weighed after the morning milking. According to this body weight (in Week 0) and according to sire, each breed group (Jersey, HF, DF and DRW) was divided into a concentrates (C) group and a roughage

TABLE I

The distribution of the heifers over breeds and diets (the number of sires involved in each group is given in parentheses)

	Breed				Total
	Jersey	HF	DF	DRW	
Concentrates group	24(11)	8(7)	8(7)	8(6)	48
Roughage group	24(14)	8(7)	8(6)	8(7)	48
Total	48(16)	16(10)	16(10)	16(10)	96

(R) group. The distribution over breeds and diets and the number of sires involved in each subgroup is given in Table I. After this division, the animals began their experimental period the next Wednesday afternoon (beginning of Week 1, on average 6 days after calving). This was possible, because the animals were accustomed to the system within a few days.

Body weight of the heifers was measured once a week after a morning milking. Gain during the experiment was calculated as weight in Week 39 minus weight in Week 1. Once a week, individual milk yield was measured at the afternoon (5.00 p.m.) and at the morning milking (5.00 a.m.). A combined sample of equal parts of afternoon and morning milk was analysed for fat and protein content. The heifers were inseminated from lactation week 8 onwards. Of these heifers, 87 conceived on average in Week 13. The remaining nine did not conceive during the trial.

Complete diets

The concentrates diet (C) consisted of 50% concentrates, 30% grass silage and 20% corn silage on a dry matter basis. The roughage diet (R) consisted of 60% of the same grass silage (about 60% d.m.) and 40% of the same corn silage (about 30% d.m.). The ingredients of the concentrates were kept constant during the whole trial. During milking 1 kg of concentrates per day was offered to the heifers of both diets groups. Salt, vitamins and minerals were added to the R diet in the same amount per kg dry matter as was available in the C diet.

Bi-weekly samples of grass- and corn silage, taken before mixing, were analysed for dry matter. Net energy (VEM* according to Van Es, 1978) was estimated from crude fibre percentage, and digestible crude protein content (d.c.p.) was estimated from crude protein percentage (Van Es, 1978). The mixed C and R diets were sampled bi-weekly and analysed for dry matter content. During the trial the C diet contained on average 968 VEM and 130 g d.c.p., and the R diet 892 VEM and 113 g d.c.p. per kg

*1 VEM = 6.9 kJ NE, 1 kVEM = 6.9 MJ NE.

dry matter. The respective standard deviations for the bi-weekly periods were 24 VEM, 8 g d.c.p., 46 VEM and 14 g d.c.p.

The heifers were offered twice daily a box with a measured amount of feed, which was a little higher than the expected intake. Refusals were fed again and once a week refusals were removed, weighed and discarded. Three times a week, the amount of feed supplied was adjusted to the intake of previous days. In this way, 4.7% of the feed supplied was refused and weighed back.

Analysis of the data

The sampled data were analysed with the following analysis of variance model:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \delta(G_{ijkl} - \bar{G}_i) + e_{ijkl}$$

Where:

Y_{ijkl}	=	observation on animal l from batch k in feed composition group j of breed i;
μ	=	general mean;
α_i	=	effect of breed i, i = 1, 2, 3, 4;
β_j	=	effect of diet group j, j = 1,2;
γ_k	=	effect of batch k, k = 1, 2
$\alpha\beta_{ij}$	=	interaction effect of breed i and diet group j
δ	=	regression of Y on weight in Week 0
G_{ijkl}	=	weight of the lth animal from batch k, diet group j and breed i in Week 0
$\bar{G}_i$	=	average weight of the animals of breed i in Week 0;
e_{ijkl}	=	error term.

Preliminary analyses of variance indicated that the interaction terms $\alpha\gamma_{(ik)}$ and $\beta\gamma_{(jk)}$ were not significant ($P > 0.05$). The regression term δ was used in order to correct for small differences in body weight between the concentrates and the roughage group within the breed groups before the start of the experiment.

Due to the relatively small differences between the HF, DF and DRW heifers and for simplicity of presentation in the tables, the average value of the HF, DF and DRW group is compared with that of the Jersey group.

To illustrate energy intake, milk production and body weight during lactation a "smooth" curve was constructed through the weekly observations of each animal, according to the principles described by Du Chateau et al. (1972). From each animal the value from the smooth curve was taken for each week, and these values were analysed within weeks with an analysis of variance model including the terms α_i, β_j, γ_k and $\alpha\beta_{ij}$ of the previous model. The values for $\alpha\beta_{ij}$ are presented in Figs. 1—5.

RESULTS

Differences between breed × feed composition group

From Table II it can be seen that for feed intake, milk yield, fat percentage and protein yield a significant breed × diet interaction was found. Within the Jersey group the difference in intake between the C and R diet was 622 kg dry matter, while this difference was 893 kg in the HF + DF + DRW group. The difference between the C and R diets for milk yield was 393 kg within the Jersey group and 1193 kg within the HF + DF + DRW group. These differences were for fat percentage + 0.41 and −0.06, respectively, and for protein production 26 and 49 kg, respectively.

From the comparison of the overall standard deviation (σ) and the residual standard deviation (σ_e), it may be concluded that the model explains a relatively higher amount of variation for feed intake characteristics and body weight than for milk production and gain.

TABLE II

Least square mean values of the breed × diet groups for feed intake, milk production and body weight characteristics in Weeks 1—39 and the overall and residual standard deviations

	Breed × diet					
	Jersey		HF+DF+DRW			
	C	R	C	R	σ*	σ_e
Dry matter intake (kg)[3]	3476	2854	4460	3567	685	271
Energy intake (kVEM)[3]	3369	2550	4315	3176	729	254
Dig. crude protein intake (kg)[3]	451	323	579	404	107	38
Milk yield (kg)[3]	3155	2762	4946	3753	1024	463
Fat (g kg^{-1})[3]	66.2	62.1	43.1	43.7	11.2	4.1
Protein (g kg^{-1})[1,2]	41.7	38.1	34.5	32.5	4.2	2.2
Fat yield (kg)[1,2]	207	171	212	164	34	20
Protein yield (kg)[3]	131	105	170	121	31	16
Average body weight (kg)[1,2]	350	324	511	491	90	19
Gain (kg)[1,2]	66	27	96	72	41	32

[1]Significant differences between breeds ($P < 0.05$).
[2]Significant differences between feeding groups ($P < 0.05$).
[3]Interaction breed × feeding group ($P < 0.05$).
σ* = overall standard deviation.

Energy intake, milk production and body weight during lactation

From Fig. 1 it can be seen that during weeks 1—13 energy intake increased in all subgroups and was relatively constant afterwards. It can be concluded from Fig. 2 that during the whole trial the differences in milk

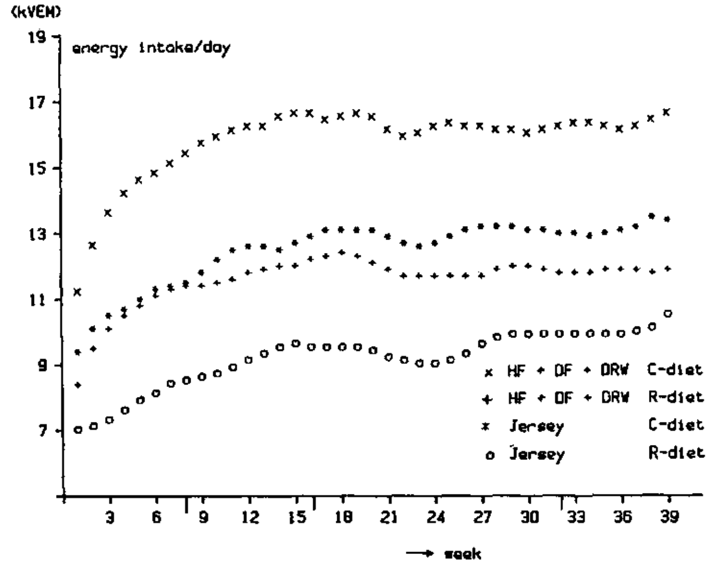

Fig. 1. Energy intake of Jersey and HF + DR + DRW heifers on a concentrates (C) or a roughage (R) diet.

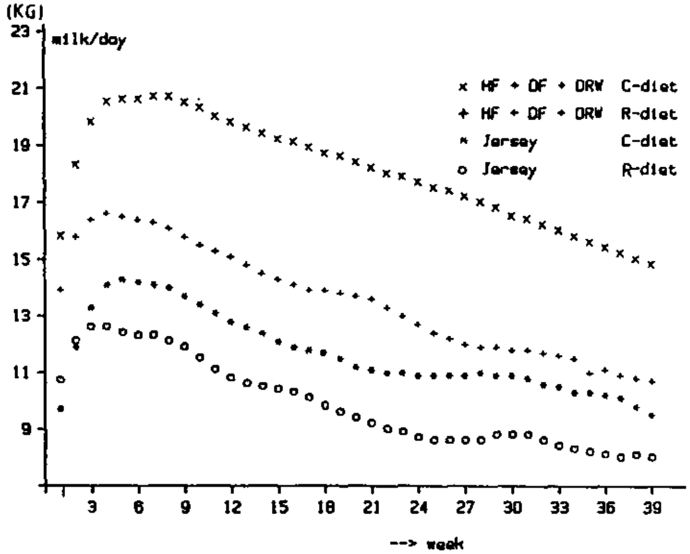

Fig. 2. Milk yield of Jersey and HF + DR + DRW heifers on a concentrates (C) or a roughage (R) diet.

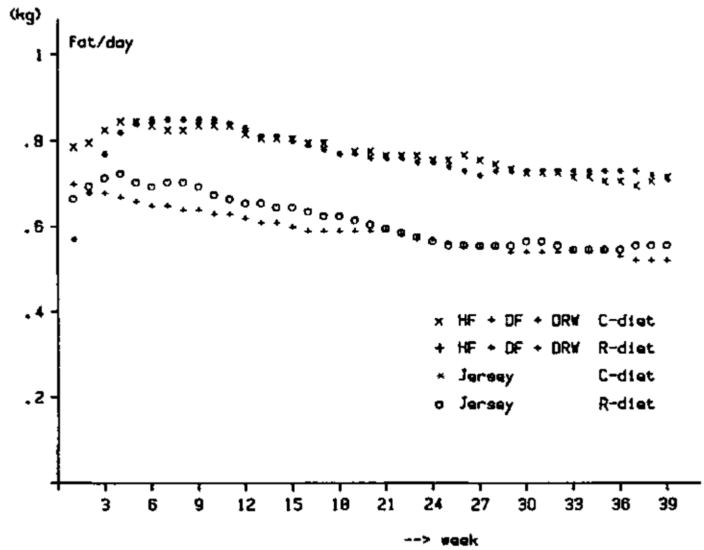

Fig. 3. Fat yield of Jersey and HF + DR + DRW heifers on a concentrates (C) or a roughage (R) diet.

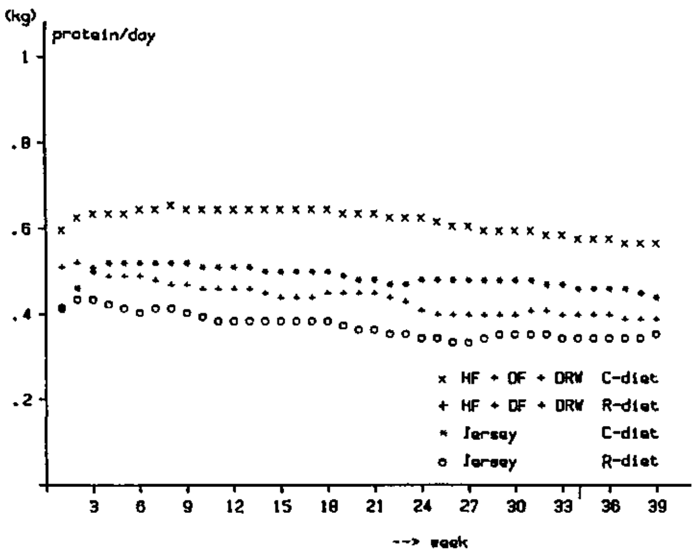

Fig. 4. Protein yield of Jersey and HF + DF + DRW heifers on a concentrates (C) or a roughage (R) diet.

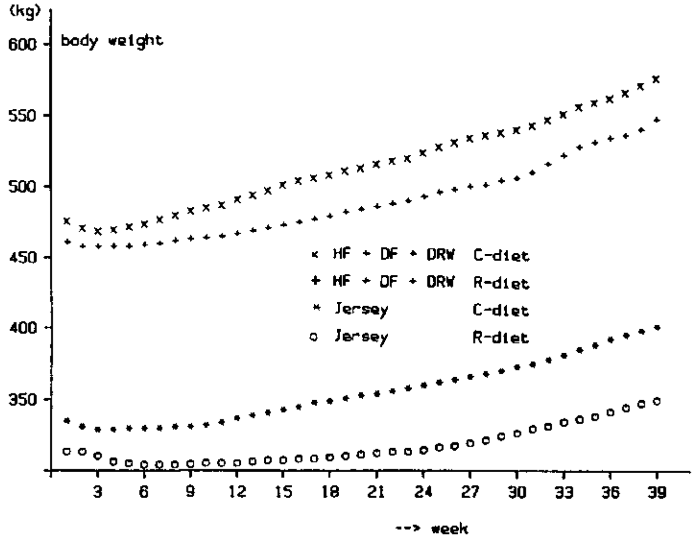

Fig. 5. Bodyweight of Jersey and HF + DR + DRW heifers on a concentrates (C) or a roughage (R) diet.

yield between the C and R diet were smaller within the Jersey group than within the HF + DF + DRW group. Fig. 3 shows that within both diets the Jersey and the HF + DF + DRW group did not differ much in fat yield. Fig. 4 leads to the same conclusions for protein yield as for milk yield (Fig. 2). Fig. 5 shows that the HF + DF + DRW group was already increasing its body weight by 4—5 weeks after calving, but in the Jersey groups weight gain was much later. The low total gain (Weeks 1—39) of the Jersey—R diet group (27 kg) was the result of stable body weight in the first 20 weeks of the trial.

Correlations between feed intake, milk yield, body weight and gain

The simple residual correlations in Table III indicate that heifers with higher milk yield had a higher energy intake, gained less during the trial, had lower fat and protein percentages in their milk and had less energy available for gain. Heifers with a higher feed intake were heavier, produced more milk and had more energy available for gain than heifers with a lower feed intake. Energy for gain (= energy balance) was calculated as energy intake minus energy for maintenance and milk energy. Therefore the error in the estimate of energy for gain is high. Besides this, energy requirements for gain vary with the composition of the gain (Alderman et al., 1982) and the calculation of the gain may be biased by variable gut contents at weighing. These facts result in a rather poor correlation (0.42) between gain and energy left for gain.

TABLE III

Simple residual correlations between feed intake, milk production and body weight characteristics

	2	3	4	5	6	7
1. Energy intake	0.43	-0.08	0.12	0.35	0.22	0.60
2. Milk yield (kg)	—	-0.54	-0.38	-0.19	-0.30	-0.35
3. Fat (%)		—	0.64	0.21	0.13	0.06
4. Protein (%)			—	0.41	0.41	0.17
5. Average body weight				—	0.87	0.35
6. Gain (kg)					—	0.40
7. Energy for gain						—

The calculated partition of energy intake over milk yield, maintenance and gain

In the same way as described by Oldenbroek (1984b) the partition of energy intake over maintenance, milk energy and energy left for gain was calculated in Table IV. On both diets the Jersey heifers used relatively less energy for the estimated lactose production and much more for milkfat production than the HF + DF + DRW heifers. The higher biological efficiency for milk production (milk energy/energy intake) was most pronounced for the Jersey heifers on the roughage diet. On both diets the

TABLE IV

The calculated partition of the energy intake (means and percentages) over milk production, maintenance and gain per breed × diet group in MJ NE

	Breed × feeding group							
	Jersey				HF+DF+DRW			
	C		R		C		R	
	Mean	%	Mean	%	Mean	%	Mean	%
Intake[3]	23245	100	17593	100	29772	100	21912	100
Lactose[3]	2499	11	2188	12	3917	13	2972	14
Milk fat[1,2]	7986	34	6585	37	8153	27	6299	29
Milk protein[3]	3217	14	2576	15	4164	14	2975	14
Milk energy[3]	13701	59	11349	65	16234	55	12247	56
Maintenance[1,2]	6472	28	6101	35	8590	29	8343	38
Gain[1,2]	3072	13	143	1	4947	17	1322	6

[1]Significant differences between breeds ($P < 0.05$).
[2]Significant differences between feeding groups ($P < 0.05$).
[3]Significant interaction breed × feeding group ($P < 0.05$).

TABLE V

The calculated partition of the energy intake (as a percentage) over milk production, maintenance and gain per breed × diet groups in different periods

Partitioned to:	Period (weeks)	Breed × feed composition group			
		Jersey		HF+DF+DRW	
		C	R	C	R
Maintenance	1–13[2,4]	29	38	29	39
	14–26[1,2]	27	34	28	37
	27–39[3]	28	33	30	39
	1–39[3]	28	35	29	38
Milk energy	1–13[3]	69	81	62	67
	14–26[3]	57	62	53	53
	27–39[1,5]	52	54	49	49
	1–39[1,2]	59	65	55	56
Gain	1–13[1,2]	1	-19	8	-7
	14–26[1,2]	16	4	19	10
	27–39[2,4]	20	13	21	12
	1–39[1,2]	13	1	17	6

[1]Significant differences between breeds ($P < 0.05$).
[2]Significant differences between feeding groups ($P < 0.05$).
[3]Significant interaction breed × feeding group ($P < 0.05$).
[4]No significant differences between breeds.
[5]No significant differences between feeding groups.

Jersey heifers had less energy available for gain, and their maintenance requirements were (also relatively) less than those of the HF + DF + DRW heifers.

Table V gives the calculated partition as a percentage of energy intake in three sub-periods and in Weeks 1–39. With respect to energy intake the difference in milk energy between the C and R diets was larger within the Jersey heifers than within the HF + DF + DRW heifers in Weeks 1–13 and Weeks 14–26. Within the Jersey heifers this difference was smaller for maintenance in Weeks 27–39 and Weeks 1–39 than within the HF + DF + DRW heifers.

DISCUSSION

Dickerson (1962) pointed out that in an analysis of variance an interaction between genotype and environment could be caused by a different ranking of the genotypes or by non-equal distances between the genotypes in the different environments. The interactions found in this study between breed and diet were of the latter type. On the roughage diet, the differences between the Jersey and the HF + DF + DRW heifers in feed intake and milk production traits were smaller (with an exception for fat %) than on the concentrates diet.

These results agree with the findings of Richardson et al. (1971), indicating a much smaller difference in milk yield between Jersey and Holstein Friesians on a roughage diet. In the same period the differences between the C and R diet within the HF + DF + DRW group were in agreement with differences between the C and R diets found in an earlier experiment without Jerseys (Oldenbroek, 1984c). In application the interaction for feed intake has no great impact. On the C diet the HF + DF + DRW group consumed 28% more dry matter than the Jersey group, while this difference was 25% on the R diet. For milk yield (and lactose yield) these differences (respectively, 57 and 36%) were much more pronounced. But due to a much bigger difference between the breed groups in fat percentage on the C diet, there was no breed—diet interaction for fat yield. The interaction for protein yield is quantitatively meaningful: on the C diet the breed groups differed by 30% and on the R diet by 15%. On the roughage diet the Jerseys produced more protein than the HF + DF + DRW heifers from a fixed amount of feed, while this result was reversed on the concentrates diet.

It is notable that on the C diet the Jersey heifers produce relatively more fat than on the R diet. In most studies in the literature a higher concentrates/roughage ratio has led to a lower fat percentage and a higher protein percentage in the milk (Macleod et al., 1984). A higher concentrates/roughage ratio promotes a higher propionic acid/acetic acid ratio in the rumen. Propionic acid can be used for lactose production. With sufficient propionic acid available, there is less need for protein to be used for lactose production. This may be the reason for a higher protein percentage on the C diets (Tamminga, 1981). Probably the production capacity of the Jersey group on the C diet for milk (lactose) was too limited to use the higher propionic acid produced in the rumen.

From Table V and Fig. 5 it can be seen that the groups on the C diet (and especially the HF + DF + DRW group) could gain again soon after calving. The groups on the R diet, especially the Jersey group, had a negative energy balance in the first part of lactation. Bines (1982) pointed out that concentrate-rich diets may result in a higher production of propionic acid in the rumen, which after absorption increases the production of insulin by the pancreas and which probably decreases the production of growth hormone. This will divert nutrients to body tissues rather than to milk yield, while an increase of growth hormone results in a net mobilisation of fatty acids. Relating body weight to energy balance is difficult, because the energetic composition of gain (or loss) may vary considerably (Alderman et al., 1982). The comparison of the body weight gain between the breed groups is complicated by the prospective differing rates of growth and composition of weight gains between breeds of different mature sizes.

The simple residual correlations between average body weight (and gain) and the feed intake and milk production characteristics differ from those found in a former study (Oldenbroek, 1984b). In the former study body weight before and around calving was also used to calculate average body weight (and gain).

On both diets the Jersey groups produced milk (energy) more efficiently than the HF + DF + DRW groups, mainly due to a more favourable ratio between milk production and body weight for the Jerseys. Usually, the VEM intake has to be corrected for the relative feeding level (Van Es, 1978). It is questionable whether to use such a correction in this experiment. Quite a difference in feed composition existed between the diets, and the breed groups differed in relative feed intake (capacity): the ratio between feed intake and body weight. If the correction according to Van Es (1978) is applied, the ratio between milk energy and energy intake was 60% for the Jerseys on the C diet, 65% for the Jerseys on the R diet and, respectively, 55 and 56% for the HF + DF + DRW group on the C and R diets. This correction only influences the level of the efficiency and does not influence substantially the differences between the experimental groups.

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RESUME

Oldenbroek, J.K., 1986. Performances des primipares des races jersey ou de plus grand format avec deux rations complètes contenant des proportions differéntes de fourrages. *Livest. Prod. Sci.*, 14: 1–14 (en anglais).

Un groupe de 48 primipares Jersey et un groupe témoin de 16 primipares de chacune des trois races Holstein Friesian (HF), Frisonnes néerlandaises (DF) et Pie rouge néerlandaises (DRW), ont reçu ad libitum après le vêlage une ration complète de fourrages (R) ou une ration complète composée du même fourrage et d'aliments concentrés (C) en proportions égales dans la matière sèche. On a enregistré le poids vif, la production laitière et la quantité d'aliments ingérée au cours des 39 premières semaines de lactation.

On a observé une interaction significative entre race et ration en ce qui concerne la quantité ingérée, la production de lait et protéines et le taux butyreux. En effet, les différences moyennes entre les Jersey et le groupe HF + DF + DRW n'ont pas été identiques avec les deux rations. Avec la ration C, elles ont été de – 946 kg VEM pour l'énergie ingérée, –1791 kg pour la quantité de lait, 2.31 pour le taux butyreux, 0.72 pour la teneur du lait en protéines, –5 kg pour la production de matières grasses et – 39 kg pour la production de protéines. Les valeurs correspondantes pour la ration R ont été : – 626 k VEM, – 991 kg, 1.84, 0.56, 7 kg et – 16 kg.

Les Jersey ont eu un poids vif moyen inférieur de 164 kg au groupe HF + DF + DRW et un gain de poids inférieur de 38 kg au cours de l'essai.

L'efficacité biologique pour la production laitière (énergie du lait/énergie nette ingérée) a été de 59 % avec la ration C et de 65 % avec la ration R pour les Jersey, au lieu de 55 et 56 % respectivement pour le groupe HF + DF + DRW.

KURZFASSUNG

Oldenbroek, J.K., 1986. Leistung von Jersey-Färsen und Färsen grösserer Milchrassen bei zwei vollständigen Rationen mit unterschiedlichen Rauhfutteranteilen. *Livest. Prod. Sci.*, 14: 1–14 (auf englisch).

Einer Gruppe von 48 Färsen der Rasse Jersey sowie einer Kontrollgruppe von je 16 Färsen der Rassen HF, DF und niederländische Rotbunte (DRW) wurden nach der Kalbung eine vollständige Ration aus Rauhfutter ad libitum (R) oder eine vollständige Ration aus denselben Rauhfutterkomponenten, jedoch mit 50% Kraftfutteranteil auf

Trockensubstanzbasis (C) vorgelegt. In den ersten 39 Wochen der Laktation wurden Körpergewicht, Milchleistung und Futteraufnahme erfasst.

Für die Merkmale Futteraufnahme, Milchmenge, Fettprozent und Eiweissmenge zeigte sich ein signifikanter Einfluss der Interaktion Rasse × Ration, der durch ungleiche Differenzen zwischen Rassen auf die verschiedenen Rationstypen verursacht wurde. Zwischen der Gruppe der Jersey-Färsen und der Gruppe der HF-, DF- und DRW-Färsen konnten folgende mittlere Differenzen festgestellt werden:

		Ration C	Ration R
Energieaufnahme (kVEM)	:	-946	-626
Milchmenge (kg)	:	-1791	-991
Fett (%)	:	2.31	1.84
Eiweiss (%)	:	0.72	0.56
Fettmenge (kg)	:	-5	7
Eiweissmenge (kg)	:	-39	-16

Zwischen den beiden Gruppen war die mittlere Differenz hinsichtlich des Körpergewichtes: -164 kg während des Versuches; die Gruppe der HF-, DF- und DRW-Färsen wies eine um 38 kg höhere Gewichtszunahme gegenüber der Gruppe der Jersey-Tiere auf. Die biologische Wirksamkeit der Rationen im Hinblick auf die Milchproduktion (Energie in der Milch/Nettoenergie im Futter) war in der Gruppe der Jersey-Färsen: 59% bei Verfütterung der C-Ration sowie 65% bei Verfütterung der R-Ration und in der Gruppe der HF-, DF- und DRW-Färsen: 55% bei Verfütterung der C-Ration sowie 56% bei Verfütterung der R-Ration.

CHAPTER 5

THE PERFORMANCE OF JERSEY COWS AND COWS OF LARGER DAIRY BREEDS ON TWO COMPLETE DIETS WITH DIFFERENT ROUGHAGE CONTENTS

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The Performance of Jersey Cows and Cows of Larger Dairy Breeds on Two Complete Diets with Different Roughage Contents

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ABSTRACT

Oldenbroek, J.K., 1988. The performance of Jersey cows and cows of larger dairy breeds on two complete diets with different roughage contents. *Livest. Prod. Sci.*, 18: 1-17.

A group of 38 Jersey cows and a control group of 12 Holstein Friesian (HF), 12 Dutch Friesian (DF) and 10 Dutch Red and White (DRW) cows were fed, after their third calving, a complete diet of roughage (R) or a complete diet of the same roughage with 50% concentrates on a dry matter basis (C). Body weight, milk production and feed intake were recorded during the first 39 weeks of lactation. All cows had already participated in this experiment in their first lactation on the same diets.

For the characteristics studied, the differences between the breeds on both diets were not equal. However, only for fat percentage was a significant breed × diet interaction found. Mean differences between the Jersey and the HF + DF + DRW group for the C diet and for the R diet (in parentheses) were −936 (−748) kVEM (1 kVEM = 6.9 MJ NE) for energy intake; −2560 (−1707) kg for milk yield; +2.82 (+2.38) for fat percentage; +0.83 (+0.77) for protein percentage; +3 (+23) kg for fat yield; −55 (−26) kg for protein yield; −199 (−216) kg for average body weight; −57 (−27) kg for weight gain. From first to third lactation, energy intake and milk yield for the Jerseys and the HF + DF + DRW increased in the C diet groups by 25 and 24%, respectively, and in the R diet groups by 48 and 51%, respectively.

The biological efficiency for milk production (energy in milk divided by net energy in feed) was 57% for the Jersey group on the C diet, 69% for the Jersey group on the R diet, 56% for the HF + DF + DRW group on the C diet and 61% for the HF + DF + DRW group on the R diet.

INTRODUCTION

In an earlier study (Oldenbroek, 1986), a group of 48 (Danish) Jersey heifers and a control group of 16 Holstein Friesian (HF), 16 Dutch Friesian (DF) and 16 Dutch Red and White (DRW) heifers were fed ad libitum a complete

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roughage diet (R) or a complete diet with 50% concentrates (C). In the first 39 weeks of lactation, a significant breed×diet interaction was found for feed intake, milk yield, percentage fat and protein yield, which was caused by non-equal differences between the breeds on the two diets. It could be concluded that the biological efficiency (energy in milk/net energy in feed) of the Jersey heifers was higher by 5% on the C diet and by 9% on the R diet than the biological efficiency of the HF+DF+DRW heifers.

For several reasons, differences in feed intake among cows of different breeds may not be simply derived from differences established among heifers. Bergström (1978) found that Jerseys reach their low mature body weight sooner than the larger dairy breeds (HF+DF+DRW). Kristenson and Ingvartson (1985) concluded that, in dairy cattle, differences in age are related to differences in body weight and milk yield, but these differences do not fully explain the differences in feed intake between age groups. Live body weight and milk yield predict voluntary intake of heifers more precisely than that of cows (Forbes, 1986).

These facts and the breed×diet interaction mentioned above were reasons to measure feed intake in the third lactation of Jersey cows and a control group of HF+DF+DRW cows, which also participated in the former study (Oldenbroek, 1986) as heifers. Their performance was studied on two complete diets with a different amount of roughage fed ad libitum. In the third lactation, each cow was fed the same type of ration as in the first lactation.

The results of this feed intake study in the third lactation are presented and discussed, and compared with the results of the same cows as heifers. The differences between the breeds in the efficiency of milk production on the two diets are calculated. Correlations among traits within and between lactations are given and differences in feed intake are related to differences in milk yield, body weight and body weight gain.

MATERIALS AND METHODS

Animals

The cows used for this experiment calved between September 1983 and February 1984 (Batch 1) and between October 1984 and June 1985 (Batch 2). The distribution over breeds and diets and the number of sires involved in each sub-group are given in Table I. The numbers of sires within sub-groups were as high as practicable in order to get a good representation for the breeds in the experimental groups. After calving, the cows were placed in a pen equipped with electronic feeding gates (Calan), which allowed measurement of individual feed intake. For 39 weeks each cow received ad libitum the same diet as in its first lactation. In their second lactation, these cows were fed ad libitum the concentrates diet during the indoor period and ad libitum grass plus 1 kg con-

TABLE I

The distribution of the cows over breeds and diets (the number of sires involved in each group is given in parentheses)

	Breed				Total
	Jersey	HF	DF	DRW	
Concentrates group	16 (8)	5 (5)	7 (6)	5 (5)	33
Roughage group	22 (13)	7 (6)	5 (5)	5 (5)	39
Total	38 (14)	12 (8)	12 (8)	10 (8)	72

centrates daily during the pasture period. Treatment and measurements during the third lactation were made as in the first lactation (Oldenbroek, 1986). The cows were inseminated from Lactation Week 7 onwards. Ten cows did not conceive during the trial. The remaining 62 conceived on average in Week 13.

Complete diets

The concentrates diet (C) consisted of 50% concentrates, 30% artificially dried grass and 20% corn silage on a dry matter (DM) basis. The roughage diet (R) consisted of 60% of the same dried grass ($\sim$90% DM) and 40% of the same corn silage ($\sim$30% DM). The ingredients of the concentrates were kept constant during the whole trial in the two batches. Rations were mixed daily and for the two diets roughages from the same batches were used. The concentrates contained 4.7% crude fat, 11.6% crude fibre, 17.8% crude protein and 17.7% starch and sugars. Feed supply, sampling of feedstuffs and calculation of feed intake characteristics were similar to those in the first lactation (Oldenbroek, 1986). During the trial, the C diet contained, on average, 971 VEM and 144 g digestible crude protein (DCP) and the R diet contained 889 VEM and 135 g DCP per kg dry matter. The respective standard deviations for bi-weekly periods were 21 VEM, 7 DCP, 34 VEM and 12 DCP.

Analysis of the data

The sampled data were analysed with the following analysis of variance model:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + e_{ijkl}$$

where:

Y_{ijkl} = observation on animal l from Batch k on Diet j of Breed i;

μ = general mean;
α_i = effect of Breed i, $i=1, 2, 3, 4$;
β_j = effect of Diet j, $j=1, 2$;
γ_k = effect of Batch k, $k=1, 2$;
$\alpha\beta_{ij}$ = effect of interaction between Breed i and Diet j;
e_{ijkl} = error term.

Preliminary analyses of variance indicated that this model was appropriate. The remaining two factor interaction terms and regression within breeds on body weight after calving (used in the former study: Oldenbroek, 1986) were not significant ($P>0.05$).

Multiple regression of energy intake on milk energy, maintenance and gain was performed to study any differences between breeds and between diets in intercepts and regression coefficients (Oldenbroek, 1984c).

Owing to relatively small differences in feed intake, milk yield and body weight between the HF, DF and DRW animals, the absence of a breed×diet interaction within this group (Oldenbroek, 1984a, b) and for simplicity of presentation in the tables and in the figures, the average values of the HF, DF and DRW groups are compared with those of the Jersey group. Figures 1–5 were constructed in the same way as in the first lactation (Oldenbroek, 1986).

RESULTS

Breed×diet interaction in the third and previous lactations

Table II gives the least square means for the measured traits in Weeks 1–39 of the third lactation. From Table II, it can be seen that only for fat concentration was a significant breed×diet interaction found. The difference between the C and R diets for fat concentration was +0.23% within the Jersey group and −0.21% within the HF+DF+DRW group. The P values of the interaction terms for milk yield and protein yield were 0.06 and 0.12, respectively. The difference between the C and R diets for milk yield was −210 kg within the Jersey group and +643 kg within the HF+DF+DRW group. For protein yield, these differences were −7 kg and +22 kg, respectively. For the remaining traits, the interaction terms were far from being significant.

Table III is a summary of feed intake, milk production and body weight in the first lactation and of milk production in the second lactation of all animals which were involved in this feed intake study during their third lactation. A comparison of the first lactation data of these animals with the data of all heifers (Oldenbroek, 1986) reveals that the loss of animals between the first and third lactation was not related to the characteristics studied. Milk production characteristics in the second lactation were only significantly influenced by breed and not significantly by diet in the first lactation.

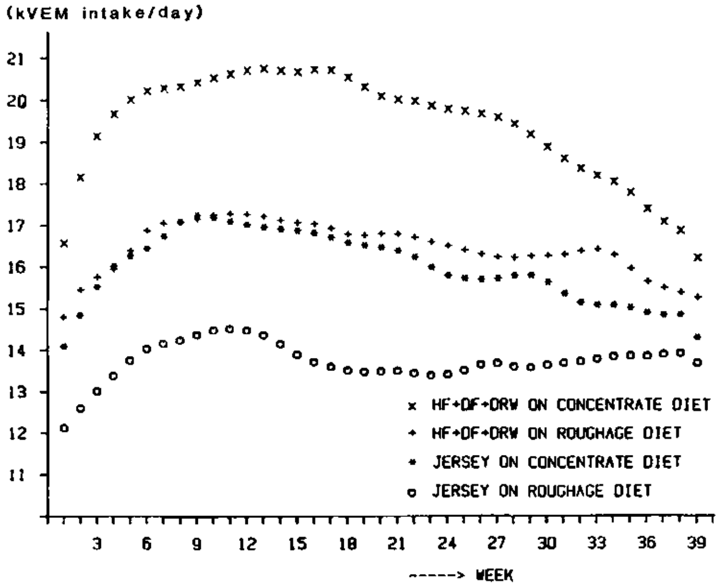

Fig. 1. Energy intake of Jersey and HF+DF+DRW cows on a concentrates (C) or a roughage (R) diet.

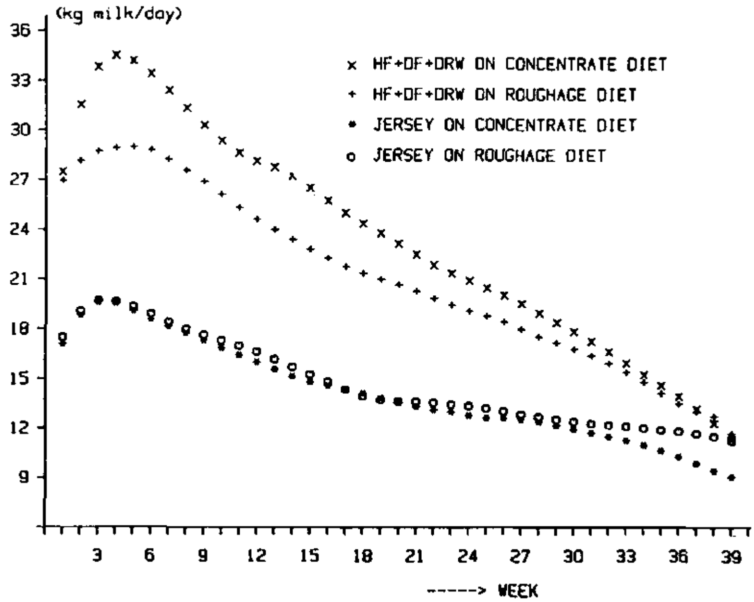

Fig. 2. Milk yield of Jersey and HF+DF+DRW cows on a concentrates (C) or a roughage (R) diet.

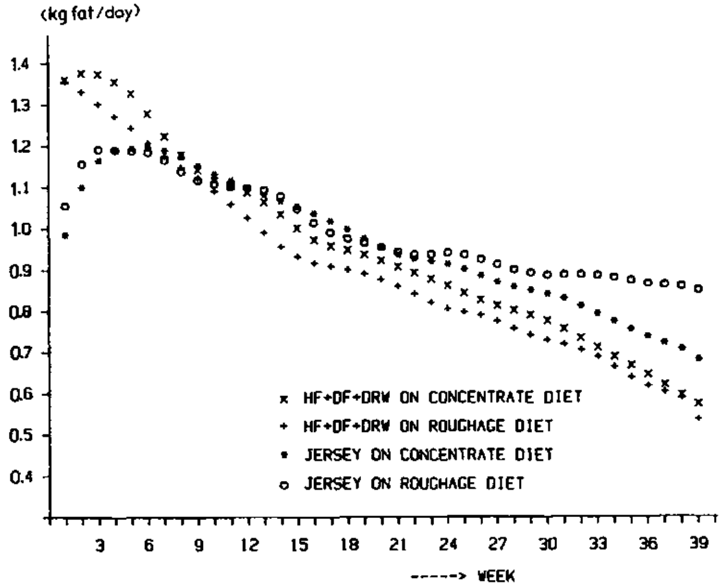

Fig. 3. Fat yield of Jersey and HF+DF+DRW cows on a concentrates (C) or a roughage (R) diet.

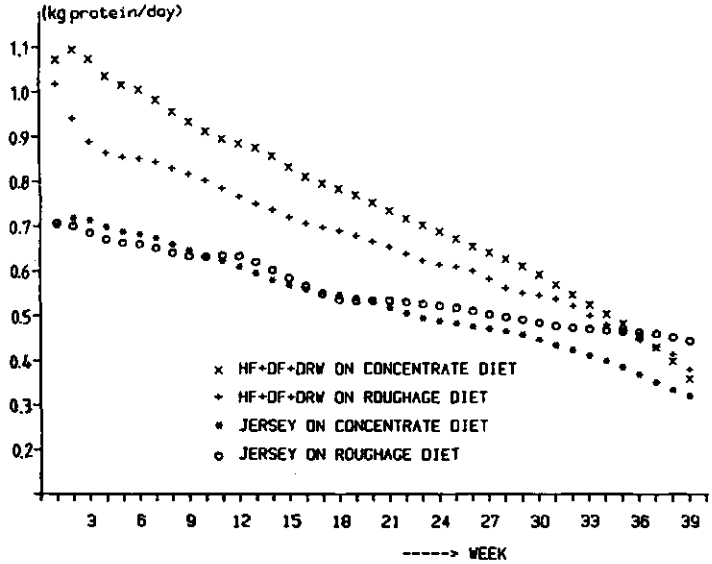

Fig. 4. Protein yield of Jersey and HF+DF+DRW cows on a concentrates (C) or a roughage (R) diet.

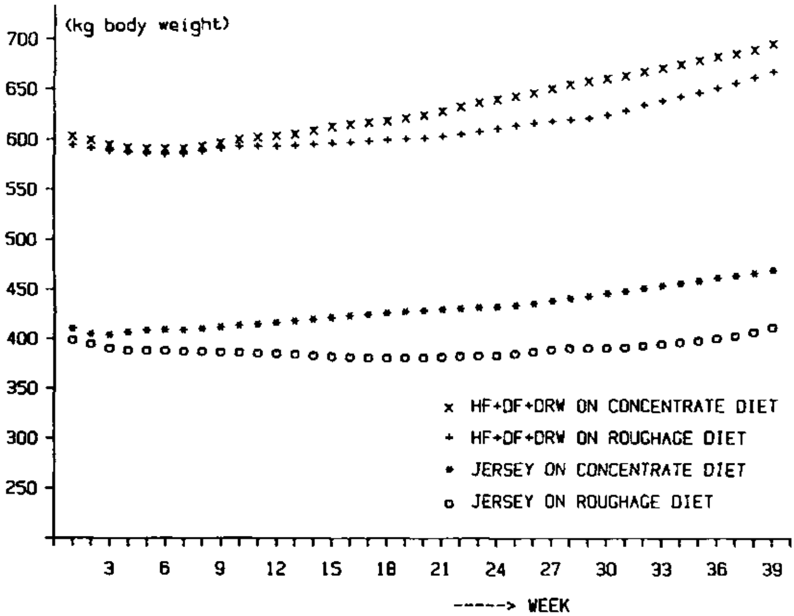

Fig. 5. Body weight of Jersey and HF+DF+DRW cows on a concentrates (C) or a roughage (R) diet.

TABLE II

Least square means of the breed×diet groups for feed intake, milk production and body weight characteristics in Weeks 1–39 of the third lactation and overall and residual standard deviations

	Jersey		HF + DF + DRW		σ^*	σ_e
	C	R	C	R		
Dry matter intake (kg)[1,2]	4476	4207	5466	5018	672	466
Energy intake (kVEM)[1,2]	4367	3764	5303	4512	715	447
Digestible crude protein intake (kg)[1,2]	649	561	786	679	109	70
Milk yield (kg)[1,2]	3872	4082	6432	5789	1436	862
Fat concentration (g kg^{-1})[3]	69.1	66.8	40.9	43.0	13.7	4.1
Protein concentration (g kg^{-1})[1]	42.1	41.5	33.8	33.8	4.6	2.1
Fat yield (kg)[1]	264	272	261	249	46	43
Protein yield (kg)[1]	162	169	217	195	38	30
Average body weight (kg)[1,2]	433	396	632	612	115	40
Weight gain (kg)[1,2]	65	21	92	78	44	33
Body weight after calving (kg)[1]	405	401	607	591	108	44

[1]Significant differences between breeds ($P<0.05$).
[2]Significant differences between diet groups ($P<0.05$).
[3]Significant interaction breed×diet group ($P<0.05$).
σ^*=Overall standard deviation; σ_e=residual standard deviation; C=concentrates group; R=roughage group; 1kVEM=6.9 MJ NE.

TABLE III

Least square means of breed × diet groups for feed intake, milk production and body weight characteristics in the first lactation and for milk production characteristics in the second lactation in Weeks 1–39 and overall and residual standard deviations

	Jersey		HF + DF + DRW		σ^*	σ_e
	C	R	C	R		
First lactation						
Energy intake (kVEM)[3]	3388	2504	4348	3109	753	305
Milk yield (kg)[3]	3190	2726	5078	3810	1063	507
Fat concentration ($g\ kg^{-1}$)[3]	66.4	62.0	42.3	43.5	11.5	4.2
Protein concentration ($g\ kg^{-1}$)[1,2]	41.9	38.0	34.4	31.8	4.3	2.2
Average body weight (kg)[1,2]	352	317	518	475	90	30
Weight gain (kg)[1,2]	63	30	98	70	41	31
Body weight after calving (kg)[1,2]	329	318	483	455	82	34
Second lactation[a]						
Milk yield (kg)[1]	3533	3550	5353	5038	1179	753
Fat concentration ($g\ kg^{-1}$)[1]	70.5	70.7	43.9	45.6	13.9	4.8
Protein concentration ($g\ kg^{-1}$)[1]	41.1	42.2	33.9	34.3	4.4	2.1
Body weight after calving (kg)[1,2]	381	366	570	530	100	38

[1]Significant differences between breeds ($P<0.05$).
[2]Significant differences between diet group ($P<0.05$).
[3]Significant interaction breed × diet group ($P<0.05$).
[a]For treatment in second lactation see Materials and methods (animals).
σ^* = Overall standard deviation; σ_e = residual standard deviation; C = concentrates group; R = roughage group.

TABLE IV

Residual correlations between feed intake, milk production and body weight characteristics in Weeks 1–39 of the third lactation

	2	3	4	5	6	7	8
1. Energy intake (kVEM)	0.67	−0.16	−0.05	0.12	−0.28	0.37	0.18
2. Milk yield (kg)		−0.45	−0.41	−0.24	−0.61	−0.35	0.10
3. Fat concentration ($g\ kg^{-1}$)			0.61	0.27	0.30	0.04	0.12
4. Protein concentration ($g\ kg^{-1}$)				0.24	0.36	0.23	0.04
5. Average body weight (kg)					0.23	0.14	0.83
6. Gain (kg)						0.37	−0.19
7. Energy for gain (kVEM)						—	−0.08
8. Body weight after calving (kg)							—

Correlations $\geqslant |0.23|$ are significantly different from zero ($P<0.05$).

The increase in energy intake from the first to third lactation on the C diet was 29% for the Jersey cows and 22% for the HF + DF + DRW cows. On the R diet, these increases were 50% and 45%, respectively. The increase for milk yield on the C diet was 21% for the Jersey cows and 27% for the HF + DF + DRW cows. On the R diet, these increases in milk yield were 50% and 52%, respectively. The increases in body weight from the first to third lactation were 23% for the Jersey–C diet group, 25% for the Jersey–R diet group, 22% for the HF + DF + DRW–C diet group and 29% for the HF + DF + DRW–R diet group.

Energy intake, milk production and body weight during the third lactation

Figures 1–5 describe energy intake, milk production and body weight during the third lactation. From Fig. 1, it can be seen that energy intake increased during Weeks 1–10 in all groups. It was relatively constant in the R diet groups afterwards. Energy intake declined in the C diet groups after Week 20. From Fig. 2, it can be concluded that within the HF+DF+DRW group the difference in milk yield between the C and R diet was established mainly in the first half of lactation. Figure 3 shows that in the first 8 weeks of lactation, fat yield was higher for the HF+DF+DRW groups, while after Week 10, fat yield was higher for the Jersey groups. Figure 4 leads to the same conclusions for protein yield as for milk yield (Fig. 2). Figure 5 shows that the C diet groups (especially the Jersey group) were already increasing their body weight soon after calving, while the R diet groups (especially the Jersey group) increased their body weight much later.

Correlations between feed intake, milk yield, body weight and gain in the third lactation

The residual correlations presented in Table IV indicate that milk yield is negatively correlated to energy available for gain (energy balance) during the trial. Energy intake is positively correlated to energy available for gain. Body weight 10 days after calving was positively related to milk yield and negatively to energy available for gain, while average body weight was negatively related to milk yield and positively to energy available for gain. The correlations in the third lactation show close similarity with those in the first lactation (Oldenbroek, 1986).

Multiple regression from energy intake on milk energy, maintenance and gain, as described by Oldenbroek (1984c), led to a multiple correlation of 0.86 and a residual standard error of 2533 MJ NE. Regression coefficients had realistic values (Van Es, 1978): 1.0 MJ NE for milk energy (SE 0.09 MJ NE), 0.348 MJ NE kg^{-1} metabolic weight day^{-1} (SE 0.071 MJ NE) and 30 MJ NE for 1 kg body weight gain (SE 10 MJ NE). Using a different intercept for the

TABLE V

Residual correlations between energy intake, milk yield and body weight in Weeks 1-39 of different lactations

	2	3	4	5	6	7	8	9	10
First lactation									
1 Energy intake (kVEM)	0.60	0.59	0.54	0.19	0.54	0.59	0.38	0.39	0.45
2 Milk yield (kg)		0.26	0.47	0.60	0.23	0.45	0.61	0.01	0.12
3 Average body weight (kg)			0.82	−0.09	0.70	0.37	0.08	0.75	0.68
4 Body weight after calving (kg)				0.11	0.57	0.35	0.22	0.50	0.50
Second lactation									
5 Milk yield (kg)					0.14	0.36	0.67	−0.31	−0.24
6 Body weight after calving (kg)						0.33	0.25	0.64	0.71
Third lactation									
7 Energy intake (kVEM)							0.67	0.12	0.18
8 Milk yield (kg)								−0.34	0.04
9 Average body weight (kg)									0.83
10 Body weight after calving (kg)									

Correlations $\geqslant |0.23|$ are significantly different from zero ($P<0.05$).

feeding groups gave a more accurate explanation of energy intake: a multiple correlation of 0.92 and a residual standard error of 1908 MJ NE, but regression coefficients were less realistic than mentioned above: 0.85 MJ NE (SE 0.08 MJ NE), 0.392 MJ NE (SE 0.066 MJ NE) and 8 MJ NE (SE 8 MJ NE), respectively.

Correlations between characteristics in different lactations

In Table V, a summary of the residual correlations between energy intake, body weight (Lactations 1, 3) and milk yield (Lactations 1, 2, 3) in Weeks 1–39 of different lactations is presented. The correlation between energy intake in the first and third lactation had the same value as the correlation between milk yield in the first and third lactation (0.6–0.7). The correlation between average body weights in the first and third lactation was high (0.75). In the first lactation, average body weight was positively correlated with milk yield (0.26), but in the third lactation this correlation was negative (−0.24). The correlation between body weight 10 days after calving and milk yield decreased from 0.47 in the first lactation to 0.04 in the third lactation.

The calculated partition of energy intake between milk yield maintenance and gain

In the same way as described by Oldenbroek (1984a), the partition of energy intake between maintenance, milk energy and energy left for gain was calcu-

TABLE VI

The calculated partition of the energy intake (means and percentages) among milk production, maintenance and gain per breed×diet group in Weeks 1-39 of the third lactation in MJ NE

	Jersey				HF+DF+DRW			
	C		R		C		R	
	Mean	%	Mean	%	Mean	%	Mean	%
Intake[1,2]	30133	100	25969	100	36593	100	31131	100
Lactose[1,2]	3067	10	3233	13	5094	14	4585	15
Milk fat[1]	10178	34	10469	40	10061	27	9598	31
Milk protein[1]	3974	13	4137	16	5305	15	4768	15
Milk energy[1]	17219	57	17839	69	20460	56	18951	61
Maintenance[1,2]	7596	26	7093	28	10071	28	9835	32
Gain[1,2]	5318	18	1037	4	6062	17	2345	7

[1]Significant differences between breeds ($P<0.05$).
[2]Significant differences between diet groups ($P<0.05$).
C=Concentrates group; R=roughage group.

TABLE VII

The calculated partition of the energy intake (as a percentage) among milk production, maintenance and gain per breed×diet group in different periods of the third lactation

Partitioned to:	Period (weeks)	Breed×diet group			
		Jersey		HF+DF+DRW	
		C	R	C	R
Maintenance	1–13[1,2]	24	27	26	31
	14–26[1,2]	25	28	26	31
	27–39[1]	29	28	31	34
	1–39[1,2]	26	28	28	32
Milk energy	1–13[1,2]	67	79	71	79
	14–26[1,2]	55	67	53	58
	27–39[3]	47	60	43	46
	1–39[1,2]	57	69	56	61
Gain	1–13[1,2]	9	−6	3	−10
	14–26[1,2]	20	5	21	11
	27–39[3]	24	12	26	20
	1–39[1,2]	18	4	17	7

[1]Significant differences between breeds ($P<0.05$).
[2]Significant differences between diet groups ($P<0.05$).
[3]Significant interaction breed×diet group ($P<0.05$).
C=Concentrates group; R=roughage group.

lated and is presented in Table VI. Lactose concentration was not measured, but was set at 4.8% (Politiek, 1957) for all breeds. Krumm (1972) found minimal differences in lactose percentage between the breeds involved in our study. On both diets, the Jersey cows used less energy for the (estimated) lactose and protein production and more for fat production than the HF + DF + DRW cows. The Jersey cows on the R diet had a much higher (8%) biological efficiency for milk production (milk energy/energy intake) than the HF+DF+DRW cows on the R diet. The P value of the interaction term for this trait was 0.07.

Table VII gives the calculated partition of energy intake in the three subperiods of Weeks 1–39. With respect to energy intake, the differences in (calculated) milk energy between the C and R diets within the HF+DF+DRW cows were smaller in Weeks 27–39 than in Weeks 1–13. This was not the case within the Jersey group. On the R diet, the HF+DF+DRW cows had more energy available for body gain during the middle and end of lactation than Jersey cows. In Weeks 1–13, the cows on the R diet had a negative energy balance, while in the same period this balance was already positive for the cows on the C diet.

DISCUSSION

Differences between breeds and diets

As in the first lactation (Oldenbroek, 1986), the differences in milk production traits between the breeds in the third lactation showed unequal differences on the two diets. On the C diet, the differences in milk and protein yield between the Jersey cows and the HF + DF + DRW cows were larger than on the R diet. However, the breed × diet interaction was not significant at the 5% level. The difference between the breeds in response to the two diets led to a significant breed × diet interaction for fat concentration. Compared to the R diet, the Jersey cows had a higher (+23%) fat concentration and the HF + DF + DRW cows had a lower (−0.21%) fat concentration on the C diet. The same phenomenon was observed in the first lactation, while in the second lactation when the animals of the C and R diets were treated alike, the fat concentrations of both Jersey groups were similar. For milk production traits in second lactation only significant differences between breeds were detected. A possible explanation for the breed × diet interaction in the first and third lactation could be the great difference in milk composition between the breeds. The Jerseys have a higher fat yield and a lower lactose and protein yield than HF + DF + DRW animals. For an optimal production, the Jersey needs more lipogenic precursors and less amino acids and glycogenic precursors for milk production than the larger dairy breeds. Roughage diets yield more lipogenic precursors than concentrates-based diets (Tamminga, 1982). In reviews of the literature (e.g., Korver, 1982; Oldenbroek, 1984a), only one indication for an interaction between breed or genotype and feeding regimes in dairy cattle was found. Richardson et al. (1971) recorded a much smaller difference in milk production between Jerseys and Holstein Friesians on a roughage diet than on a diet with concentrates supplied according to milk yield. In our experiments, we found that in the first lactation the interaction for milk production traits was associated with an interaction for feed intake traits, but this interaction was absent in the third lactation. This was caused through a higher increase (absolutely, not relatively) in feed intake from the first to third lactation (+1403 kVEM) for the larger breeds compared to Jerseys (+1260 kVEM) on the R diet.

Kristensen and Ingvartson (1985) commented that, in Denmark, the intake capacity of Jersey cows is estimated at 88% of that of the Black and White breed, although their body weight is only about two-thirds of that of the Black and White. Our study indicates that the intake capacity of the Jersey cow is 82–84% of that of cows of larger dairy breeds. For heifers, this value is 78–80% (Oldenbroek, 1986). Blake et al. (1986), using a concentrates-based diet fed ad libitum, found an intake capacity of 79% in the first 6 months of lactation for the U.S. Jersey in comparison with the U.S. Holstein. Gibson (1986) found an intake capacity of 82% for the U.K. Jersey in comparison with the U.K. Friesian in the first and second lactation, while feeding a complete low-energy diet ad libitum. In our study, both in heifers and cows, the relative intake capacity (DM intake/live weight) of the Jersey was highest on the R diet. Bergström (1978) found that the ratio between weight of intestines and live weight was much higher for Jerseys than for the larger dairy breeds. Forbes (1986) concluded that equations to predict voluntary intake of Friesian dairy cows underestimate voluntary intake of Jersey cows. Their high relative intake capacity enables Jersey cows to reach their potential milk yield on the R diet and makes concentrates feeding less valuable compared to the larger dairy breeds.

Differences between the first and third lactation

The only conditioned difference in treatment between the first and third lactation was the substitution of grass silage by artificially dried grass. This had no influence on the energy content of the complete diets, but it resulted in a higher DCP content of the complete diets in third lactation. To some extent, it may have influenced the physical structure of the diets (artificially dried grass was harvested directly after cutting; grass for silage was harvested some days after cutting). Dulphy and Demarquilly (1983) mentioned a lower consumption of grass silage than of artificially dried grass. To some extent this may explain why the increase in feed intake from the first to third lactation was much larger on the R diet than on the C diet. This was associated with a higher increase in milk yield on the R diet. The DM intake/live weight ratio within breeds in the first and third lactation was similar on the C diet, but on the R diet it was lower in the first lactation. On roughage-based diets, physical regulation primarily affects intake (e.g., Kristensen and Ingvartson, 1985). They stated that the differences in voluntary intake between age groups of dairy cows depend on the energy value and the fill of the ad libitum feed. Krohn et al. (1983) found larger differences in intake between concentrates-based diets and roughage-based diets for heifers than for older cows. Poole (1986), however, did not find, in ad libitum feeding a high and low energy diet, an interaction between parity and type of the diet.

In comparison with the first lactation, the course of the energy intake curve of the C diet groups during the third lactation was more curvilinear. In the third lactation, the R diet groups showed the same flat curves as in the first lactation. In both lactations, our results are in agreement with the statements of Journet and Remond (1976) that on low-energy diets peak intake is at a later stage of lactation than on high-energy diets and that differences in energy intake of dairy cows between the start and finish of lactation are larger on high-energy diets than on low-energy diets. Especially for the larger breeds, the differences between the C and R diet groups in milk production traits were much smaller at the end of the third lactation compared to the end of the first lactation. The same phenomenon was observed in a previous study with the larger breeds over two lactations (Oldenbroek, 1984b). Differences between the first and third lactation were more pronounced in the first half of lactation than in the second half.

Differences in efficiency

The residual correlations within both lactations indicate that a higher energy intake is indeed associated with a higher milk energy production, but also with a higher gain. A higher milk energy production is associated with a higher energy intake, but with a lower gain. From a practical point of view, dairy farmers should focus their attention more on milk production than on feed intake capacity. Body weight in the first lactation was more positively related to energy intake than in the third lactation. Kristensen and Ingvartsen (1985) gave as a possible explanation the observation that in cows fat deposition increases weight, but decreases feed intake. In heifers, this fat deposition plays a less important role. The absence of a clear relation between energy intake and body weight in the third lactation caused a lower multiple correlation coefficient between energy intake and milk production, body weight and gain, compared to the first lactation (Oldenbroek, 1984c).

From the first to the third lactation, an increase in the biological efficiency (milk energy/net energy in feed) was only observed in the roughage groups. In the third lactation, they used a smaller part of energy intake for maintenance, or in other words: in the first lactation on the roughage diet, it was not possible to express the genetic ability of the animals for milk production due to a limited intake capacity. Older cows have a shorter period of negative energy balance than heifers, which in our experiments is also reflected in the difference in protein percentage of the milk between the diet groups. Milk protein percentage in the first lactation was higher on the C diet than on the R diet, which is caused by a negative energy balance (Grieve et al., 1986) on the R diet. In the third lactation, no difference in protein percentage was observed between the diet groups.

According to Dickerson (1970), the ratio between milk yield and maintenance is a predictor for the efficiency of milk production. Independent of parity, the ratio between energy in milk/energy for maintenance in our studies was higher for the Jerseys than for the larger breeds. Blake et al. (1986) found no differences between U.S. Jerseys and U.S. Holsteins in the efficiency for milk production, when feeding a concentrates-based complete diet ad libitum. From our study, it can be concluded that in the first (Oldenbroek, 1986) and in the third lactation, Jerseys were more efficient than HF+DF+DRW, especially on the R diet. The higher efficiency of the (Danish) Jersey is due to breeding for a high production of butterfat with a constant body weight.

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RÉSUME

Oldenbroek, J.K., 1988. Performances de vaches Jersey et de vaches laitières de plus grand format recevant deux rations complètes avec des proportions de fourrages différentes. *Livest. Prod. Sci.*, 18: 1-17 (en anglais).

On a comparé un groupe de 38 vaches Jersey à un groupe témoin de 12 Holstein Friesian (HF), 12 Frisonnes néerlandaises (DF) et 10 Pie rouge néerlandaises (DRW) au cours de leur troisième lactation avec deux rations: une ration de fourrage seul (R) et une ration complète constituée pour moitié (sur la base de la matière sèche) du même fourrage et pour moitié de concentré (C). On a enregistré le poids vif, la production laitière et la consommation alimentaire au cours des 39 premières semaines de lactation. Toutes les vaches avaient participé au cours de leur première lactation à la même expérience avec les mêmes rations.

Les différences entre les races n'ont pas été les mêmes avec les deux rations. Cependant, seule l'interaction race × ration sur le taux butyreux a été significative. Les différences entre les Jersey et le groupe témoin HF + DF + DRW, ont été en moyenne les suivantes pour la ration C et pour la ration R (entre parenthèses): −936 (−748) kVEM pour l'ingestion d'énergie; −2560 (−1707) kg de lait; +2,82 (+2,38) pour le taux butyreux; +0.83 (+0.77) pour le taux protéique; +3 (+23) kg de matières grasses; −55 (−26) kg de protéines; −199 (−216) kg de poids vif moyen; −57 (−27) kg de gain de poids. Entre la 1ère et la 3ème lactation, la consommation d'énergie et la production laitière ont augmenté pour les Jersey et pour le groupe témoin de 25 et 24% respectivement avec la ration C et de 48 et 51% avec la ration R.

Le rendement biologique pour la production laitière (énergie du lait: énergie nette ingérée) a

été pour les Jersey de 57% sur la ration C et de 69% sur la ration R et, pour le groupe témoin HF + DF + DRW, de 56 et de 61%, respectivement.

KURZFASSUNG

Oldenbroek, J.K., 1988. Die Leistung von Jersey-Kühen und von Kühen größerer Milchrassen bei zwei Futtermischungen mit unterschiedlichem Rauhfutteranteil. *Livest. Prod. Sci.*, 18: 1-17 (auf englisch).

Eine Gruppe aus 38 Jersey-Kühen und eine Kontrollgruppe aus 12 Holstein Friesian (HF), 12 niederländischen Friesian (DF) und 10 niederländischen Rotbunten (DRW) erhielten nach dem 3. Kalben eine komplette Rauhfuttermischung (R) oder eine Mischung mit dem gleichen Rauhfutter und 50% Kraftfutteranteil bezogen auf Trockensubstanz (C). Körpergewicht, Milchleistung und Futteraufnahme während der ersten 39 Wochen der Laktation wurden gemessen. Alle Kühe hatten bereits mit den gleichen Rationen in ihrer ersten Laktation an diesem Experiment teilgenommen. Für die untersuchten Merkmale waren die Unterschiede Zwischen den Rassen bei beiden Rationen nicht gleich. Jedoch nur für Fettgehalt wurde eine signifikante Rasse × Ration-Interaktion nachgewiesen. Die mittleren Unterschiede Zwischen der Jersey- und der HF+DF+DRW-Gruppe für die C-Diät (und R-Diät) betrugen −936 (−748) kVEM für Energieaufnahme, −2560 (−1707) kg für Milchleistung, +2.82 (+2.38) für Fettgehalt, +0.83 (+0.77) für Eiweißgehalt, +3 (+23) kg für Fettmenge, −55 (−26) kg für Eiweißmenge, −199 (−216) kg für durchschnittliches Körpergewicht und −57 (−27) kg für Zunahmen. Die Energieaufnahme und Milchleistung der Jerseys und der HF+DF+DRW stieg von der ersten zur dritten Laktation bei der C-Diät um 25 bzw. 24% und in der R-Diät um 48 bzw. 51%. Die biologische Effizienz der Milchproduktion (Energiegehalt der Milch dividiert durch Nettoenergie im Futter) betrug 57% für die Jerseygruppe mit der C-Diät, 69% für die Jerseygruppe mit der R-Diät, 56% für die HF+DF+DRW-Gruppe bei der C-Diät und 61% für die HF+DF+DRW-Gruppe bei der R-Diät.

CHAPTER 6

PARITY EFFECTS ON FEED INTAKE AND FEED EFFICIENCY IN FOUR DAIRY BREEDS FED AD LIBITUM TWO DIFFERENT DIETS

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ABSTRACT

Oldenbroek, J.K., 1988. Parity effects on feed intake and feed efficiency in four dairy breeds fed ad libitum two different diets. Livest.Prod.Sci. 00-000-000

Parity effects on feed intake and feed efficiency were analysed in Jerseys, Holstein Friesians, Dutch Friesians and Dutch Red and Whites. These cows were fed ad libitum a complete diet of roughage only (R) or a complete diet of the same roughage and 50 per cent concentrates on a dry matter basis (C) for at least 39 weeks in first and second or in first and third lactation. Of 159 cows in total 265 lactations were analysed.

A significant three-way interaction parity x breed x diet was found, caused by unequal variances between breeds in the different parity x diet groups and by differences in ranking for the breed in the different parity x diet groups. In general, the differences between the C- and R-diet groups decreased with increasing parity. No differences existed between parities in the ratio between milk energy production and Net Energy intake. Returns from milk minus feed costs increased in higher parities. Repeatabilities for fat concentration (0.75), protein concentration (0.68) and average body weight (0.69) were high. Repeatability for dry matter intake (0.39), milk yield (0.47), biological efficiency (0.46) and economic efficiency (0.37) were lower. Gain during lactation had a low repeatability (0.27).

INTRODUCTION

Cows in first and later parities differ not only in body weight and milk production, but also in ad libitum feed intake. These differences in feed intake can not be fully explained by differences in body weight and milk yield among parities (Kristensen and Ingvartsen, 1985). They fed their cows a fixed amount of concentrates and silage ad libitum. Kirchgessner and Schwarz (1984) found a significant relationship between body weight and feed intake in heifers while feeding concentrates according to milk production and ad libitum a mixture of roughages, but this relationship was not significant in older cows. Oldenbroek (1988) confirmed this phenomenon in a comparison of heifers and third calved cows fed ad libitum a roughage or a concentrates based diet. In a review Forbes (1986) showed a more close statistical relationship between feed intake and body weight, and between feed intake and milk production in heifers than in cows. Bines (1979) concluded, in a review, that heifers consumed less dry matter per unit of live weight than older cows. Broster et al. (1985) found that second-calved cows and adult cows consumed respectively 13 and 19 per cent dry matter more than heifers, which calved at 33 months of age. On a live weight basis, as well as in proportion to metabolic body weight ($G^{0.75}$), the adult cows consumed more dry matter. They fed their cows three diets which differed in amount of digestible energy by differences in the concentrates to the roughage ratio.

Hence it can be concluded that differences in feed intake of older cows can not simply be derived from feed intake of heifers, because of differences between parities in the relationship between feed intake and body weight and milk production. When comparing breeds, which differ in milk production and body weight, it is necessary to know parity effects on feed intake.

The efficiency of the conversion of feed energy into milk energy is influenced by many factors. Losses in the conversion of gross energy in feed are closely related to the composition of the diet (Van Es and Van der Honing, 1979). The efficiency of this conversion depends on energy losses in faeces (digestibility), urine and methane. The utilization of the remaining metabolisable energy and the partition between maintenance, milk production, reserve tissue and heat is difficult to determine (Moe and Tyrrell, 1975). Differences in the utilization of metabolisable energy may occur due to differences in maintenance requirements (per kg metabolic body weight) or differences in level and type of production (milk production, gain). Energy requirements for maintenance (per kg metabolic body weight) may be different for animals which differ greatly in body composition (Hanset, 1987). Van Es (1961) concluded that differences in maintenance requirements among animals measured in respiration chambers are small (coefficient of variation = 5 %). However, Andersen (1980) calculated in feed intake studies with beef animals, that differences in maintenance requirements between breeds were up to 16 %. A higher milk yield is associated with a higher feeding level. A higher feeding level depresses digestibility of energy, but this reduction is partly compensated for by a better utilization of metabolisable energy. Apart from this, there are no indications that at a higher level of milk yield metabolisable energy is utilized with a different efficiency than at lower yields (Van Es and Van der Honing, 1979). The energetic composition of live weight gain can be very variable. The ratio between energy required for 1 g gain of adipose tissue and 1 g gain of protein tissue is about 11 (Van Es, 1974).

The first aim of this paper is to establish the parity effects in Jersey, Holstein Friesian (HF), Dutch Friesian (DF) and Dutch Red and White (DRW) cows fed ad libitum two complete diets with different roughage contents.

The second aim is to study differences between parities within the breed x diet groups in the efficiency for milk production.

Body weight, milk production and feed intake play an important role in the biological and economic efficiency of milk production. In this paper mainly biological efficiency defined as: energy in milk versus Net Energy intake in feed (Van Es, 1978) will be considered. Little attention will be paid to economic efficiency, defined as returns from milk minus feed costs. For this second aim it is assumed that irrespective of breed, diet and parity the maintenance requirements are 0.293 kJ NE per kg metabolic body weight per day and that 1 MJ NE in feed results in 1 MJ milk energy (Van Es, 1978). These assumptions will be tested.

MATERIAL

Feed intake, milk production and body weight data was available from cows of four different breeds, which were fed ad libitum a complete diet with roughage only or a complete diet of the same mixture of roughage and 50 per cent concentrates on a dry matter basis for at least weeks 1 - 39 of lactation.

The data originated from:

- A study with HF, DRW and DF cows from 2 months before first calving until 10 months after calving (Oldenbroek, 1984a) and from 2 months before the second calving until 10 months after the second calving (Oldenbroek, 1984b).
- A study with Jersey, HF, DRW and DF heifers (Oldenbroek, 1986) and third calved cows (Oldenbroek, 1988) from calving until 39 weeks of lactation.

Table I. The distribution of cows and sires over breeds and diets in different parities.

	Breed	Jersey		HF		DF		DRW		Total	
	Diet	C	R	C	R	C	R	C	R	C	R
Parity 1	Cows	24	24	19	17	18	18	20	19	81	78
	Sires	11	14	15	14	15	13	14	16	55	57
Parity 2	Cows	-	-	3	8	7	5	4	7	14	20
	Sires	-	-	3	8	7	5	3	7	13	20
Parity 3	Cows	16	22	5	7	7	5	5	5	33	39
	Sires	8	13	5	6	6	5	5	5	24	29

Table I gives the distribution of cows and sires over breed x diet groups in different parities. In total 265 lactations of 159 cows were available. For each animal the following variables were calculated:

Net Energy intake (MJ NE), corrected for a feeding level of 2.38 (15 kg FCM, 550 kg body weight (Van Es, 1978))

metabolic body weight (average body weight to the power 0.75)

gain (final weight - starting weight)

milk energy (kg milk x 0.792 + kg fat x 38.5 + kg protein x 24.5) in MJ according to Kleiber (1961)

biological efficiency: milk energy/energy intake

economic efficiency: returns from milk - feed costs

returns from milk: (kg milk x Dfl. -0.12*) + (kg fat x Dfl. 9.50*) + (kg protein x Dfl. 11.50*)

feed costs: kg dry matter x Dfl. 0.45* (C diet) or
kg dry matter x Dfl. 0.40* (R diet).

* current Dutch pricing system and prices

ANALYSIS OF THE DATA

The data were analysed with the split-plot model:

$$Y_{ijklmn} = u + a_i + b_j + c_k + d_l + f_{m:ij} + ab_{ij} + ad_{il} + bd_{jl} + abd_{ijl} + e_{ijklmn}$$

where:

Y_{ijklmn} = observation on animal m of breed i, diet group j, batch k and parity l

u = general mean

a_i = effect of breed i, i = 1, 2, 3, 4

b_j = effect of diet j, j = 1, 2

c_k = effect of batch k, k = 1, 2, 3, 4, 5 (see Oldenbroek, 1984a and Oldenbroek, 1986)

d_l = effect of parity l, l = 1, 2, 3

$f_{m:ij}$ = random effect of cow m in breed class i and diet class j, component of variance σ^2_f

ab_{ij} = effect of interaction between breed i and diet j

ad_{il} = effect of interaction between breed i and parity l

bd_{jl} = effect of interaction between diet j and parity l

abd_{ijl} = effect of interaction between breed i, diet j and parity l

e_{ijklmn} = random error term, residual component of variance σ^2_e

Repeatability was defined as $\dfrac{\sigma^2_f}{\sigma^2_e + \sigma^2_f}$

Correlations between cow effects for variables y_1 and y_2 were defined as:

$$\frac{\mathrm{cov}(f_{y_1}, f_{y_2})}{\sigma_{f_{y_1}} * \sigma_{f_{y_2}}}$$

Correlations between residual effects within cows were defined as:

$$\frac{\mathrm{cov}(e_{y_1}, e_{y_2})}{\sigma_{e_{y_1}} * \sigma_{e_{y_2}}}$$

Components of variance were estimated with Henderson's method III (Searle, 1971). Components of co-variance were derived in a similar way from sums of squares of products. Approximations of standard deviations of estimators were derived, assuming normal distributions using first order Taylor series approximations and properties of quadratic and bi-linear forms (Wetherill, 1981) .

The previous model was expanded with appropriate covariables to study the possible differences between breeds, diets and parities in the utilization of Net Energy intake for milk production, maintenance and body weight gain.

RESULTS

Effect of parity

For feed intake, milk production and body weight a significant interaction between breed x diet x parity was found. As is illustrated in figures 1, 2 and 3, for dry matter intake, body weight and milk yield respectively, these interactions are caused by unequal differences between breeds in the parity x diet groups and by differences in ranking for the breeds in the different diet x parity groups. Table II presents the results by breed x diet groups in the different parities for dry matter intake, milk yield and average body weight. Table III illustrates the increases from parity 1 to parity 2 and 3 for these traits in percentages. In general the increases in dry matter intake were higher on the R-diet than on the C-diet. On both diets Jerseys increased their dry matter intake more from parity 1 to 3 than the larger breeds. From first to second and third lactation the DRW C-diet group showed a low increase in milk yield. From first to third lactation the increase in milk yield was in general much higher for the R-diet than for the C-diet. The increase in body weight from parity 1 to 2 varied between 7 and 17 per cent and from parity 1 to 3 between 17 and 31 per cent.

Table IV and V summarize the calculated partition of energy intake over milk production, maintenance and (as a residual) gain. As could be expected an increase in energy intake from parity 1 to 2 and 3 was associated with an increase in milk energy and maintenance requirements. The biological efficiency of the DF and DRW cows was not influenced by diet and parity (Table V). Second-calved HF cows on the C-diet and third-calved HF cows on the R-diet were more efficient than they were in parity 1. Also Jersey cows on the R-diet were more efficient than they were as a heifer. In general the R-diet groups used significantly less Net Energy for maintenance on a per cent basis in parity 3 figure 1: dry matter intake per breed/diet/parity

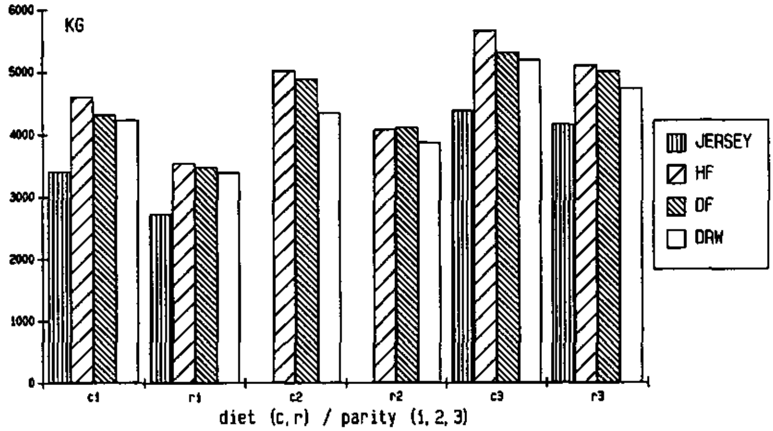

figure 2: body weight per breed/diet/parity

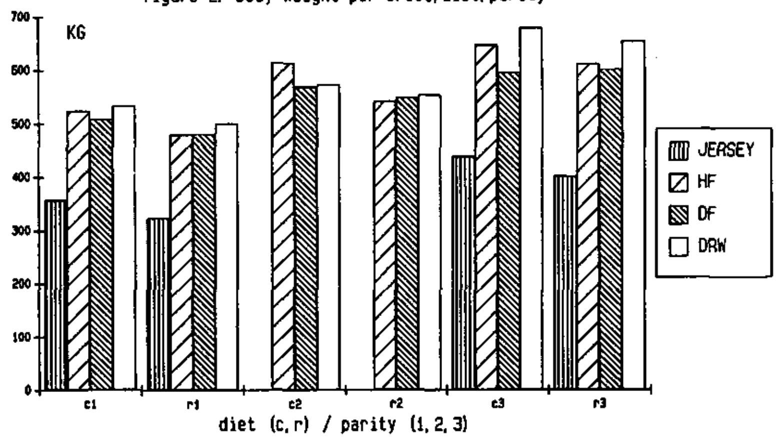

figure 3: milk yield per breed/diet/parity

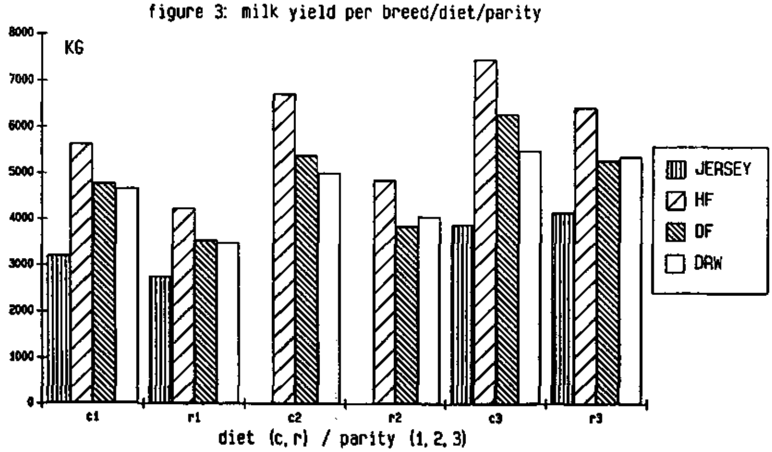

Table II. Least square means and standard errors of the breed x diet groups for feed intake, milk production and body weight in weeks 1 - 39 in parity 1 and contrasts from parity 2 and 3 with parity 1.

Trait	Parity	Breed / Diet	Jersey C	Jersey R	HF C	HF R	DF C	DF R	DRW C	DRW R
Dry matter intake (kg)	1	Mean	3417 ≠	2739	4614 ≠	3548	4330 ≠	3484	4248 ≠	3344
		SE	87	87	94	90	86	88	82	84
	2	Contrast	-	-	403	530*	553*	625*	105	530*
		SE	-	-	222	144	151	176	143	143
	3	Contrast	963*	1413*	1042*	1539*	963*	1506*	932*	1322*
		SE	152	92	176	152	152	176	175	175
Milk yield (kg)	1	Mean	3215 ≠	2764	5636 ≠	4238	4779 ≠	3549	4670 ≠	3490
		SE	144	144	155	148	142	145	135	138
	2	Contrast	-	-	1083*	612*	615*	296	338	564*
		SE	-	-	353	227	239	278	307	238
	3	Contrast	667*	1387*	1827*	2192*	1508*	1741*	828*	1875*
		SE	163	144	278	241	240	279	278	278
Body weight (kg)	1	Mean	358 ≠	324	525 ≠	481	510 ≠	481	535 ≠	501
		SE	7	7	9	8	9	8	9	8
	2	Contrast	-	-	90*	62*	60*	68*	40*	54*
		SE	-	-	15	10	10	12	13	10
	3	Contrast	81*	78*	123*	132*	86*	120*	145*	154*
		SE	7	6	12	10	10	12	12	12

≠ Significant difference between diets within breeds in parity 1 ($p < 0.05$).

* Significant increase compared to parity 1 within breed x diet group ($p < 0.05$).

(Table V) as compared to parity 1. The older Jersey cows showed a similar decrease on the C-diet. In parity 3 Jersey cows deposited a significantly greater part of their feed energy intake in gain than in parity 1. In parity 2 the HF cows on the C-diet deposited less feed energy in gain on a per cent base than they did in the first lactation. In all parities the C-diet groups deposited more feed energy in gain on a per cent base than the R-diet groups.

Table III. Contrasts (as a percentage) from parity 2 and 3 with parity 1 (= 100) within the breed x diet groups for feed intake, milk production and body weight in weeks 1 - 39.

	Breed	Jersey		HF		DF		DRW	
	Diet	C	R	C	R	C	R	C	R
Trait	Parity								
Dry matter intake	2	-	-	109	115	113	118	102	116
	3	128	152	123	143	122	143	122	139
Milk yield	2	-	-	119	114	113	108	107	116
	3	121	150	132	152	132	149	118	154
Body weight	2	-	-	117	113	112	114	107	111
	3	123	124	123	127	117	125	127	131

Table IV. Least square means of the breed x diet groups for energy intake and its calculated partition in weeks 1 - 39 in parity 1 and contrasts from parity 2 and 3 with parity 1 (MJ NE).

	Breed	Jersey		HF		DF		DRW	
	Diet	C	R	C	R	C	R	C	R
	Parity								
Intake	1 Mean	22816 ≠	16816	30653 ≠	21905	28751 ≠	21461	28248 ≠	20923
	2 Contrast	-	-	1907	2791*	3228*	3753*	278	2560*
	3 Contrast	6639*	8801*	7078*	9466*	6853*	9616*	6114*	8283*
Milk	1 Mean	13619 ≠	11057	17690 ≠	13208	15578 ≠	11739	15144 ≠	11325
	2 Contrast	-	-	3181*	2308*	1618*	955	1248	2037*
	3 Contrast	3326*	6766*	4741*	7263*	4771*	6014*	2425*	5828*
Maintenance	1 Mean	6580 ≠	6103	8770 ≠	8212	8583 ≠	8222	8895 ≠	8467
	2 Contrast	-	-	1126*	776*	737*	859*	483*	683*
	3 Contrast	1088*	1079*	1504*	1640*	1059*	1498*	1760*	1895*
Gain	1 Mean	2616 ≠	-345	4192 ≠	484	4589 ≠	1499	4209 ≠	1130
	2 Contrast	-	-	-2248*	-289	778	1946*	-1485	-93
	3 Contrast	2226*	971*	781*	542	1011	2095*	1964*	620

≠ Significant differences between diets within breeds in parity 1 ($p < 0.05$).

* Significant increase compared to parity 1 within breed x diet group ($p < 0.05$).

Table V. The calculated partition of energy intake in percentages (x 100) of the breed x diet groups in weeks 1 - 39 in different parities.

	Breed	Jersey		HF		DF		DRW	
	Diet	C	R	C	R	C	R	C	R
	Parity								
Milk	1	60	65	58	61	54	55	54	54
	2	-	-	68*	64	54	51	57	57
	3	57	69*	59	65*	57	57	51	58
Maintenance	1	29	36	29	38	30	39	32	41
	2	-	-	32	37	29	37	33	39
	3	27*	28*	28	32*	28	32*	31	36*
Gain	1	11	-1	13	2	16	7	15	5
	2	-	-	1*	-1	17	13	9	3
	3	16*	2*	13	3	15	11	18	6

* Significant difference with respect to parity 1 ($p < 0.05$).

Table VI. Least square means of the breed x diet groups for income from milk minus feed costs in weeks 1 - 39 in parity 1 and contrasts from parity 2 and 3 with parity 1 (in Dfl.).

Breed		Jersey		HF		DF		DRW	
Diet		C	R	C	R	C	R	C	R
Parity 1	mean	1533	1336	1536≠	1211	1301≠	1019	1260≠	960
Parity 2	contrast	-	-	416*	281*	38	-45	184	234
Parity 3	contrast	335*	1029*	420*	915*	538*	709*	41	694*

≠ Significant differences between diets within breeds in parity 1 ($p < 0.05$).

* Significant increase compared to parity 1 within breed x diet group ($p < 0.05$).

Table VI is a presentation of the economic efficiency of the subgroups in different parities. For all breeds the increase in income from milk minus feed costs from parity 1 to 3 is much higher on the R-diet than on the C-diet, so that with an exception for the DF cows, the economic efficiency in parity 3 was higher on the R diet than on the C-diet.

Correlations between lactations

Tables VII is a summary of repeatabilities, correlations between cow effects and the correlations between residual effects within cows. These parameters are upperbounds for heritabilities and genetic correlations and represent the residual correlations, respectively.

Table VII. Correlations between cow effects (below diagonal), repeatabilities (diagonal) and residual correlations within cows (above diagonal) for feed intake, milk production and body weight traits (x 100) with standard errors (SE).

		1	2	3	4	5	6	7	8
1. Dry matter intake		39	61	-2	21	1	-13	-20	37
	SE	9	7	10	10	10	10	10	9
2. Milk yield		52	47	-17	6	-26	-24	58	89
	SE	11	8	10	10	10	10	7	2
3. Fat concentration		-5	-55	75	28	16	-6	3	11
	SE	13	10	4	10	10	10	10	10
4. Protein concentration		-5	-58	69	68	15	22	-12	20
	SE	14	11	6	5	10	10	10	10
5. Average body weight		67	14	15	21	69	2	-23	-21
	SE	11	13	10	10	5	10	10	10
6. Gain		-8	-76	27	50	55	27	-25	-26
	SE	21	16	15	14	16	9	10	10
7. Milk energy/		1	79	-34	-39	-29	-82	46	77
energy intake	SE	16	7	11	11	12	16	8	4
8. Returns milk -		42	82	-16	-21	4	-76	90	37
feedcosts	SE	15	5	13	14	14	18	5	9

From Table VII it can be concluded that repeatabilities for fat and protein concentration and body weight were higher (0.68 - 0.75) than for dry matter intake, milk yield, biological and economic efficiency and gain (0.27 - 0.47). Relatively high positive "genetic" correlations (> 0.50) were found between dry matter intake and milk yield, between dry matter intake and average body weight, between fat and protein concentration in the milk, between milk yield and both types of efficiency and between biological and economic efficiency. Especially milk yield and fat concentration, milk yield and protein concentration, milk yield and gain and the efficiency traits and gain showed negative "genetic" correlations (< -0.50). Relatively high positive residual correlations (> 0.50) were found between dry matter intake and milk yield and between the two types of efficiency.

Differences in the utilization of net energy

Table VIII summarizes the results of the multiple regression of energy intake on milk energy, maintenance and gain. Coefficients of variation for these

Table VIII. Results of multiple regression analysis of energy intake (in MJ in 273 days) on milk energy production, maintenance and gain with intercepts for breed x parity x diet-groups and different regression coefficients for breed, parity, diet and their interactions.

Different regression coefficients for:	Variance accounted for	Residual standard error	Degrees of freedom error	F-value with model ( )	P-value
1. Breed x parity x diet	92.4	1562	174	-	-
2. Two-factor interactions	92.0	1609	188	1.83(1)	0.04
3. Breed x diet, parity x diet	90.8	1727	221	2.44(2)	0.00
4. Breed x diet	90.6	1740	227	1.99(2)	0.00
5. Parity x diet	90.2	1780	230	2.23(2)	0.00
6. Breed, parity, diet	90.2	1778	218	2.61(2)	0.00
7. Breed	89.5	1838	227	2.75(6)	0.00
8. Parity	89.5	1840	230	2.37(6)	0.01
9. Diet	90.3	1769	233	0.85(6)	0.62
10. Overall regressions	89.6	1836	236	7.02(9)	0.00

traits were respectively: 20, 24, 11 and 62 per cent. In all different models breed x parity x diet subgroups were included as fixed effects. In model 1 different covariables for each three-way interaction subgroup were calculated. This model accounted for 92.4 per cent of the total variance in energy intake. The residual standard error was 1562 MJ (= 5.72 MJ/day). Model 10, including an overall covariable for milk energy, metabolic weight and gain accounted for 89.6 per cent of the total variance in energy intake with a residual standard error of 1836 MJ (= 6.73 MJ/day). Strictly, from a statistical point of view, it is not allowed to replace the covariables of all three-way interaction subgroups by those of the two-way interaction subgroups. A model with different covariables for diets accounted for 90.3 per cent of the total variance in energy intake with a residual standard error of 1769 MJ. Omitting diet as a factor leads to a lower explanation of energy intake. From the single factors, diet seems to be more important than breed or parity. The estimated regression coefficients for milk energy, maintenance and gain in the models 1 - 10 (Table VIII) varied widely between subgroups (from negative values up to two times the expected values). The overall estimates of the regression coefficients had sometimes unrealistic values. E.g. in model 1 the overall regression coefficients for milk energy, maintenance and gain were respectively: 0.42 MJ NE/MJ (SE 0.15 MJ NE), 0.34 MJ NE/kg metabolic body weight per day (SE 0.18 MJ NE) and -14.0 MJ NE/kg (SE 11.2 MJ NE). SE represents the standard arror of the overall estimates. In model 10 these regression coefficients were respectively 0.85 MJ NE/MJ (SE 0.06 MJ NE), 0.50 MJ NE/kg metabolic body weight per day (SE 0.08 MJ NE) and 7.8 MJ NE/kg (SE 3.7 MJ NE).

DISCUSSION

The significant three-way interaction breed x parity x diet is partly caused by differences in ranking for breeds within the different parity x diet groups and partly by unequal variances between breeds in the different parity x diet groups. Maybe the fact plays a role, that parity effects were partly confounded with previous treatment and with differences between parities in diet components. Hence, cows in parity 2 were indeed fed a similar diet as in the first lactation, but diet in the first lactation had a marked influence on body weight at second calving (Oldenbroek, 1984b). Cows in parity 3 of both diet groups had been fed the same diet in second lactation and the grass silage in parity 1 was replaced by artificially dried grass in parity 3.

In general, the differences between the C- and R-diet groups decreased with increasing parity. Probably, feed intake capacity is more a limiting factor in heifers than in older cows to reach milk production capacity. Feed intake capacity, expressed as the ratio between dry matter intake and body weight, increased with increasing parities. This agrees with the literature (Bines, 1979; Broster et al., 1985).

In general no differences existed among parities in biological efficiency: milk energy/Net Energy in feed. Ad libitum fed older cows partitioned more energy towards gain and needed relatively less for maintenance than ad libitum fed heifers, despite the fact that heifers still have to grow. With respect to parity, a difference existed between biological and economic efficiency (income from milk minus feed costs). In all breed x diet groups economic efficiency increased significantly in higher parities. Prices for milk and feed have a large effect on economic efficiency. E.g. a 20 per cent decrease (with respect to the current price) in the price of concentrates increases returns from milk minus feed costs of the C diet groups with on average 15 per cent.

When the environmental correlation between lactations within cows for the same trait is zero, repeatability equals heritability. Because the animals were fed similar rations in different lactations and were handled as equally as possible, environmental correlation cannot be excluded. Therefore, heritabilities for feed intake, milk production and body weight of cows fed ad libitum will be lower than the corresponding repeatabilities. In the four studies within parities (Oldenbroek, 1984a, 1984b, 1986 and 1988) the residual correlations between traits were phenotypic correlations consisting of a genetic and a residual component. In the present study it was possible to separate, to some extent, these two because the genetic components also contain common environmental covariance. The phenotypic relationships among traits in the four studies within parities were determined by an animal or a "genetic" covariance. Although biological and economic efficiency showed a close relationship, their relationships with feed intake and body weight ("genetic" and residual) are slightly different. Biological efficiency had no relationship with feed intake and was negatively correlated with body weight, while economic efficiency was positively correlated with feed intake and had no relationship with body weight.

A large part of the variance in Net Energy intake can be explained by a model including the three-way interaction as a fixed effect and different coefficients for covariables for the three-way interaction subgroups. However, the residual standard error still equals the Net Energy value of approximately 1 kg dry matter per day. With this regression technique it is not possible to test differences between breeds/parities/diets in the energy requirements for milk energy, maintenance and gain. Maybe regression analysis is not the appropriate statistical technique to explain differences in energy intake, because the independent variables are not established without error and because of relationships among the independent variables. (e.g. milk energy and gain). Milk energy is calculated after weighing the milk, sampling and analysing the milk for fat and protein content once a week; full body weight is measured once a week and the energetic composition of the gain, which can vary widely (Webster, 1977), is not known. In contradiction to beef production (Andersen, 1980), it is not possible in milk production to calculate differences between breeds in Net Energy requirements by multiple regression analysis.

In this study energy intake of the breed x diet groups was not corrected for differences in feeding level. Net Energy content of feed is estimated at a feeding level of 2.38 (Van Es, 1978). The breed x diet groups differ more or less in feeding level: Net Energy in feed versus maintenance requirements. Net Energy content of feed decreases with 1.8 per cent for an increase of a unit of feeding level (Van Es, 1978). Differences in formulas for calculating milk energy for the different breeds exist and may be caused by differences in the relationships between fat, protein and lactose between the breeds. Hermansen and Petersen (1987) mentioned differences between Jerseys and Black and Whites in milk fat composition. Jerseys had a slightly higher content of short chain fatty acids and palmitic acid at the expense of long chain fatty acids compared to Black and Whites. The energy content of Jersey milk can be estimated as 455 * fat percentage + 1222 (kJ/kg) and for Friesian milk as 471 * fat percentage + 1255 (kJ/kg) (Crovetto and Van der Honing, 1984). In additional calculations Net Energy intake of the breed x diet groups was corrected for differences in feeding levels and the appropriate formulas of Crovetto and Van der Honing (1984) were used to calculate milk energy production. These calculations resulted in ratios between milk energy production and Net Energy intake, which deviated 1 per cent or less compared to the values in Table V.

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CHAPTER 7

THE EFFECT OF TREATMENT OF DAIRY COWS OF DIFFERENT BREEDS WITH RECOMBINANTLY DERIVED BOVINE SOMATOTROPIN IN A SUSTAINED DELIVERY VEHICLE

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ABSTRACT

Oldenbroek, J.K., 1988. The effect of treatment of dairy cows of different breeds with recombinantly derived bovine somatotropin in a sustained delivery vehicle. Livest.Prod.Sci., 00-000-000.

After calving 16 Friesian, 16 Jersey and 16 Dutch Red and White cows were taken into a 252-day experiment to determine the response in milk production, body weight and feed intake to the administration of Somidobove: (recombinantly derived bovine somatotropin) in a sustained delivery vehicle. The experiment was divided into an 84 days preliminary period and six consecutive 28-day treatment periods. Four treatments were used: an untreated control and three different levels of somatotropin, 320 mg, 640 mg and 960 mg in a sustained delivery vehicle, administered once every 28 days by subcutaneous injection. Animals were housed and individually fed *ad libitum* a complete diet of 50 per cent concentrates and 50 per cent roughage.

For none of the analysed characteristics a significant breed x treatment interaction was detected. The 640 mg-dosage gave optimum results: in the treatment period the calculated milk energy output increased on average 19 % in Dutch Red and White, Jersey and Friesian cows by an increase in milk yield (3.3 kg) and fat percentage (0.24 %). Treatment with somatotropin did not

affect protein and lactose percentage, somatic cell count, calcium, magnesium and phosphorus levels in milk. NEFA in milk of treated cows tended to be lower than in control cows. Glucose, insulin and thyroxin levels in plasma were not affected by somatotropin treatment. The plasma levels of 3-hydroxybutyrate tended to be higher and the level of urea tended to be lower in treated cows; somatotropin was significantly higher in treated cows. High yielders in the preliminary period showed a slightly lower increase in milk production after treatment with somatotropin than low yielders.

INTRODUCTION

In the dairy cow the pituitary hormone somatotropin is involved in the long term control of nutrient partitioning during pregnancy and lactation (Bauman and Currie, 1980). It plays a substantial role in partitioning nutrients between body deposition and milk production. Hart (1983) concluded that plasma somatotropin is higher in high yielding than in low yielding cows, that changes in somatotropin plasma concentrations are positively correlated with changes in milk yield and that exogenous somatotropin increases the efficiency of converting food into milk.

Asimov and Krouze (1937) were the first to demonstrate that injections of crude pituitary extracts increased milk production in dairy cows of several USSR breeds. Limitations in the supply of pituitary somatotropin and in purification techniques slowed down the rate of research on the mechanisms by which somatotropin alters milk production and impeded practical application. However, several short time studies with a limited number of animals and a few long term experiments (up to 27 weeks) published so far, showed increases in milk yield from 10 to 45 per cent, using daily injections of highly purified pituitary somatotropin (Bauman et al., 1985). Bauman and McCutcheon (1986) concluded that, when cows have a positive energy balance during BST treatment, no alterations in milk composition occur and feed intake increases slightly in the long term.

Now recombinant DNA techniques are available to synthesize bovine somatotropin (BST) on a larger scale. Hart et al. (1984) and Bauman et al. (1985) demonstrated that recombinantly derived and pituitary derived BST have similar biological activities. The biotechnological production of BST facilitates long term studies in dairy cows and creates possibilities for practical application. The practical application of BST treatment would be facilitated by the development of a slow release vehicle, which would make daily injections unnecessary. Lilly Research Laboratories developed such a sustained release vehicle for subcutaneous injection of BST once every 28 days (Somidobove; McGuffey et al., 1987a, 1987b).

So far, most studies with exogenous BST have been conducted in Friesian cows (Peel and Bauman, 1987). Some authors (Hart et al., 1978, Peel et al., 1985 and Hemken et al., 1986) reported that cows of other breeds were also involved in their studies. However, differences between breeds in reaction to BST treatment were not systematically described. It is questionable whether BST treatment of other breeds, e.g. the Dutch Red and White (DRW) or the Jersey, will give similar results as in the Friesian (Fr). These three breeds differ more or less in milk yield, milk composition, body weight, voluntary feed intake and in the utilization of feed energy for milk production, maintenance and gain (Oldenbroek, 1984a, 1984b, 1986, 1988a).

To establish the optimum dosage of recombinantly derived BST in a sustained release vehicle, supplied by Lilly Research Laboratories, a 252-day experiment was conducted with Black and White Friesian, Jersey and DRW cows. Attention was paid to possible breed x treatment interaction, to the affect of the three BST treatments and to activity of the sustained release vehicle within a 28 day-treatment period. The effect of administration of three different dosages of BST was determined for milk production, body weight, voluntary feed intake and some blood/milk constituents. Because of the involvement of BST in calcium metabolism and the nutritive significance of this mineral in milk, calcium and also phosphorus and magnesium in milk were determined.

MATERIAL AND METHODS

Treatment of animals

Sixteen Black and White Friesian (Fr) cows with on the average 50 per cent Holstein Friesian genes, sixteen Jersey cows of Danish origin and sixteen Dutch Red and White (DRW) cows from the dairy herd of the experimental farm "'t Gen" were placed in a cubicle house equipped with electronic feed gates at 5 - 19 days post partum. No heifers were involved in this trial and only one Fr and one Jersey cow had parity 2. The cows were fed once daily a complete diet ad libitum throughout the experimental period of 252 days. The cows were milked twice daily with a 12-hours interval. Throughout the trial, the individually fed complete diet consisted of 50 per cent concentrates, 30 per cent artificially dried grass and 20 per cent corn silage on a dry matter basis. At each milking 0.5 kg of additional concentrates was fed in the milking parlour.

The trial was divided into an 84-day preliminary period and six consecutive 28-day treatment periods. Four treatments were used: an untreated control (C) and three different dosages of somatotropin, 320 mg (L), 640 mg (M) and 960 mg (H) in a sustained release vehicle, administered once every 28 days by subcutaneous injections over the ribs behind the shoulder. Based on their calving date (October 1985 - December 1985) and on their 4 per cent fat corrected milk yield in the first 28 days of the preliminary period, the cows were assigned to a treatment. Cows were inseminated from 60 days after calving onwards.

Observations

Throughout the 252-day experimental period milk yield was recorded daily from Monday p.m. to Saturday a.m. Composite samples of p.m. and a.m. milkings on Monday/Tuesday and Thursday/Friday were analysed for fat, protein and lactose contents. The individual daily feed intake was measured from Monday till Thursday. Every 14 days samples of the roughages and the complete ration were taken to determine feed composition. On average the complete ration contained 60 per cent dry matter, 6.61 MJ NE (= 958 VEM) per kg dry matter and 124 g digestible crude protein per kg dry matter. The respective standard deviations for bi-weekly periods were 18 VEM and 7 g digestible crude protein per kg dry matter. The cows were weighed every Monday after a.m. milking. Clinical diseases, heats and inseminations were recorded.

Two animals had to be slaughtered during the trial. A DRW-cow of the C-treatment group had a severe lameness and a Fr cow of the H-treatment group suffered from a fat-necrosis (death of intestinal adipose tissue).

During the trial veterinary treatment was required for 8 C cows (7), 13 L cows (9), 9 M cows (7) and 10 H cows (8). The figures in parentheses represent lameness problems within the total number of treatments. One C cow, one L cow, one M cow and three H cows did not conceive during the experimental period and were slaughtered afterwards. The remaining cows within each group conceived on the average on day 78, 81, 117 and 79 after calving respectively. They needed

1.7, 1.6, 2.0 and 1.5 inseminations per pregnancy, respectively.

In the middle of each 28-day period, including the 3 x 28-day preliminary period, blood samples were taken at 9 a.m. from each animal from the jugular vein just before the daily feeding. The same morning, 4-quarter milk samples were collected and preserved with formaldehyde (50 µl 36 %, w/v per 100 ml milk). The milk and heparinized blood samples were cooled on ice. Blood plasma was seperated by centrifugation within two hours after collection. Aliquots were stored frozen at -20 ^{o}C until assayed for total L-thyroxine (T4), insulin and somatotropin. Glucose, 3-hydroxybutyrate, nonesterified-fatty-acids (NEFA) and urea levels in plasma were determined immediately. Somatic cell count, NEFA, total calcium (Ca), total magnesium (Mg) and total phosphorus (P) in milk were also measured on the day of sampling.

Chemical analysis

Blood plasma

Plasma levels of free fatty acids were measured using the method of Dalton and Kowalski (1967); glucose after deproteinisation by the glucose oxidase method (Werner et al., 1970) and 3-hydroxybutyrate by an enzymatic method as described by Bergmeyer and Bernt (1965). Urea was measured by a spectrophotometric method (Wybenga et al., 1971).

Hormones

Total L-thyroxine was assayed in duplo with a commercial radioimmunoassay kit (RIA-gnost T4 "coated tube", Hoechst-Behring, Marburg, West-Germany). Inhibition curves with increasing volumes of bovine plasma were parallel to T4 standards. Interassay and intraassay coefficients of variation were 8 and 5 %. Plasma insulin concentration was measured in duplicate by a double antibody method of radioimmunoassay (Hales and Randle, 1963). The pre-precipitated antibody (guinea pig anti-porcine-insulin serum plus rabbit anti-guinea pig globulin) was from Wellcome Research Labs (Beckenham, U.K.; Insulin Binding Reagent RD 12). ^{125}I-labeled bovine insulin with a specific activity of 50 µCi/µg was from the Radiochemical Centre (Amersham, U.K.) Monocomponent bovine insulin for standardization was obtained from NOVO Biolabs (Bagsvaerd, Denmark; biopotency: 26.9 i.u./mg). The procedure followed was largely as outlined in the Wellcome brochure.

Plasma bovine somatotropin concentration was measured in duplicate by a specific, sensitive, homologous double-antibody radioimmunoassay. Bovine somatotropin was purified to a high degree from fresh frozen whole pituitaries as described by Reichert (1975) and used for immunization and radioiodination. Antisera to the purified BST were raised in New Zealand white rabbits by multiple intradermal injections of BST in saline emulsified with Freund's complete adjuvant (Vaitukaitis et al., 1971). The antiserum giving high sensitivity and specificity was selected for use at a final dilution of 1:16,000 which resulted in 50 % binding of iodinated BST in the assay. For standardization purposes a purified BST standard (lot no. USDA-bGH-B-I, AFP-5200) was used; biopotency by Tibia method was 1.9 i.u./mg. A standard curve of 0.1 - 50 ng was employed in each assay. The sensitivity was 0.2 µg/l plasma. The intra- and interassay coefficients of variation were 1.8 and 9.7 % (n = 20), respectively. Cross reaction with bGH NIH-G-B18 was 37 % and with b-PRL << 1 %.

Milk

Somatic cell counts were determined according to standard procedures. Free fatty acids were measured using the method of Shipe et al. (1980). Total phosphorus, Ca and Mg were determined after wet destruction of an aliquot of raw milk with HNO_3 and $HClO_4$ and the appropriate dilution. Phosphorus was determined as phosphate according to Bartlett (1969), Ca and Mg by atomic absorption using standard methods. Analytical standards and blanks were prepared in the same matrix as the digested samples.

Statistical analysis

Measurements on each cow were averaged for the preliminary period of 12 weeks, for the 24-weeks treatment period (weeks 13 - 36) and for the whole experimental period. Furthermore, the difference between the average value in the treatment period and in the preliminary period was calculated for each animal. Within the six consecutive 28-day treatment period the average values of the traits in the first, second, third and fourth weeks were calculated to determine possible fluctuations in the activity of the sustained release vehicle.

Gain during a period was calculated as: half of (body weights in the two final weeks of that period minus body weights in the first and second week). Milk energy was calculated according to the energy contents of milk components described by Kleiber (1961). Maintenance requirements were estimated as 0.293 MJ NE per kg metabolic weight (average body weight to the power of 0.75) per day (Van Es, 1975). Energy available for gain was calculated as net energy intake minus milk energy and maintenance requirements.

The data was analysed with the analysis of variance model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \xi_{ijk}$$

where: Y_{ijk} = observation on animal k of breed i and treatment j
μ = general mean
α_i = effect of breed i, i = 1, 2, 3
β_j = effect of treatment j, j = 1, 2, 3, 4
$\alpha\beta_{ij}$ = effect of interaction between breed i and treatment j
ξ_{ijk} = error term.

For none of the analysed traits was a significant breed x treatment interaction detected (Table I). In a second analysis (Table II - IX) the interaction term was omitted.
In order to study the relationship between the treatment effects (differences in weeks 13 to 36 minus weeks 1 to 12) and the parameter values in weeks 1 - 12, this model was extended with a within treatments covariable of parameter values in weeks 1 - 12:

$$\gamma_j(Y_{ijk} - \bar{Y}_j) \text{ where}$$

γ_j = regression of Y for treatment j on parameter value of Y in weeks 1-12
$\bar{Y}_j$ = average parameter value in weeks 1 - 12 for treatment j.

To analyse fluctuations in the activity of the sustained release vehicle the model including breeds and treatments was extended with the factor weeks (1, 2, 3 and 4 within the six 28-day-treatment periods) and the interaction weeks x treatment.

The least square means for the breed x treatment groups in the 168-day treatment period (weeks 13 - 36) are presented in Table I. Because of the small number of cows (3 - 4) per breed x treatment group, the standard errors of the least square means are rather high. A significant breed x treatment interaction was not found for any of the traits analysed.

Table II indicates significant differences among breeds in feed intake, milk yield, milk fat and milk protein concentration and body weight during the preliminary period and the treatment period.

Table III shows significant differences among breeds in energy intake, milk energy and energy for maintenance in weeks 1 - 12. In weeks 13 - 36 these differences are only significant with respect to energy intake and energy for maintenance. The milk energy output of the Jerseys in weeks 13 - 36 was 88 % of that in weeks 1 - 12, while this figure was 83 % for the Fr and DRW cows.

Table III. The calculated partition of the energy intake among milk energy, maintenance and gain of breeds in weeks 1 - 12 and 13 - 36 (in MJ/day).

	Period	1 - 12			13 - 36		
	Breed	DRW	Jersey	Fr	DRW	Jersey	Fr
Intake	Mean	*145.5	129.5	154.1	*132.9	123.3	144.4
	%	100	100	100	100	100	100
Milk	Mean	* 95.4	90.2	107.1	79.2	79.2	88.6
	%	66	70	70	60	64	61
Maintenance	Mean	* 37.5	27.0	36.5	* 38.4	28.0	37.0
	%	* 26	21	24	* 29	23	26
Gain	Mean	12.5	12.4	10.5	15.2	16.2	18.8
	%	9	9	7	11	13	13

* Significant differences among breeds, $p \leq 0.05$

Table IV. Least square means for concentrations of metabolites and hormones in plasma; somatic cell count, NEFA and minerals in milk of breeds in weeks 1 - 12 and weeks 13 - 36.

Period	1 - 12				13 - 36			
Breed	DRW	Jersey	Fr	SE	DRW	Jersey	Fr	SE
Glucose (mmol/l)	3.72	3.57	3.66	0.07	3.30	3.40	3.27	0.07
3-Hydroxybutyrate (µmol/l)	667	700	752	66	* 683	658	562	32
NEFA-plasma (µmol/l)	243	200	236	16	* 170	176	125	13
Urea (mgN/100 ml)	11.8	13.1	11.9	0.5	14.8	15.4	15.5	0.4
Cell count (log counts/ml)	5.4	5.4	5.3	0.1	5.5	5.6	5.4	0.1
NEFA-milk (µmol/l)	* 180	263	175	13	159	160	145	9
Calcium (mg/l)	*1049	1379	1099	21	*1097	1434	1117	21
Magnesium (mg/l)	* 107	119	103	2	* 113	125	103	2
Phosphorus (mg/l)	* 760	803	718	19	* 948	1065	925	20
Insulin (ng/l)	335	306	337	23	457	434	398	30
T4 (µg/l)	45.1	43.8	42.8	2.2	49.1	55.2	49.9	2.4
Somatotropin (µg/l)	1.22	1.33	1.25	0.07	1.45	1.42	1.51	0.06

* Significant differences among breeds ($p \leq 0.05$)

Table IV is, in a similar way as Table II, a presentation of least square means for metabolites and hormones in plasma and of somatic cell count, NEFA and minerals in milk. NEFA in milk of Jersey cows was significantly higher in weeks 1 - 12 in comparison to milk of Fr and DRW cows. In weeks 13 - 36 3-hydroxybutyrate and NEFA in plasma were significantly lower in Fr cows. The Jerseys had higher levels of calcium, magnesium and phosphorus per kg milk than Dutch Red and Whites and Friesians.

Due to the loss of two animals minor differences in fat-corrected milk arose among treatment groups in the preliminary period (weeks 1 - 12). In order to calculate treatment effects properly the average difference between weeks 13 - 36 and weeks 1 - 12 is presented in Table V for each treatment group. For the L, M and H treatment groups the effect of treatment is expressed as a percentage with respect to the C group, after correction for the minor differences among treatment groups in weeks 1 - 12. Table V indicates a higher feed intake in the treated animals and a lower body weight gain compared to the control cows. Treatment with BST had a favourable effect on fat concentration of the milk, as can be deducted from a higher increase in fat yield than in milk yield. BST treatment in weeks 13 - 36 gave a significant increase in daily milk yield traits, which was the highest in the M group: 3.3 kg milk (16 %) 223 g fat (21 %), 130 g protein (18 %), 155 g lactose (16 %) and 14.3 MJ (19 %) milk energy.

Table VI gives the differences in the four treatment groups, analogous to Table V, for plasma and milk constituents. The differences for hormone levels of the C group are in accordance with observations that during lactation basal levels of insulin and T4 increase (Smith et al., 1975; Walsh et al., 1980) and that basal levels of somatotropin are highest in early lactation and lowest in late stages of lactation (Koprowski and Tucker, 1973).Only the somatotropin concentration was significantly increased in treated animals. Non significant tendencies were a higher 3-hydroxybutyrate and a lower urea level in plasma of treated cows. NEFA in milk of treated cows (M + H) tended to be lower than in C + L cows.

Table V. Least square means in weeks 1 - 12 and differences between weeks 13 - 36 and 1 - 12 for energy intake, milk production and body weight traits per treatment group.

		Weeks 1 - 12 Mean	Treatment C	L	M	H
			Differences			
Energy intake (MJ/day)		143.0	-14.9	-9.5	-6.0	-7.6
	%			4	7	6
Milk yield (kg/day)	*	28.5	- 7.6	-6.7	-4.3	-4.7
	%			4	16	14
Fat yield (g/day)	*	1338	- 288	-204	- 65	- 91
	%			8	21	19
Protein yield (g/day)	*	961	- 219	-175	- 89	-112
	%			6	18	14
Lactose yield (g/day)	*	1364	- 417	-363	-262	-262
	%			6	16	16
Milk energy (MJ/day)	*	97.6	-23.3	-18.1	-9.0	-10.6
	%			7	19	17
Body weight (kg)		562	25	14	12	11
	%			- 2	- 2	- 2

* Significant differences among treatments ($p \leq 0.05$)

$$\% = \frac{\text{L (or M or H)} - \text{C}}{\text{Weeks 1 to 12} + \text{C}} \times 100$$

Table VI. Least square means in weeks 1 - 12 and differences between weeks 13 - 36 and weeks 1 - 12 for levels of metabolites and hormones in plasma and somatic cell count, NEFA and minerals in milk per treatment group.

	Weeks 1 - 12	Treatment			
		C	L	M	H
	Mean	Differences			
Glucose (mmol/l)	3.65	-0.40	-0.25	-0.25	-0.41
3-Hydroxybutyrate (μmol/l)	706	- 152	- 69	- 55	- 11
NEFA (plasma) (μmol/l)	226	- 48	- 121	- 57	- 51
Urea (mg N/100 ml)	12.3	3.5	3.1	2.3	2.9
Cell count (log counts /ml)	5.4	0.0	0.2	0.2	0.1
NEFA (milk) (μmol/l)	206	- 35	- 35	- 68	- 67
Calcium (mg/l)	1175	20	67	59	16
Magnesium (mg/l)	110	3	5	5	4
Phosphorus (mg/l)	761	201	241	223	237
Insulin (ng/l)	326	84	112	90	126
T4 (μg/l)	43.9	5.6	4.6	10.7	9.1
Somatotropin (μg/l) *	1.27	-0.08	0.10	0.22	0.37

* Significant differences among treatments ($p \leq 0.05$)

Table VII. Residual correlations (x 100) between performance traits and plasma constituents in weeks 1 - 36.

	Energy intake	Milk yield	Fat yield	Protein yield	Lactose yield	Body weight	Gain
Glucose	-4	-32	-36	-20	-30	49	39
3-Hydroxybutyrate	9	21	15	9	23	12	-8
NEFA	8	-9	-5	2	-4	31	18
Urea	-25	-8	6	-15	-7	-56	11
Insulin	-13	-43	-49	-31	-46	46	22
T4	-27	-45	-50	-42	-43	34	40
Somatotropin	5	22	23	16	23	-51	-15

Correlations in absolute value larger than 28 are significantly different from zero.

Table VII is a summary of residual correlations between performance traits and plasma metabolites and hormones in weeks 1 - 36. Corresponding residual correlations in weeks 1 - 12 and weeks 13 - 36 showed close similarity and are therefore not presented separately. Milk yield traits were significantly negatively correlated with glucose, insulin and T4 levels, while the residual correlation with somatotropin tended to be positive. Body weight was significantly positively correlated with glucose, insulin and T4, and negatively with somatotropin.

Table VIII is an overview of residual correlations between plasma traits. Plasma-glucose level was positively associated with NEFA, insulin and T4 levels and negatively with the somatotropin concentration. The concentration of 3-hydroxybutyrate was positively correlated with NEFA and negatively with somatotropin, NEFA levels were positively related to T4 and insulin levels and negatively to somatotropin concentration. Insulin and T4 levels were positively correlated and showed individually a negative correlation with somatotropin.

Table VIII. Residual correlations (x 100) between plasma metabolites and hormones in weeks 1 - 36.

	2	3	4	5	6	7
1. Glucose	-24	38	-22	59	57	-28
2. 3-Hydroxybutyrate		38	-16	-7	12	-31
3. NEFA			-8	35	33	-32
4. Urea				-36	-16	53
5. Insulin					60	-39
6. T4						-30
7. Somatotropin						-

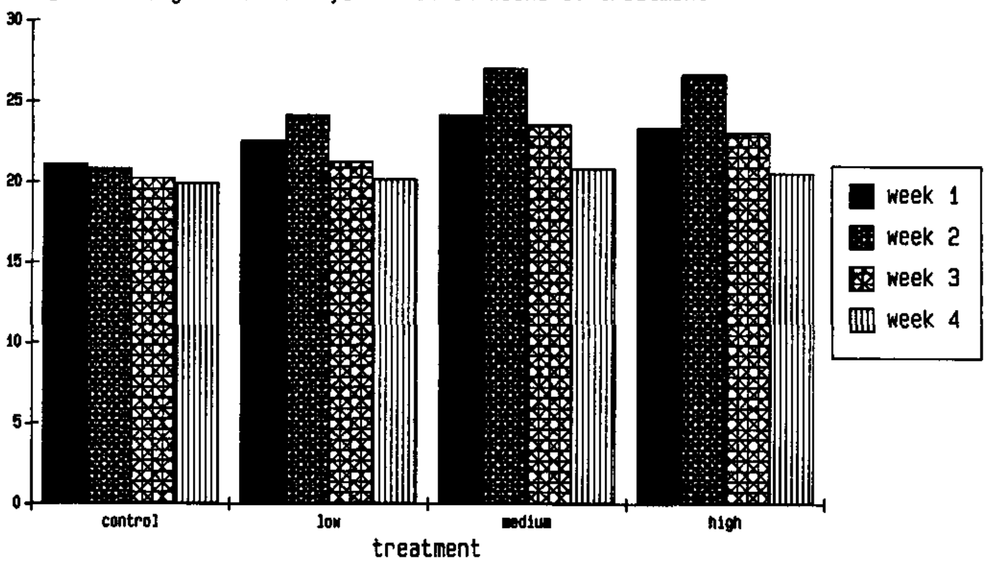
Correlations in absolute value larger than 28 are significantly different from zero.

Table IX is a description of the relationships between the difference in weeks 13 to 36 minus weeks 1 - 12 and the parameter values in weeks 1 - 12. For all traits of Table IX it can be concluded that the higher the value of the trait in the preliminary period the more negative is the difference between the treatment period (weeks 13 to 36) and the preliminary period (weeks 1 - 12). From the differences in the value of the regression coefficients among treatments it may be deducted that high yielders in the preliminary period may give a slightly lower milk production during BST treatment than low yielders.

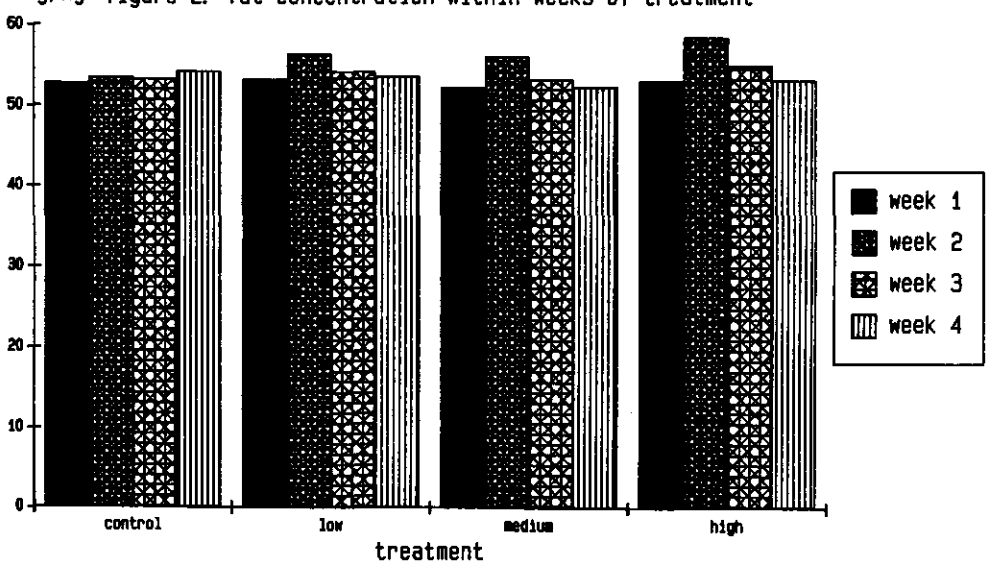
Table IX. Regression coefficients per treatment for the differences (week 13 to 36 minus week 1 - 12) on the averages in weeks 1 to 12.

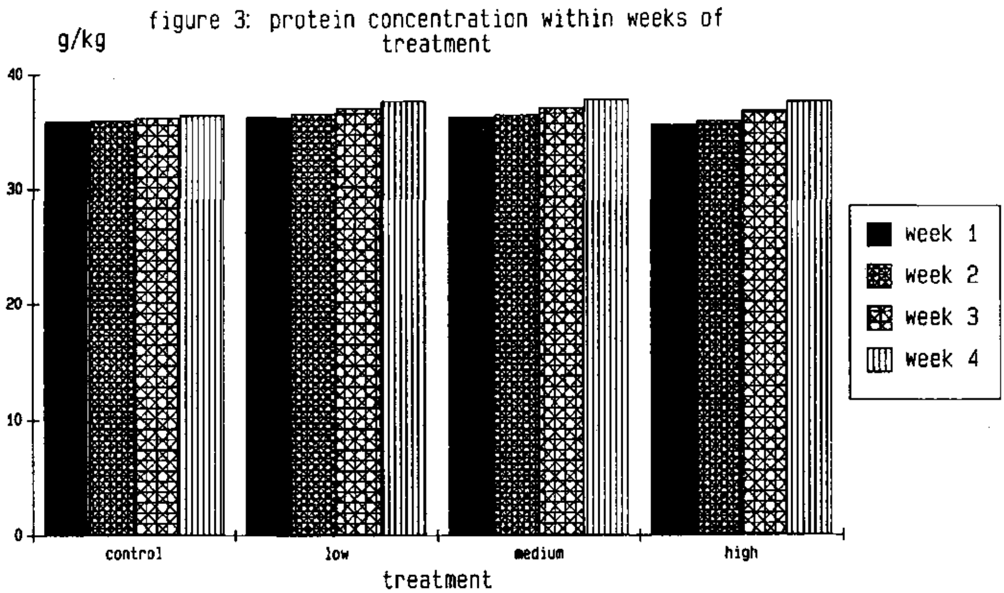
	Overall	p value	Treatment C	L	M	H	p value treatment
Energy intake (kJ)	-0.15	0.21	0.00	-0.05	-0.03	-0.51	0.28
Milk yield (kg)	-0.32	0.00	-0.01	-0.45	-0.25	-0.56	0.19
Fat yield (g)	-0.30	0.02	-0.02	-0.47	-0.40	-0.31	0.50
Protein yield (g)	-0.18	0.09	0.07	-0.47	-0.16	-0.18	0.29
Lactose yield (g)	-0.35	0.00	-0.04	-0.43	-0.30	-0.62	0.21
Body weight (kg)	-0.10	0.17	-0.23	+0.02	-0.02	-0.16	0.40
Glucose (mmol/l)	-0.35	0.06	-0.24	-0.55	-0.40	-0.19	0.88
3-Hydroxybutyrate (μmol/l)	-0.79	0.00	-0.78	-0.94	-0.56	-0.87	0.64
NEFA (plasma) (μmol/l)	-0.92	0.00	-0.53	-0.84	-1.16	-1.14	0.45
Urea (mg N/100 ml)	-0.55	0.00	-0.05	-0.64	-0.64	-0.88	0.29
Insulin (ng/l)	-6.44	0.01	-0.85	-4.17	-10.45	-10.28	0.36
T4 ($\mu g \times 10^{-3}/l$)	-2.49	0.10	-4.41	-4.96	-1.64	1.04	0.28
Somatotropin ($\mu g \times 10^{-3}/l$)	-4.86	0.00	-4.98	-6.28	-1.51	-6.69	0.64

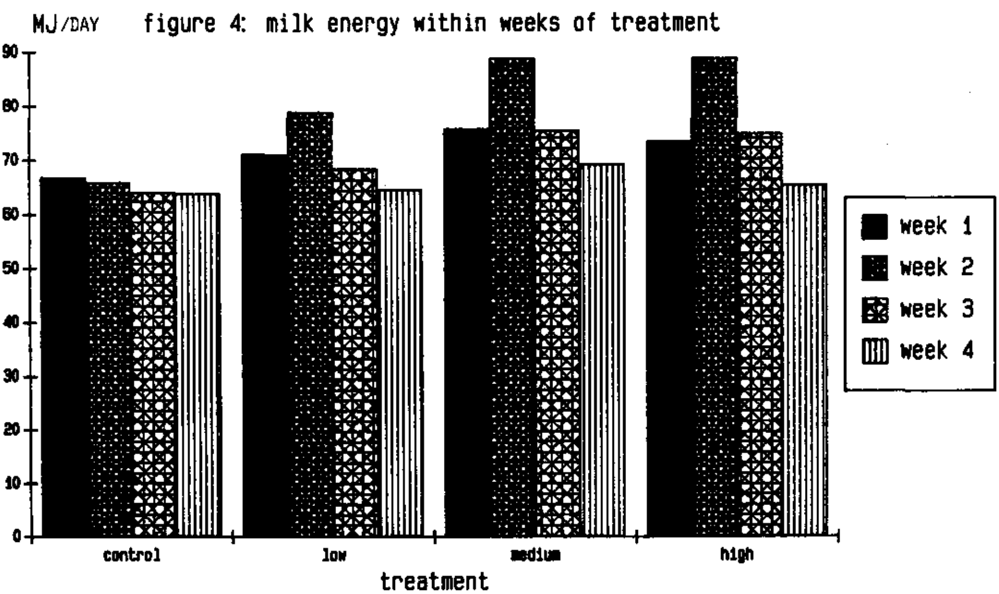
kg /DAY figure 1: milk yield within weeks of treatment



g/kg figure 2: fat concentration within weeks of treatment




g/kg
figure 3: protein concentration within weeks of treatment
40
30
20
10
0
control
low
medium
high
treatment
week 1
week 2
week 3
week 4


MJ/DAY
figure 4: milk energy within weeks of treatment
90
80
70
60
50
40
30
20
10
0
control
low
medium
high
treatment
week 1
week 2
week 3
week 4

Figures 1 to 4 illustrate the fluctuations in milk yield, fat concentration, protein concentration and milk energy among the four weeks of the six 28-day-treatment periods. For these traits significant week effects were found. For milk yield and milk energy an increase was established in the treated cows every second week and a decrease was found in every fourth week after treatment. Fat concentration was significantly higher in the second week after treatment in the treated animals. Protein percentage increased during a 28-day-treatment period, especially in the treated animals.

DISCUSSION

Breed x treatment interaction

So far, most studies with exogenous BST have been conducted in Friesian cows (Peel and Bauman, 1987). In the present study the DRW, Jersey and Fr cows differed significantly in energy intake, milk energy output and maintenance requirements. Compared to the Fr cows, energy intake of the DRW and Jersey cows was 7 and 15 per cent lower, milk energy was 11 and 13 per cent lower respectively, while metabolic body weight was 4 per cent higher for DRW cows and 25 per cent lower for Jersey cows. Despite these large differences among the breeds and among the BST treatments in milk production, no breed x treatment interaction was found for the studied traits.

The three dosages of somatotropin were administered irrespective of the differences among the breeds in average (metabolic) body weight. However, a statistical model including metabolic weight as an independent variable gave similar results as the statistical model used. So, optimum dosages of exogenous BST may be established without taking into account body weight of cows. A cautious conclusion of the present study might be that BST treatment will give quite similar results across dairy/dual purpose breeds in absolute values of yield traits.

Differences among breeds

In the present study differences among the breeds involved for feed intake, milk production and body weight were slightly smaller than reported by Oldenbroek (1988b) for the same breeds fed a similar complete diet in third lactation. He concluded that parity effects up to parity 3 influence differences among breeds and may be this could also apply to the present study with cows of higher parities. It is remarkable that, in spite of the large differences among breeds in performance traits, no differences were found in hormone levels. This could be associated with the rather small differences among the breeds in their utilization of feed energy for milk production (Table III).

Milk from Jersey cows have higher NEFA levels than milk from DRW and Fr cows. However, one has to take into account that fat concentration in Jersey milk is 1.5 times higher than in milk from DRW and Fr cows. The Jersey milk contains per liter more calcium, magnesium and phosphorus than milk from DRW and Fr cows. The milk calcium production ((mg/l) x kg milk) per kg dry matter intake was respectively 1363, 1409 and 1445 for the DRW, Jersey and Fr cows, for milk magnesium output 140, 122 and 134 respectively, and for milk phosphorus output 1117, 973 and 1113 respectively. So, differences among the breeds in mineral composition of the milk result in smaller differences among breeds in mineral requirements for milk production per kg dry matter.

Differences among treatments

Chronic administration of somatotropin to dairy cows in a positive energy balance generally shows an increase in milk yield (Peel and Bauman, 1987); milk composition, body weight and blood metabolites are not influenced. When cows in a negative energy balance are treated with somatotropin, milk fat concentration increases, milk protein concentration decreases and higher levels of 3-hydroxybutyrate in blood of treated animals might be expected. In our study an increase in milk fat concentration was found in treated animals, which was most pronounced in the second week of each 28-day-treatment period. An increase in protein percentage was found in treated animals during a period of 28 days. Plasma levels of 3-hydroxybutyrate tended to be higher in treated cows. This indicates that the increase in milk production of BST treated cows partly originates from body reserves in the first weeks after treatment, while on average the energy balances in these weeks were positive. Due to both the increase in milk production and only a slight increase in feed intake, the M and H cows gained slightly less. So body reserves play a role in the increase in milk production after BST treatment. This makes it necessary to estimate the effects of BST treatment over more than one lactation; such work is currently in progress.

In the present trial, BST treatment was started between 89 - 103 days after calving. This procedure gave the cows the opportunity to conceive before the start of treatment. Eight C, eight L, four M and six H cows did conceive before the start of BST treatment. This explains the differences in interval between calving and conception among the treatment groups. More animals should be studied in more than one lactation to facilitate conclusions about possible differences in fertility and diseases among treatment groups. A second reason to start BST treatment between 89 - 103 days after calving was to create a preliminary period for each animal in order to estimate effects of BST treatment within cows. This facilitates an accurate estimate of treatment effects with a small number of cows and facilitates to study the relationship between traits in the preliminary period and the effect of BST treatment.

Within breeds a negative relationship was found between milk production traits measured in the preliminary period and the increase in milk production after BST treatment. This means that within breeds low yielders may give a slightly higher milk production during BST treatment than high yielders. This agrees with findings of Leitch et al. (1987) which concluded that lower producing cows tended to respond better than their high producing counterparts. It is remarkable that in our study this relationship does not exist across the breeds.

From the results it can be concluded, that the M-dosage gave optimum results. The increase in milk production was less in the H group compared to the M group. If the slow release vehicle had given a steady output of BST over 28 days, the daily delivery would have been 11.4 mg, 22.9 mg and 34.3 mg for the L, M and H group, respectively. Increases in milk energy were respectively 7, 19 and 17 per cent. Bauman et al. (1985) found increases in milk energy of 19, 37 and 36 per cent for daily dosages of 13.5, 27.0 and 40.5 mg. They injected BST daily and adjusted the composition of the complete diet in the course of lactation according to individual milk yields which influenced energy intake and milk yield of control cows negatively. These two facts, and the release characteristics of the slow release vehicle, are probably the main reasons for a higher increase in milk energy in the study of Bauman et al. (1985) than in the present study. Both experiments indicate that the dose-response curve for exogenous BST is curvilinear and that the optimum dosage contains 20 - 30 mg

BST per day. The fluctuations in milk yield and milk composition indicate that the release characteristics of the release vehicle should be improved to get a more natural lactation curve for treated animals.

Relationships between traits

The effects of BST treatment were only significant for milk production and for somatotropin level in plasma. Residual correlations with somatotropin, estimated in a model including treatments, were corrected for exogenous somatotropin and differences in milk yield due to BST treatment. A discrepancy existed between the relationships among somatotropin and some other traits based on residual correlations and these relationships based on differences among the BST treated groups. E.g. a negative residual correlation was found between somatotropin and 3-hydroxybutyrate, whereas this metabolite increased for higher BST dosages. Urea had a positive residual correlation with somatotropin, whereas it tended to be lower in BST treated groups. The effects of exogenous BST on 3-hydroxybutyrate indicates fat mobilisation for milk production and the higher urea level in treated cows is an indication of the use of protein for lactose synthesis. The sign of the respective residual correlations of these metabolites with endogenous somatotropin can not be explained.

Concluding remarks

Six administrations with 640 mg BST in a slow release vehicle increased milk energy output by 19 % in weeks 13 - 36 in DRW, Jersey and Fr cows. For a total lactation of about 44 weeks this means an increase by 11 per cent. Within breeds the reaction in milk production after BST treatment is very variable and maybe slightly negatively related to milk production potential. Introduction of BST treatments in practice will influence milk recording data and could affect breeding value estimation, especially for bull dams. A possible interaction between genetic potential for milk production and BST treatment within breeds cannot be excluded.

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CHAPTER 8. GENERAL DISCUSSION

GENERAL DISCUSSION

In this chapter four subjects, which are studied in the previous chapters, will be discussed in general and conclusions will be drawn. These four subjects are:

1. Differences in feed intake between and within breeds; 2. Differences in feed efficiency between and within breeds; 3. The relationship between feed efficiency and feed intake, milk production and body weight; and 4. Possibilities to manipulate feed intake and feed efficiency. The discussion will be focussed on performance for milk production in a 39-weeks lactation period. Sometimes part-lactations will be considered and little attention will be paid to beef production. Throughout this chapter two definitions of feed efficiency for milk production will be used: a. biological efficiency = ratio between milk energy production and Net Energy (NE) intake and b. economic efficiency = returns from milk minus feed costs.

Differences in feed intake between and within breeds

In the experiments with HF, DF and DRW cows the largest difference in ad libitum dry matter intake was found between HF and DRW cows: on average 8 per cent (Table 1). When Jerseys were also involved, the largest difference existed between HF en Jersey cows: on average 22 per cent. These differences have great impact on the dairy farm. However, feed intake capacity, defined either as dry matter intake per kg metabolic body weight per day or as dry matter intake per kg body weight per day, was highest in the Jersey cows and lowest in the DRW cows (Table 1). The high feed intake capacity of the Jersey cow might be related to a different body conformation compared to the other breeds. E.g. the ratio between rump length and body weight is for the Jersey, HF, DF and DRW cows respectively: 0.37, 0.28, 0.28 and 0.27 cm per kg. The ratio between pelvic height and body weight is respectively: 0.31, 0.24, 0.24 and 0.22 cm per kg (De Rooy and Oldenbroek, 1988). Probably, these differences in body conformation allow the Jersey cow to consume more feed per kg (metabolic) body weight than e.g. the DRW cow. Feed intake capacity has a negative relation with the score for fleshiness on the alive animal and with dressing percentage after slaughter, which might explain the differences in feed intake capacity between the HF, DF and DRW cows.

Table 1. Dry matter intake and two parameters for feed intake capacity in weeks 1 - 39 of lactation for Jersey, HF, DF and DRW cows in parity 1 - 3 on a concentrates (C) diet or a roughage (R) diet.

Trait	Parity	Breed/diet							
		Jersey		HF		DF		DRW	
		C	R	C	R	C	R	C	R
Dry matter intake (kg)	1	3417	2739	4614	3548	4330	3484	4248	3344
	2	-	-	5017	4078	4883	4109	4353	3874
	3	4380	4152	5656	5087	5293	4990	5180	4666
Dry matter intake per kg body weight per day (g)	1	35	31	32	27	31	27	29	24
	2	-	-	30	28	31	27	28	26
	3	37	38	32	30	33	30	28	26
Dry matter intake per kg metabolic weight per day (g)	1	152	131	154	127	148	124	140	116
	2	-	-	149	133	154	133	136	124
	3	167	169	161	151	161	150	142	132

The ranking of the breeds for these slaughter quality traits is reversed compared to feed intake capacity and is for the Jersey, HF, DF and DRW cows respectively 3.2, 3.7, 6.5 and 6.9 for the score for fleshiness in the EUROP system on a scale from 1 (= poor) to 15 (= highest) and respectively: 43, 45, 47 and 49 per cent for dressing percentage of culled cows (De Rooy and Oldenbroek, 1988). So, from the comparison among breeds it might be concluded that, relatively to body weight, long and tall cows have a high feed intake capacity. A higher feed intake capacity is associated with a lower fleshiness and a lower dressing percentage after slaughter. It will be worthwhile to study, for predictive purposes, these relationships within breeds, because body traits can be measured more easily than feed intake capacity. Differences between breeds in dry matter intake were, on an absolute basis, slightly higher for higher parities, especially on the roughage diet. This was associated with smaller differences between breeds in milk production for higher parities on the roughage diet. The increase in feed intake capacity in higher parities gives more possibilities for feeding high amounts of roughage to cows of higher parities. The higher feed intake capacity of older cows was not associated with higher ratios for rump length and body weight and pelvic height and body weight, compared to heifers. Within breeds (within breed x diet x parity groups) there still exists a considerable phenotypic standard deviation of 1.15 kg d.m. per day. The repeatability of dry matter intake (0.39) is slightly lower than that for milk yield (0.47), but indicates a genetic variance within breeds for feed intake.

After these studies the question can be raised, whether possibilities exist to predict differences in feed intake between and within breeds, without conducting feed intake experiments. Table 2 indicates, that within diets, the calculated percentage of energy available for gain in general shows minor differences between breeds (with an exception for parity 2, where the DF had exceptional high values for this trait). Practically, differences in feed intake among breeds fed a similar diet, may be approximated from differences among breeds in requirements for milk production and maintenance. The residual energy for gain will depend on the concentrates level of the diet. A higher concentrates level is associated with higher levels of propionic acid, resulting in more glucogenic nutrients at the expense of lipogenic nutrients. Such a situation is believed to cause a higher level of insulin in the blood, which results in a higher fat deposition in the body and a relatively lower milk energy output, particular energy in fat. Within breed x diet x parity groups the differences among animals in ad libitum Net Energy intake were mainly related to differences in milk energy production, metabolic body weight and gain. These three characteristics explain approximately 90 per cent of the variance in Net Energy intake within breed x diet x parity groups. The residual standard error in such a model is equal to the energetic value of approximately 1 kg roughage (d.m. per day). So, the prediction of voluntary feed intake of an individual cow is far from precise.

Table 2. Residual energy for gain per breed in the diet groups in weeks 1 - 39 in different parities (in MJ).

Parity		Diet/breed							
		Concentrates				Roughage			
		Jersey	HF	DF	DRW	Jersey	HF	DF	DRW
1	MJ	2626	4192	4589	4209	-345	484	1499	1130
	% *	11	13	16	15	-1	2	7	5
2	MJ	-	1944	5367	2724	-	195	3445	1037
	%		1	17	9		1	13	3
3	MJ	4842	4973	5600	6173	626	1026	3594	1750
	%	16	13	15	18	2	3	11	6

* intake = 100

Conclusion: Large differences between breeds exist in voluntary feed intake which are related to differences in feed requirements for milk production and maintenance. Feed intake capacity increases with parity, especially on a roughage diet. Only when Jerseys are involved in the comparison, these differences in feed intake depend on the concentrates level of the diet. Also within breeds variation in voluntary feed intake exists, which has partly a genetic origin. Differences in feed intake capacity between breeds may be related to differences in body conformation and are negatively related to slaughter quality.

Differences in feed efficiency between and within breeds

The main factors affecting biological efficiency for milk production were breed, stage of lactation and within the Jersey breed the type of the diet. The differences among breeds in biological efficiency are associated with differences in the ratio between milk energy production and maintenance requirements. This ratio is higher in the dairy breeds (Jersey, HF) than in the dual purpose breeds (DF, DRW). Between these breeds no differences were found in plasma levels of hormones involved in metabolism: insulin, thyroxin and somatotropin. Maybe the absence of these differences is associated with minor differences among breeds in the ratio milk energy production and energy for gain. The effect of stage of lactation on biological efficiency is a change in partition of feed energy between milk production and gain during lactation (Chapter 2: Table VI; Chapter 3: Table VII; Chapter 4: Table V and Chapter 5: Table VII). This was a reason to study differences in efficiency among breeds at least during a full lactation period. Mobilising body tissues or restoring them has a large impact on efficiency in respectively the first and the last part of lactation. When efficiency for milk production between breeds has to be determined in a short period of measuring feed intake, the second three months of lactation will be the best period. In that part biological efficiency for milk production reflects best the biological efficiency for milk production in total lactation. Jersey cows had a higher biological efficiency on the roughage diet than on the concentrates diet. Compared to the other breeds Jerseys need 7 % more lipogenic, 2 % less aminogenic and 5 % less glucogenic precursors for milk synthesis. Therefore, a roughage based diet fits better to their feed requirements than a concentrates based diet. Within breeds (breed x diet x parity groups) the phenotypic standard deviation of biological efficiency for milk production is 4.6 per cent (mean = 58.7 per cent). Its repeatability is 0.46, which indicates a genetic variance for this trait within breeds.

Using current Dutch prices for milk components and diet components, economic efficiency for milk production was considerably influenced by breed, diet and parity. Within diet groups the dairy breeds had a higher economic efficiency for milk production than the dual purpose breeds. In first and second lactation the concentrates diet gave more profit than the roughage diet, while especially in the dairy breeds, economic efficiency in the third parity was higher on the roughage diet. However, differences in feed costs between the diets depends largely on the price ratio between concentrates and roughage. The increase in feed intake capacity in higher parities facilitates the use of cheaper roughage for milk production in older cows. In situations where cows are used to produce milk and beef, the economic efficiency for milk production does not fully determine the total economic efficiency of a breed. Oldenbroek (1984) showed in an economic evaluation of a comparison of HF, DF and DRW cows that the economic advantage of a breed is a function of its milk and beef production traits and the prices for milk, beef and feeds. In a study after the introduction of the milk quota system in the EEC, Oldenbroek and De Rooy (1986) pointed out that in the short term the replacement of a dual purpose breed (DRW) by a dairy breed (HF) was not worthwhile for many Dutch farms, despite the much higher economic efficiency for milk production of the dairy breed. Within breeds (within breeds x diet x parity groups) the phenotypic standard deviation of economic efficiency for milk production is Dfl. 295.-. The repeatability (0.37) indicates also a genetic variation within breeds for this trait.

Conclusion: Because of a higher ratio between milk production and body weight, dairy breeds have a higher biological and economic efficiency for milk production. Also within breeds variation exists for these two traits of efficiency for milk production, which is partly of genetic origin. However, price ratios between milk, beef and feed and market restrictions considerably influence the total economic efficiency of a breed at farm level.

Relationship between efficiency and feed intake, milk production and body weight

The two efficiency traits are a function of milk production and feed intake. Besides for milk production, consumed feed is needed for maintenance and eventually for gain. Therefore it is worthwhile to study the relationship between efficiency and the traits involved in the partition of consumed Net Energy. Table 3 presents correlations between cow effects in different lactations (RF) and residual correlations (RE) between performance traits and biological and economic efficiency for milk production within breed x diet x parity groups. (The method of calculation is described in Chapter 6.) From the correlations between cow effects it can be concluded that biological and economic efficiency may become improved by a higher milk yield and by a lower gain during lactation. Dry matter intake has no relationship with biological efficiency, but has a positive relationship with economic efficiency. This may be caused by a favourable ratio between the current Dutch prices for milk and feed.

Table 3: Correlations between cow effects (RF) and residual correlations (RE) between performance traits and efficiency traits (x 100).

	Biological efficiency		Economic efficiency	
	RF	RE	RF	RE
Dry matter intake	1	-20	42	37
Milk yield	79	58	82	89
Average body weight	-29	-23	4	-21
Gain	-82	-25	-76	-26

Conclusion: Breeding and management activities aimed at a higher milk yield will improve biological and economic efficiency. Increasing dry matter intake or average body weight has no positive effect on biological efficiency. Increasing gain during lactation has a negative effect on biological and economic efficiency. Increasing milk production is most effective to improve economic efficiency.

Possibilities to manipulate feed intake and feed efficiency

Three possibilities to manipulate feed intake and feed efficiency will be considered:

- changing the concentrates to roughage ratio of the diet
- administration of dairy cows with bovine somatotropin
- genetic improvement.

Adding concentrates to a roughage diet increases the energy content of the ration, but roughage intake will decrease. Because of the substitution rate between roughage and concentrates is less than unity, the ad libitum dry matter intake of the total ration increases. The substitution rate depends on roughage and concentrates characteristics, amount of concentrates supplied, parity (Kirchgessner and Schwarz, 1984) and stage of lactation (Korver, 1982). Effects of parity and stage of lactation are not consistent in this literature. Oldenbroek (1979) found no differences between HF, DF and DRW cows in the substitution rate of roughage and concentrates. The C diet contained 50 cent concentrates on a dry matter basis, apart from the similar roughage components as the R diet. Therefore, the substitution rate between roughage and concentrates for the breed x parity groups can be derived from differences in intake between the C and R diet. The results of these calculations are presented in Table 4.

Table 4. The substitution of roughage by concentrates per breed x diet group.

Parity	Breed			
	Jersey	HF	DF	DRW
1	0.60	0.54	0.61	0.57
2	-	0.63	0.68	0.78
3	0.90	0.80	0.89	0.80

From Table 4 it can be concluded that breed effects on the substitition rate are smaller than parity effects. Adding concentrates to a diet results in a lower increase of total dry matter intake in older cows than in heifers. Probably, on a roughage diet the feed requirements of older cows are better fulfilled because of a higher feed intake capacity of older cows compared to heifers. Based on the residual energy for gain in different periods of lactations of different parities (Chapter 2: Table VI; Chapter 3: Table VII; Chapter 4: Table V and Chapter 5: Table VII) a feeding strategy might be developed for feeding complete diets ad libitum to dairy cows. In the first three months cows and heifers can be fed with a concentrates based diet. In the next three months heifers should remain on this diet, while older cows can already be fed a high quality roughage diet. The latter diet can be fed to cows as well as heifers in the last months of lactation.

As outlined previously, concentrates feeding slightly decreases the biological efficiency of the dairy breeds, because it slightly stimulates gain. The effect of concentrates feeding decreases with increasing parity, especially in the dairy breeds.

Long term treatment of dairy cows with recombinantly derived bovine somatotropin (BST) increases milk production, gives a slight increase in voluntary feed intake and increases feed efficiency by diluting maintenance requirements per kg milk (Peel and Bauman, 1987). In our study 640 mg BST, administered once per 28 days, increased milk energy production by 19 per cent (from 12482 MJ to 14885 MJ per day) and increased energy intake by 7 per cent (from 21521 MJ NE to 23016 MJ NE per day) during a treatment period of 168 days, which started on average 96 days after calving. Practiced in this way, BST treatment can be regarded as a tool to increase persistency of lactation. During the treatment period biological efficiency for milk production was improved from 58 to 65 per cent. BST treated cows had less energy available for gain than control cows. Milk composition and plasma concentrations of metabolites indicated the involvement of adipose tissues in milk synthesis. Synthesis of milk via adipose tissues is less efficient than a direct synthesis of milk from nutrients (Van Es and Van der Honing, 1979). This is one of the reasons to study the effects of BST treatment over more than one lactation. Energy balance studies may give a complete view of the effect of BST treatment on the involvement of adipose tissues in milk synthesis. Within breeds the reaction in milk production on BST treatment is highly variable and maybe slightly negatively related to milk production potential. Introduction in practice will considerably influence breeding value estimation. Therefore BST treatment should be registered in milk recording data bases. The profitability of BST treatment depends on farm and market conditions: nutritive value of roughages, milk prices, quota systems, feed costs and the costs of injections. At the moment practical recommendation of BST treatment to improve efficiency of milk production can not be made. More facts should be known about effects in consecutive lactations and about the effects on fertility and health.

Feed costs determine a great part of production costs in dairy production. It is, to some extent, curious to discuss possibilities to increase feed intake of dairy cows by selection, because it would result, at first sight, in increasing production costs. Nevertheless, selection for feed intake may give lower feed costs by avoiding milk synthesis from adipose tissues in early lactation and by creating possibilities to supply cheaper feeds (roughage) during lactation (Gravert, 1985 and Korver, 1987). It is questionable whether milk synthesis from adipose tissues can be avoided in early lactation by a higher feeding level. Several studies with high energy diets in early lactation (e.g. Van der Honing et al., 1982 and De Visser et al., 1983) or with feeding more concentrates in early lactation (e.g. Broster et al., 1969) showed an increase in milk yield and an equal gap between energy intake and energy requirements as the control groups, which were tried to feed according to their requirements. Table 5 is a summary of residual correlations between energy intake and milk energy, maintenance requirements, energy available for gain and biological efficiency in different periods of lactation.

Table 5. Residual correlations (x 100) in two experiments for different subperiods of lactation between energy intake and milk energy, maintenance, gain and biological efficiency.

		Milk energy		Maintenance		Gain		Efficiency	
	Experiment*	1	2	1	2	1	2	1	2
	months:								
Energy	1 - 3	58	62	52	26	53	36	-25	-9
intake	4 - 6	58	68	45	22	63	55	-19	1
	7 - 9	49	73	15	-9	67	42	-19	37
	1 - 9	60	76	28	13	51	37	-7	23

* Experiment 1 = material chapter 4, 2 = material chapter 5.

The correlation between energy intake and maintenance and efficiency differs between the parities (experiment 1 (heifers) versus 2 (cows)). The correlations do not differ substantially between subperiods of lactation. Gravert (1985) found a much lower genetic correlation between milk yield and feed intake in early lactation than in later lactation, which resulted in an advice to use feed intake capacity in early lactation as a selection goal. A high feed intake capacity during the entire lactation might be a better selection goal. It creates the possibility to feed more roughage throughout lactation. As can be deducted from Table 3, when cow effects reflect genetic effects, selection on feed intake will not improve biological efficiency for milk production and is less effective than milk yield to improve economic efficiency.

Within the present breeding schemes there is hardly a possibility to select at reasonable costs for a high feed intake. At the moment, only the performance test of potential AI bulls at central stations offers the possibility to measure feed intake between 4 - 12 months of age (Korver, 1987). It is questionable whether feed intake of a young growing bull will have a strong rela tionship with the feed intake of his daughters at a higher age during lactation. Danish and Dutch trials are underway to study this relationship (Korver, 1987). Nucleus breeding schemes (Nicholas and Smith, 1983) offer the possibility to measure feed intake of potential bull dams because these cows are kept at a limited number of farms. As discussed previously in this chapter, maybe body measurements can predict feed intake capacity. This should considerably facilitate selection for feed intake capacity.

Conclusion: Feed intake of dairy cows can be manipulated by changing the ratio between diet components and to a limited extent by BST treatment. Possibilities to improve feed intake by selection are limited at the moment. Feed efficiency can be slightly influenced by diet manipulation. Administration of BST to dairy cows and selection for milk yield have a positive effect on feed efficiency by diluting maintenance costs per kg milk.

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CHAPTER 9. SUMMARY

FEED INTAKE AND ENERGY UTILIZATION IN DAIRY COWS OF DIFFERENT BREEDS

SUMMARY

Improvement of nutrition of dairy cows and improvement of the genetic capacity for milk production aim to improve the efficiency of converting feed into milk. This efficiency can be expressed as the ratio between energy in milk and Net Energy intake (defined as the biological efficiency) or as the difference between returns from milk and feed costs (defined as the economic efficiency). In these two definitions of efficiency the relationship between feed intake and milk production is very important. Little is known about genetic differences in feed intake and feed efficiency and a possible interaction with diet composition. Genetic differences among cows may be reflected in differences between groups of cows of different breeds, which are selected with a different breeding goal. Differences in diet composition are reflected in complete diets, which differ in the ratio between concentrates and roughages.

The aim of this thesis is to describe differences between dairy breeds in feed intake and in partition of Net Energy between milk production, maintenance and gain in different circumstances: different parities, different parts of lactation, feeding ad libitum complete diets which differ in roughage content and treatment with different dosages of bovine somatotropin. Relationships between feed intake and milk production, maintenance and gain are presented in the different circumstances. Possibilities to manipulate feed intake and energy utilization in dairy cattle are outlined.

The study is based on feed intake experiments with cows of four breeds: the Jersey, the Holstein Friesian (HF), the Dutch Friesian (DF) and the Dutch Red and White (DRW). In four experiments the cows were fed ad libitum two completely mixed diets with respectively 0 and 50 per cent concentrates. In a fifth experiment cows of different breeds were treated with bovine somatotropin (BST), while fed ad libitum a diet with 50 per cent concentrates. In all trials the roughage was a mixture of corn silage and of high quality grass silage or artificially dried grass.

In Chapter 2 an experiment with HF, DF and DRW heifers is described. From 2 months before the first calving until 10 months of lactation they were fed ad libitum a complete diet with roughages or a complete diet of the similar roughages with 50 per cent concentrates on a dry matter basis. In the experimental period of 52 weeks the breeds differed significantly in energy intake, milk energy production and in biological efficiency. In the HF, DF and DRW heifers these figures were respectively: 32601, 30884 and 30581 MJ NE in feed; 16553, 15086 and 14814 MJ energy in milk and 51, 49 and 48 per cent. Despite large differences in feed energy intake and milk energy production between the concentrates (C) and roughage (R) diet (8500 MJ NE and 4246 MJ) no significant interaction was found between breed and diet composition for any of the studied characteristics. The biological efficiency for milk production was equal for the C and R diet: 49 per cent. Body weight gain of the concentrates group was 59 kg higher than that of the roughage group.

In Chapter 3 the results of a feed intake study with HF, DF and DRW cows in second lactation are presented and discussed. These cows participated in the study described in Chapter 2 on the same diets. In this experiment their feed intake was measured from two months before the second calving until 10 months of the second lactation. For none of the studied traits a significant interaction between breed and diet composition was found: differences between breeds were independent of diet composition. In the HF, DF and DRW cows feed energy intake was 35052, 35182 and 32015 MJ NE respectively; milk energy was 18700, 15475 and 15548 MJ respectively and biological efficiency 55, 44 and 48 per cent respectively. Between the concentrates and the roughage diet the difference in feed energy intake was 6210 MJ NE, in milk energy production 4423 MJ and in biological efficiency on an absolute basis 4 per cent. The increase in milk yield from first to second lactation was significantly higher in the HF cows than in the DF and DRW cows. The body weight gain of the concentrates group in second lactation was much less than in first lactation.

Chapter 4 reports on an experiment with Jersey heifers and a control group of HF + DF + DRW heifers, which were fed a complete diet of roughages or a complete diet of the similar roughages and 50 per cent concentrates on a dry matter basis in the first 39 weeks of lactation. Significant interactions between breed and diet composition were found for feed energy intake, milk yield, fat percentage in milk, milk protein yield and milk energy production. For these traits the differences between the breeds were dependent of the diet composition. Mean differences between the Jersey and the HF + DF + DRW heifers on the C diet and on the R diet (in parentheses) were: -6527 (-4319) MJ NE for feed energy intake; -1791 (-991) kg for milk yield; 2.31 (1.84) for fat percentage; -5 (-16) kg for protein yield and -2533 (-898) MJ for milk energy production. These breed x diet interactions might be caused by a higher feed intake capacity of the Jersey heifers compared to the HF + DF + DRW heifers and the relatively higher need of Jerseys for lipogenic precursors and a lower need for aminogenic and glucogenic precursors for milk synthesis, which have better been provided for on the roughage diet. The biological efficiency for milk production was 65 per cent for the Jersey heifers on the roughage diet, 59 per cent for the Jersey heifers on the concentrates diet, 56 per cent for the HF + DF + DRW heifers on the R diet and 55 per cent for the HF + DF + DRW heifers on the C diet.

In Chapter 5 a further study with Jersey cows and a control group of HF + DF + DRW cows is described. After their third calving these cows, which participated in the former study as a heifer, were fed the same diets as in the previous described study. Again body weight, milk production and feed intake were recorded in the first 39 weeks of lactation. Only for fat percentage of milk a significant interaction between breed and diet composition was found. Mean differences between the Jersey and the HF + DF + DRW cows on the C diet and on the R diet (in parentheses) were -6460 (-5162) MJ NE for feed energy intake; -2560 (-1707) kg for milk yield; 2.82 (2.38) for fat percentage in the milk; -55 (-26) kg for protein yield and -3241 (-1112) MJ for milk energy production. The increase in Net Energy intake and milk yield from first to third lactation was for the Jerseys and the HF + DF + DRW cows on the C diet 25 and 24 per cent, respectively and on the R diet 48 and 51 per cent respectively. The biological efficiency for milk production was 69 per cent for the Jerseys on the roughage diet, 57 per cent for the Jerseys on the C diet, 61 per cent for the HF + DF + DRW cows on the R diet and 56 per cent for the HF + DF + DRW cows on the C diet.

In Chapter 6 the effect of parity on feed intake and feed efficiency are established in weeks 1 - 39 of lactation. For this purpose 265 lactations of 159 cows out of the experiments described in the Chapters 2 - 5 were available. Unequal variances among breeds in the different parity x diet groups and some differences in ranking of the breeds caused a significant three-way interaction parity x breed x diet. In general, the differences between the C and R diet groups in feed intake and milk production decreased with increasing parity. Biological efficiency was not affected by parity. Economic efficiency increased in higher parities, which was most pronounced on the R diet. The presence of data from cows in two lactations facilitated calculations of repeatabilities for the studied traits. Repeatabilities for fat concentration (0.75), protein concentration (0.68) and average body weight (0.69) were high. Repeatabilities for dry matter intake (0.39), milk yield (0.47), biological efficiency (0.46), economic efficiency (0.37) and gain during lactation (0.27) were lower. An attempt to detect possible differences between parities, diets and breeds in Net Energy requirements for milk production, maintenance and gain was not successful. A multiple regression of Net Energy intake on milk energy, metabolic weight and gain yielded unrealistic coefficients of regression, which might be due to measurement errors for the independent variables and to relationships between these variables.

Chapter 7 is a description of an experiment with Jersey, Friesian and Dutch Red and White cows, which were treated from week 13 to week 36 of lactation with recombinantly derived bovine somatotropin in a sustained delivery vehicle. After an 84 days pretreatment period four treatments were used: an untreated control and three different levels of somatotropin administered once every 28-days in a sustained delivery vehicle by subcutaneous injection. From weeks 1 - 36 the cows were fed ad libitum a complete diet of 50 per cent concentrates and 50 per cent roughage. No significant interaction between breeds and treatment was detected. In the three breeds the 640 mg-dosage gave optimum results: an increase in daily milk yield of 3.3 kg was found and fat percentage increased by 0.24 per cent. The plasma levels of 3-hydroxybutyrate tended to be higher in treated cows and fat percentage of their milk showed large variations within a four weeks period, which both indicate the involvement of adipose tissues in the response in milk fat production after BST-treatment. This is one of the reasons to study effects of exogenous bovine somatotropin over more than one lactation. Cows with a higher milk yield in the pretreatment period, showed a slightly lower increase in milk production after treatment with somatotropin than cows with a lower milk yield in the pretreatment period.

Chapter 8 is a general discussion, which founds the conclusions of this thesis. Between breeds differences exist in voluntary feed intake, which are related to differences in their feed requirements. Jerseys have a much lower voluntary feed intake than Holstein Friesians, Dutch Friesians and Dutch Red and Whites. However, the feed intake capacity (feed intake in relation to body weight) is higher in the Jerseys. When Jerseys are involved in a breed comparison, the differences between the breeds depend on the concentrates level of the diet. Jerseys have a different ratio between fat, protein and lactose in the milk compared to the other breeds, which might be an explanation for the breed x diet interaction, when Jerseys are involved in a comparison with larger breeds. Differences in feed intake capacity between breeds are associated with differences in body conformation and are negatively related to slaughter quality traits. Feed intake capacity increases with parity, especially on a roughage diet. The Jerseys and Holstein Friesians have a higher biological and economic efficiency for milk production than Dutch Friesians and Dutch Red and Whites, because of a higher ratio between milk energy production and maintenance requirements. Stage of lactation has a considerable effect on biological efficiency. Biological efficiency for milk production is slightly lower on a concentrates diet than on a roughage diet. Differences between breeds in biological efficiency are more pronounced on the roughage diet. Differences between breeds in economic efficiency are dependent on the diet. The profitability of concentrates feeding decreases with increasing parity, especially in the dairy breeds. The total economic efficiency of a breed on farm level is mainly determined by prices for milk, beef and feed and by market restrictions. Biological and economic efficiency can be improved by a higher milk yield. Biological efficiency is not affected by differences in dry matter intake or body weight. Feed intake of dairy cows is greatly influenced by the ratio between concentrates and roughage in the diet and to a limited extent by treatment with bovine somatotropin. The ratio between concentrates and roughage in the diet has a minor effect on feed efficiency. Administration of bovine somatotropin and selection for milk yield has a positive effect on feed efficiency by diluting maintenance costs per kg milk.

CHAPTER 10. SAMENVATTING

VOEROPNAME EN ENERGIEBENUTTING BIJ MELKKOEIEN VAN VERSCHILLENDE RASSEN

VOEROPNAME EN ENERGIEBENUTTING BIJ MELKKOEIEN VAN VERSCHILLENDE RASSEN

SAMENVATTING

In de melkveehouderij wordt getracht de voeding van melkkoeien en hun erfelijke aanleg voor melkproduktie te verbeteren met als doel de efficiëntie van de omzetting van voer in melk te verhogen. De efficiëntie van de omzetting van voer in melk kan weergegeven worden als de verhouding tussen de netto energie in melkproduktie en in voeropname: de biologische efficiëntie of als het verschil tussen de geldelijke opbrengst van de melkproduktie en de voerkosten: de economische efficiëntie. In beide definities speelt de relatie tussen de voeropname en de melkproduktie een belangrijke rol. Er is weinig bekend over erfelijke verschillen in voeropname en in de omzetting van voer in melk en over een eventuele wisselwerking met de samenstelling van het rantsoen. Erfelijke verschillen tussen koeien kunnen weerspiegeld worden door verschillen tussen groepen koeien van verschillende rassen, die gefokt zijn voor een verschillend doel. Verschillen tussen rantsoenen kunnen aangebracht worden door gebruik te maken van complete voeders voor melkvee, die verschillen in ruwvoer-krachtvoer verhouding.

Het doel van dit proefschrift is het beschrijven van de verschillen tussen melkveerassen in voeropname en in de verdeling van de netto energie in het voer over melkproduktie, onderhoud en groei. De effecten van leeftijd (pariteit), lactatiestadium, de verhouding tussen ruwvoer en krachtvoer in het rantsoen en van behandeling met verschillende doses bovine somatotropine op deze verschillen zijn vastgelegd. De mogelijkheden om de voeropname en de efficiëntie van de omzetting van voer in melk te veranderen, worden besproken.

De basis van het onderzoek wordt gevormd door voeropnameproeven met koeien van vier verschillende rassen: de Jersey, de Holstein Friesian (HF), de Nederlandse zwartbonte (FH) en de Nederlandse roodbonte (MRIJ). In vier proeven werden twee volledig gemengde rantsoenen (complete voeders) met respectievelijk 0 en 50 procent krachtvoer ad libitum gevoerd. In een vijfde proef werden de koeien behandeld met runder somatotropine (BST), terwijl ze ad libitum gevoerd werden met een compleet voer met 50 procent krachtvoer. In alle proeven

bestond het ruwvoer uit een mengsel van maissilage en grassilage van hoge kwaliteit of kunstmatig gedroogd gras.

In hoofdstuk 2 wordt een proef met HF, FH en MRIJ vaarzen beschreven. Vanaf 2 maanden voor tot en met 10 maanden na afkalven zijn ze ad libitum gevoerd met een compleet voer, dat alleen uit ruwvoer bestond of een compleet voer dat bestond uit hetzelfde ruwvoer aangevuld met 50 procent krachtvoer op drogestof basis. In de proefperiode van 52 weken waren er significante verschillen tussen rassen in energieopname uit voer, melkenergieproduktie en in biologische efficiëntie voor melkproduktie. De waarden van deze kengetallen waren voor de HF, FH en MRIJ vaarzen respectievelijk: 32601, 30884 en 30581 MJ NE*) in voer, 16553, 15086 en 14814 MJ energie in melk en 51, 49 en 48 procent. Ondanks de grote verschillen tussen de krachtvoer- (K) en de ruwvoergroep (R) in energieopname uit voer (8500 MJ NE) en in melkenergieproduktie (4246 MJ) werd voor geen van de onderzochte kenmerken een significante wisselwerking tussen ras en rantsoen aangetoond. De biologische efficiëntie voor melkproduktie was op het krachtvoer- en ruwvoerrantsoen gelijk (49 procent). Tijdens de proef nam de K-groep 59 kg meer in lichaamsgewicht toe dan de R-groep.

In hoofdstuk 3 worden de resultaten van een proef met HF-, FH- en MRIJ-koeien in de tweede lactatie gepresenteerd en besproken. De koeien waren afkomstig uit de proef die in hoofdstuk 2 beschreven is. Aan hen werd hetzelfde rantsoen verstrekt als in de eerste lactatie. In deze proef werd de voeropname gemeten vanaf de tweede maand voor de geboorte van het tweede kalf tot en met de tiende maand van de tweede lactatie. Ook in deze proef werd geen wisselwerking aangetoond tussen ras en voersamenstelling: de verschillen tussen rassen waren voor alle kenmerken onafhankelijk van het gevoerde rantsoen. De voeropname van de HF-, FH- en MRIJ-koeien was respectievelijk: 35052, 35182 en 32015 MJ NE, de melkenergieproduktie was respectievelijk: 18700, 15475 en 15548 MJ en de biologische efficiëntie voor de melkproduktie was respectievelijk 55, 44 en 48 procent. Tussen de krachtvoergroep en de ruwvoergroep was het verschil in voeropname 6210 MJ NE, in melkenergieproduktie 4423 MJ en in biologische efficiëntie 4 procent (absoluut verschil). De stijging in melkproduktie van de eerste naar de tweede lactatie was voor de HF-koeien hoger dan voor de

*) 1 MJ NE = 145 VEM

FH- en MRIJ-koeien. In de tweede lactatie nam de krachtvoergroep veel minder in gewicht toe dan in de eerste lactatie.

In hoofdstuk 4 worden de resultaten van een proef met Jersey-vaarzen en een controlegroep van HF + FH + MRIJ-vaarzen samengevat. In de eerste 39 weken van de lactatie werden deze vaarzen ad libitum gevoerd met een compleet voer, dat geheel uit ruwvoer bestond of met een compleet voer met hetzelfde ruwvoer, aangevuld met 50 procent krachtvoer op basis van de drogestof. Voor de Netto Energieopname, de melkproduktie, het vetgehalte van de melk, de melkeiwitproduktie en de melkenergieproduktie werd een wisselwerking gevonden tussen ras en voersamenstelling. Voor deze kenmerken waren de verschillen tussen de rassen afhankelijk van het rantsoen. Gemiddeld waren de verschillen tussen de Jersey-vaarzen en de controlegroep van HF + FH + MRIJ-vaarzen op het krachtvoerrantsoen en op het ruwvoerrantsoen (tussen haken): -6527 (-4319) MJ NE voor voeropname, -1791 (-991) kg voor melkproduktie, 2,31 (1,84) voor vetpercentage van de melk, -5 (-16) kg voor melkeiwitproduktie en -2533 (-898) MJ voor melkenergieproduktie. Deze wisselwerkingen tussen ras en voersamenstelling zijn waarschijnlijk veroorzaakt door een groter voeropnamevermogen (ad lib voeropname in relatie tot het lichaamsgewicht) van de Jersey-vaarzen ten opzichte van de HF + FH + MRIJ-vaarzen en door een grotere behoefte van de Jerseys aan grondstoffen voor de synthese van melkvetten en een kleinere behoefte aan grondstoffen voor de synthese van melkeiwit en melksuiker. Een ruwvoerrantsoen voorziet beter in deze behoeften dan een krachtvoerrantsoen. In deze proef hadden de Jerseys op het ruwvoerrantsoen een biologische efficiëntie voor melkproduktie van 65 procent en op het krachtvoerrantsoen van 59 procent. Voor de HF + FH + MRIJ-vaarzen was deze efficiëntie respectievelijk 56 en 55 procent.

In hoofdstuk 5 wordt een voeropnameproef met Jersey-koeien en een controlegroep met HF + FH + MRIJ-koeien beschreven. Na de geboorte van hun derde kalf werd aan deze koeien, die als vaars aan de vorige proef hadden deelgenomen, dezelfde rantsoenen gevoerd als in het voorgaande experiment. Ook werden voeropname, melkproduktie en gewicht bepaald in de eerste 39 weken van de lactatie. Nu werd alleen voor het vetgehalte in de melk een wezenlijke wisselwerking tussen ras en rantsoensamenstelling aangetoond. Gemiddeld waren de verschillen tussen de Jersey koeien en de controlegroep van HF + HF + MRIJ-koeien op het krachtvoerrantsoen en op het ruwvoerrantsoen (tussen haken): -6460 (-5162) MJ NE voor voeropname, -2560 (-1707) kg voor melkproduktie, 2,82 (2,38) voor vetpercentage van de melk, -55 (-26) kg voor melkeiwitproduktie en -3241 (-1112) MJ voor melkenergieproduktie. Voor de Jersey koeien en voor de HF + FH + MRIJ-koeien was de toename van eerste naar derde lactatie in energieopname en in melkproduktie op het K-rantsoen respectievelijk 25 en 24 procent en op het R-rantsoen respectievelijk 48 en 51 procent. De biologische efficiëntie voor de melkproduktie was voor de Jersey-koeien op het ruwvoerrantsoen 69 procent en op het krachtvoerrantsoen 57 procent. Voor de HF + FH + MRIJ-koeien was deze efficiëntie respectievelijk 61 en 56 procent.

In hoofdstuk 6 wordt het effect van pariteit (het aantal keren dat een koe gekalfd heeft) bestudeerd op de voeropname en op de omzetting van voer in melk in de eerste 39 weken van de lactatie. Voor dit doel waren de gegevens beschikbaar uit 265 lactaties van 159 koeien, die afkomstig zijn uit de proeven beschreven in de hoofdstukken 2 tot en met 5. In dit materiaal werd voor alle kenmerken een wezenlijke wisselwerking gevonden tussen ras, pariteit en rantsoen. Dit werd veroorzaakt door ongelijke varianties en ongelijke rangorde tussen rassen in de verschillende pariteit-voergroep combinaties. In het algemeen werden de verschillen in voeropname en melkproduktie tussen de K-groep en de R-groep kleiner met het toenemen van de pariteit. Gemiddeld had pariteit geen grote invloed op de biologische efficiëntie voor melkproduktie. Met het toenemen van de pariteit steeg de economische efficiëntie voor melkproduktie, in het bijzonder op het R-rantsoen. Omdat van verschillende koeien de gegevens in twee lactaties verzameld waren, konden er herhaalbaarheden voor de verschillende kenmerken berekend worden. De herhaalbaarheid voor melkvetgehalte (0,75), melkeiwitgehalte (0,68) en gemiddeld gewicht (0,69) was hoog. De herhaalbaarheid voor de voeropname (0,39), de melkproduktie (0,47), de biologische efficiëntie voor de melkproduktie (0,46), de economische efficiëntie (0,37) en voor de groei tijdens de lactatie (0,27) was lager. Een poging om rekenkundig verschillen tussen rassen, pariteiten en rantsoenen in Netto Energiebehoefte voor melkproduktie, onderhoud en groei vast te stellen, slaagde niet. Een multiple regressie van energieopname uit voer op melkenergieproduktie, metabolisch gewicht en groei leverde irreële regressiecoëfficiënten op. Dit wordt veroorzaakt worden doordat de verklarende variabelen niet zonder fouten zijn geschat en doordat ze niet onafhankelijk van elkaar zijn.

Hoofdstuk zeven is de beschrijving van een proef met Jersey, zwartbonte en roodbonte koeien, die in de 13e - 36e week van de lactatie behandeld zijn met een langwerkend preparaat dat runder somatotropine (BST) bevatte. Na een voorperiode van 12 weken werden drie groepen behandeld met een verschillende dosis BST en één groep werd niet behandeld (controlegroep). Gedurende de 36 weken van de proef werden de koeien ad libitum gevoerd met een compleet voer dat op basis van drogestof voor 50 procent uit krachtvoer en voor 50 procent uit ruwvoer bestond. Er werd geen wisselwerking aangetoond tussen ras en BST-dosering: de verschillen tussen de groepen met de verschillende BST-doseringen zijn gelijk binnen de drie rassen. De beste resultaten werden behaald met 640 mg BST, dat 6 maal om de 28 dagen geïnjecteerd werd. De melkproduktie steeg in de behandelingsperiode met 3,3 kg en het vetgehalte met 0,24 procent. De concentratie van ketonlichamen in het bloed was bij de behandelde koeien iets hoger dan bij de controledieren. De behandelde koeien lieten sterke schommelingen in het vetgehalte van de melk zien binnen een 28-daagse behandeling met BST. Deze twee feiten wijzen erop, dat na een behandeling met BST, het lichaamsvet betrokken is bij de verhoogde melkvetproduktie. Dit maakt het noodzakelijk dergelijke proeven langer te laten duren dan één lactatie, omdat lichaamsvetten een positieve bijdrage kunnen leveren aan de melkproduktie in een volgende lactatie. Koeien met een lagere melkproduktie in de voorperiode lieten een iets hogere melkproduktie zien in de periode dat ze met BST behandeld werden dan koeien met een hogere melkproduktie in de voorperiode.

Hoofdstuk acht is een algemene discussie, waarin de conclusies van dit proefschrift nader onderbouwd worden. Tussen rassen bestaan verschillen in voeropname, die gerelateerd zijn de verschillen in voerbehoefte. De verschillen in voeropname zijn groot wanneer Jerseys in de vergelijking betrokken worden. Bij de Jerseys heeft het krachtvoeraandeel in het rantsoen andere effecten dan bij de drie overige rassen. De Jerseys hebben een hogere voeropnamecapaciteit. Het voeren van krachtvoer heeft minder effect op de totale voeropname en melkproduktie dan bij de andere rassen. Daarnaast hebben de Jerseys een andere verhouding tussen vet, eiwit en lactose in de melk en daardoor een andere nutriëntenbehoefte dan de zwaardere rassen. De verschillen tussen rassen in voeropnamevermogen gaan samen met verschillen in lichaamsbouw. Deze verschillen hebben een negatieve relatie met de slachtkwaliteit. Met het toenemen van de pariteit neemt de voeropnamecapaciteit toe. Door een gunstiger verhouding tussen melkenergieproduktie en onderhoudsbehoefte hebben de Jerseys en de Holstein Friesians een hogere biologische en economische efficiëntie voor melkproduktie dan de Nederlandse zwart- en roodbonten. Pariteit en rantsoen hebben gemiddeld weinig invloed op de biologische efficiëntie. Het stadium van de lactatie heeft grote invloed op de biologische efficiëntie. De verschillen tussen rassen in biologische efficiëntie komen beter tot uiting op een ruwvoerrantsoen. De verschillen tussen rassen in economische efficiëntie zijn afhankelijk van het type rantsoen. Het rendement van het voeren van krachtvoer neemt sterk af bij het ouder worden van de koeien, vooral bij de melkveerassen. Een hogere melkproduktie heeft gunstige effecten op de biologische en economische efficiëntie voor melkproduktie. De totale economische efficiëntie van een ras wordt mede bepaald voor de prijsverhoudingen tussen melk, vlees en voer en door maatregelen die de produktie beperken. De biologische efficiëntie voor melkproduktie wordt niet beïnvloed door verschillen in voeropname of lichaamsgewicht. De voeropname wordt sterk beïnvloed door de ruwvoer-krachtvoer verhouding in het rantsoen en wordt zwak beïnvloed door behandeling met BST. De ruwvoer-krachtvoer verhouding van het rantsoen heeft slechts een gering effect op de biologische efficiëntie voor melkproduktie. Behandeling met BST en selectie op melkproduktie verbeteren de efficiëntie voor melkproduktie duidelijk omdat de hoeveelheid voer, die nodig is voor het onderhoud van de koe, per kg melk lager wordt.

CURRICULUM VITAE

Kor Oldenbroek werd op 17 februari 1951 geboren te Ens, gemeente Noordoostpolder. In 1968 behaalde hij het HBS B-diploma aan het Johannes Calvijn Lyceum te Kampen. In juni 1973 studeerde hij met lof af aan de Landbouwuniversiteit te Wageningen in de studierichting Veeteelt met als afstudeervakken de Veeteelt, de Gezondheids- en Ziekteleer der Huisdieren (verzwaard) en de Erfelijkheidsleer. Van juli tot december 1973 was hij in dienst van de Landbouwuniversiteit werkzaam als wetenschappelijk medewerker bij de Stichting Bloedgroepenonderzoek. Sinds 1 december 1973 is hij verbonden aan het Instituut voor Veeteeltkundig Onderzoek "Schoonoord" te Zeist, waar hij belast is met het experimentele rundveefokkerij-onderzoek.