Feed intake and production in dairy breeds dependent on the ration

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FEED INTAKE AND PRODUCTION IN DAIRY BREEDS DEPENDENT ON THE RATION

Proefschrift
ter verkrijging van de graad van
doctor in de landbouwwetenschappen
op gezag van de rector magnificus,
dr. C.C. Oosterlee,
hoogleraar in de veeteeltwetenschap
in het openbaar te verdedigen
op vrijdag 1 oktober 1982
des namiddags te vier uur in de aula
van de Landbouwhogeschool te Wageningen

STELLINGEN

1. De kenmerken ruwvoeropname en gewichtsverandering tijdens de lactatie vertonen een duidelijke variatie bij melkkoeien op een rantsoen met ad libitum ruwvoer en een gelijke krachtvoergift per dier.

Dit proefschrift.

2. De produktieverschillen tussen melkveepopulaties op een rantsoen met ad libitum ruwvoer zijn groter bij een systeem met krachtvoer naar melkproduktie dan bij een gelijke krachtvoergift per dier. Hiermee dient men rekening te houden bij de vaststelling van de genetische verschillen tussen melkveepopulaties.

Dit proefschrift.

3. De mogelijkheden om door middel van wijzigingen in de voedingsstrategie een verbetering van de persistentie van de melkproduktie bij eenzelfde totale lactatieproduktie te bewerkstelligen worden onvoldoende onderkend.

Broster, W.H., 1980. ADAS Quarterly Rev., 39, 234-255.

4. De mogelijkheden van de herkauwer, in het bijzonder het rund, om ruwvoer om te zetten in voor de mens nuttige produkten worden vanuit het oogpunt van de wereldvoedselvoorziening niet maximaal benut.

Winrock International, 1978. The role of ruminants in support of man. Winrock Intern. Livest. Research and Training Centre, Morrilton, USA.

5. Een optimaal gebruik van de eigenprestatietoets van jonge proefstieren, bij ad libitum voersystemen, vereist de meting van de individuele voeropname.

6. De gebruiksduur van melkkoeien binnen een bedrijf heeft een duidelijke invloed op het bedrijfseconomisch resultaat, het effect van de gebruiksduur op de genetische vooruitgang voor melkproduktie is echter gering.

Renkema, J.A. and J. Stelwagen, 1979. Livest. Prod. Sci., 6, 15-27.
Korver, S. and J.A. Renkema, 1979. Livest. Prod. Sci., 6, 29-37.

7. De beschikbare kengetallen per koe, welke in het kader van de melkcontrole routinematig worden berekend, zoals de produktie-index, bieden onvoldoende ondersteuning voor een economisch optimale vervangingbeslissing.

Bakker, H., J.H. Wallinga, J. Dommerholt, H.G. Kooper, S.R. Sijbrandij and W.M.G. Wismans, 1979. Bedrijfsontwikkeling, 10, 611-616.

8. Bij de rijpaardfokkerij heeft de evaluatie van de verzamelde gegevens een te lage prioriteit en derhalve worden selectiemogelijkheden onvoldoende benut.

9. Voor een verantwoorde uitoefening van de preventieve gezondheidszorg bij landbouwhuisdieren is een goede zoötechnische en economische kennis noodzakelijk.

Ellis, P.R. and A.D. James. Veterinary Record, 105, 523-526.

10. De bereidheid van het K.F.R.S. en het K.N.R.S. om deel te nemen aan de in de toekomst op te richten Nederlandse Bond voor de Rundveeverbetering zou op korte termijn gedemonstreerd kunnen worden door het samenvoegen van hun maandbladen.

11. De "bedenktijd" van kandidaat-lijsttrekkers geeft te denken.

Proefschrift van S. Korver
Feed intake and production in dairy breeds dependent on the ration.
Wageningen, 1 oktober 1982.

aan Suze

aan Marleen en Gabe

Korver, S., 1982. Feed intake and production in dairy breeds dependent on the ration (Voeropname en produktie bij melkveerassen afhankelijk van het rantsoen). Departments of Animal Breeding and Animal Nutrition of the Agricultural University, Wageningen, The Netherlands.
Also: Doctoral thesis, Wageningen.

VOORWOORD

Het in dit proefschrift beschreven interdisciplinair onderzoek is uitgevoerd in het kader van een promotie-assistentschap bij de vakgroepen Veefokkerij en Veevoeding van de Landbouwhogeschool te Wageningen.

Mijn promotor, prof.dr.ir. R.D. Politiek, dank ik voor de belangstelling, discussies en suggesties bij de aanpak en uitvoering van het onderzoek en voor de genoten gastvrijheid.

Mijn promotor, prof.ir. S. Boer Iwema, dank ik voor de betoonde belangstelling en de geboden mogelijkheden.

Mijn collega's en in het bijzonder J. Dommerholt, A.A. Dijkhuizen, Y. van der Honing, J. Jansen, W.J. Koops en G.E. Shook wil ik danken voor de discussies en hun inbreng bij het doornemen van de proefopzet en het manuscript.

Het onderzoek is uitgevoerd op het proefbedrijf van de Landbouwhogeschool te Swifterbant (Ir. A.P. Minderhoudhoeve). De medewerkers van de afdeling veehouderij van dit proefbedrijf in samenwerking met studenten van de Hogere Agrarische Scholen en de Landbouwhogeschool onder leiding van de bedrijfsleider, de heer Tj. van der Wal, hebben de proefdieren verzorgd en meegewerkt aan het verzamelen van gegevens. Hartelijk dank voor de inzet.

De heer H. Vos wil ik danken voor het verrichte werk gedurende de laatste fase van het proefschrift.

Het typewerk is op snelle en accurate wijze uitgevoerd door mw. E.T. van Beek-Geurtsen en mw. P.E. l'Amie-van Eden. De heer W. Heije heeft de grafieken nauwgezet getekend.

Het LEB-fonds heeft de afronding van dit proefschrift financieel ondersteund.

Tenslotte wil ik iedereen bedanken die aan dit proefschrift heeft bijgedragen maar in dit voorwoord ongenoemd is gebleven.

CONTENTS

Symbols and abbreviations

n	number of sample units
s.d.	standard deviation
df	degrees of freedom
P	probability
SS	sum of squares $(\Sigma(y-\bar{y})^2)$
R^2	determination coefficient $(\{\Sigma(y-\bar{y})^2 - \Sigma(y-\hat{y})^2\}/\Sigma(y-\bar{y})^2)$
μ	overall mean
GE	gross energy
ME	metabolizable energy
NE	net energy
VEM	Dutch feed unit (net energy for lactation)
FCM	fat corrected milk (mass fraction of fat 4.00% = (0.4 + 0.15 fat %) milk yield)
FPCM	fat protein corrected milk (section 3.1.4)

Treatment groups and experiments (chapter 3)

DF	Dutch Friesians
HF	Crosses between Holstein Friesian and Dutch Friesian
Roughage	Ration with a low concentrate level and ad libitum roughage
Concentrate	Ration with a high concentrate level and ad libitum roughage
Experiment I_1	First experimental lactation
Experiment I_2	First experimental lactation of the cows with a second experimental lactation
Experiment II	Second experimental lactation

1 INTRODUCTION

Over the last 10 years there has been a marked increase in the milk production of the dairy cows. Between 1970 and 1979 in the Netherlands the yield of Black and White (Friesian) cows in recorded herds rose by an average of 1040 kg per cow in a full lactation (C.M.D., 1979). In general this was the result of improved nutrition and efficient methods of selection.

In the early stages of lactation the intake of nutrients, especially energy and protein, does not meet the requirements of the high yielding cow. The gap between supply and demand can be reduced by either increasing the concentration (nutrient density) of the ration, increasing the feed intake, or by a combination of these two factors. The extent, in practice, to which the concentration can be increased is limited because approximately 30% of the dry matter should be from long roughage to enable the rumen to function normally.

The roughages fed to ruminants consist predominantly of cellulose, hemicellulose and lignin. Because of man's inability to digest them they can make no direct contribution to human nutrition. On the other hand, the ruminant has the ability not only to digest these roughages but also to convert them into products of high nutritional value for man, e.g. milk and meat.

The higher quality roughages such as hay and grass silage are usually grown on land that is unsuitable for arable crops. An economic change or greater food shortage could result in the need to use more roughage and food crop by-products with a higher crude fiber content. In these circumstances the variation in roughage intake between cows will be of increasing importance.

The milk production capability of dairy cows is, at present,the main characteristic on which their selection is based. In determining this the cows are generally given rations high in concentrates. Between 1970 and 1979 the concentrate intake per cow per year doubled in the Netherlands to an average level of approximately 1625 kg (Nota Melkveehouderij, 1981). High producing herds and/or modern herds already used more than 2000 kg concentrates per cow a year. The question that arises is whether the selection decision would remain the same if the cows were fed on rations with a high roughage content. Conrad et al. (1964) and Baumgardt (1970) have suggested that the meachamisms regulating the intake of feed may vary according to its digestibility.

The importance of the interaction between genotype and nutrition in dairy cattle has been studied in some experiments but only within a breed (Korver, 1979). Reports of experiments with different breeds (dairy, dual purpose) in temperate zones were not found in the literature. The exchange of semen between countries and especially the import into the Netherlands of Holstein Friesian semen emphasises the need for such experiments. The Holstein Friesian had a higher genetic potential for milk production of approximately 16% compared with the Dutch Friesian (Oldenbroek, 1979). These breeds were selected in different environmental circumstances (e.g. different feeding regimes).

An experiment covering two successive lactations was therefore designed, its objectives being to study:

- Variance in feed intake (energy and roughage), milk production and components, and live weight change during the two lactations in dairy cattle within and between two subpopulations and dependent on the ration. The subpopulations were characterized as Dutch Friesian and crosses between Holstein- and Dutch Friesians and the rations as a high and a low concentrate level with ad libitum roughage.
- The importance of the interaction between genotype and ration on milk production (including components), feed intake and live weight change during the lactation.

In chapter II the literature is summarized briefly. This is based on the more extensive review of Korver (1979) and publications of other authors. Materials and methods are described in chapter III and results in IV. The results start with the description of the individual characteristics in total and partial lactations and end with the relationships between these characteristics within a genotype-ration group. Each subchapter ends with a short discussion. The general discussion is the subject of chapter V.

2 LITERATURE

2.1 Feed intake

2.1.1 Regulation of the feed intake

2.1.1.1 Introduction

The feeding of the animal involves a series of chemical and physiological processes in which food contributes to the demands for maintenance, milk production, body tissues and other activities. Control of the total metabolic system involves two types of regulation namely homeostasis and homeorhesis (Bauman and Currie, 1980). Homeostasis is the maintenance of a physiological equilibrium and homeorhesis is the coordinated control of metabolism in the various tissues to support a physiological state. Ruminants, as well as monogastrics, try to achieve in the long run a balance between their intake of nutrients and the requirement for them (Baumgardt, 1970; Baile and Forbes, 1974; Rohr, 1977). In this way the animal attempts to reach equilibrium at a certain physiological level (e.g. the extent of fat reserves - Baumgardt (1970)).

The hypothalamus is probably the central organ for the regulation of the feed intake and stimuli of metabolic or physical origin (neural, endocrine or other) may provide a feedback to the central organ to limit feed intake. The features affecting the regulation of intake and the mechanisms of regulation are very incompletely known as shown by the reviews of Balch and Campling (1969), Campling (1970), Baumgardt (1970), Baile and Mayer (1970), Jones (1972), Baile and Forbes (1974), Journet and Rémond (1976), Rohr (1977) and De Jong (1981). As in most reviews a distinction is made between the physical and metabolic regulation mechanisms. These mechanisms will be described very briefly in 2.1.1.2 and 2.1.1.3 and in later sections (2.1.2, 2.1.3) the feed and animal factors which play a role in these systems are reviewed.

2.1.1.2 Physical regulation

A high forage ration (bulky and with a high crude fiber content) can result in a lower intake of nutrients than the requirement of the individual would demand.

This normally results in a negative energy balance in the ruminant. The inadequacy of the intake can usually be compensated by a mobilization of the body reserves. The feed intake in such situations is dependent on the capacity of the alimentary tract, especially of the reticulo rumen, and the rate of disappearance of the digesta from the reticulo rumen (Conrad et al., 1964; Campling, 1970; Baumgardt, 1970).

The capacity of the reticulo rumen depends on the size of the animal, the deposition of fat within the abdominal cavity, stage of pregnancy and lactation (Campling, 1970; Bines, 1976b; Journet and Rémond, 1976; Forbes, 1977a; Forbes, 1977b). According to Tulloh (1966) and Bines (1976b) it is possible that the increased demand for nutrients in the lactating cows can be met partly by a hypertrophy of the alimentary tract.

The rate of disappearance of digested and undigested material from the reticulo rumen is dependent on the chemical composition of the feed, the degree of mastication and rumination, the rate of breakdown (microbial activity, motility of the rumen, fermentation conditions), the capacity of the muscular contractions of the gut and the reticulo-omasal orifice. Warwick and Cobb (1975) suggested possible differences in the rate of disappearance between cows independent of the physiological state of the animal and the nature of the offered food. Decreasing the size of the food particles generally improves the feed intake, however it is possible that intake of ground forage is inhibited by the distal part of the alimentary tract (Van der Honing, 1975). The digestibility of the feed is positively correlated with the feed intake for rations of low digestibility (Conrad et al., 1964) (2.1.2).

2.1.1.3 Metabolic regulation

The intake of a ration with a high digestible nutrient concentration may not be inhibited by the capacity of the rumen but by the requirement of the individual, unless the concentrate roughage ration causes digestion problems (off-feed). The energy intake is constant in such a situation and the feed intake will decrease with an increase in the energy concentration (Baumgardt, 1970).

Several workers have done research on metabolites such as volatile fatty acids, glucose, insulin and free fatty acids in the reticulo rumen and blood.

The central reaction in the rumen is the fermentation of carbohydrates and proteins to volatile fatty acids, methane and carbon dioxide. The ratio of the volatile fatty acids produced (acetic, propionic and butyric acid) depends on the ratio of roughage to concentrates (Sutton, 1976; Kaufmann, 1976; Rohr, 1977).

These acids have received considerable attention in the research. Intra rumenal infusions with acetate or propionate (often in amounts beyond the physiological limits) have a negative influence on the feed intake, whereas the results with butyrate were more variable (Baile and Mayer, 1970; Baile and Forbes, 1974). De Jong (1981) did not find any influence of the infusion of a physiologically normal amount of volatile fatty acids in rumen fluid or blood on the feeding patterns in free-feeding non-lactating goats. Insulin may play a role in the regulation of the feed intake (De Jong, 1981).

According to Baile (1971) and Rohr (1977) the fat reserves may have an effect on the regulation of the energy balance in the long term. Metabolites (e.g. free fatty acids) and hormones (e.g. growth hormone) may possibly form a communication system between body fat reserves and the central nervous system (Baile and Forbes, 1974; Journet and Rémond, 1976). A relationship between fat mobilization post partum and the low intake has also been postulated (Journet and Rémond, 1976).

Metabolic regulation by temperature is not thought to be important within the thermoneutral zone (Jones, 1972). In most Dutch situations cattle are within this zone. Outside of it extra energy is needed for temperatures below the thermoneutral zone whereas temperatures above it will result in an increase of the heat loss or a lower energy intake (Jones, 1972; Bines, 1976a; Zemmelink, 1978; Verstegen, 1978).

The relation between physical and metabolic regulation seems to be dependent on the digestibility of the ration and the physiological state of the animal (Conrad et al., 1964; Baumgardt, 1970)(2.1.2).

2.1.2 Feed and management factors

Quality of the feed

Conrad et al. (1964) found a positive relation between digestibility of the dry matter and the dry matter intake (linear regression: $y = -17.0 + 0.67x$; x = dry matter digested (%), y = dry matter intake (lb)). However, after adjustment for metabolic weight and the estimated energy content of the milk, they showed a positive relation in the range of 52 to 67% digestibility but above this there was no relation. This indicates an alteration from a physical to a metabolic regulation but the point at which it occurred depended on the physiological state of the animal (Conrad et al., 1964).

The digestibility of roughage is negatively correlated with the crude fiber content in the dry matter. However, some crude fiber of long forage is necessary for the function of the rumen and the optimum for the maintenance an acetic to propionic acid ratio of 3:1 varies between 15-20% crude fiber in the dry matter (Kaufmann, 1976; Journet and Rémond, 1976; Rohr, 1977). Increasing the supply of nitrogen to give a crude protein content in the dry matter of about 10% may increase the intake of low quality roughage by ruminants. However, the optimum is dependent on the physiological state of the animal, the ration composition and nature and solvability of proteins in the feed (Jones, 1972; Tamminga et al., 1978; Bines, 1979).

A dry matter content below 30-35% has a negative influence on the intake of silage but above this level no effect could be shown (Jackson and Forbes, 1970; Van der Honing and Van Reeuwijk, 1971). This negative relation may be caused by a change in the chemical composition of the silage as a result of the preservation process (Rohr, 1977).

Processing and preservation

The extensive reduction of the particle size of roughages impairs rumen motility and saliva flow. On the other hand, rate of passage of the small particles is increased. The effect on intake of grinding roughage is generally inversely related to the quality of the roughage (Bines, 1979). According to Van der Honing (1975) and Rohr (1977) the grinding of straw results in an increase in intake but little or no effect of grinding was found with good quality artificially dried forage.

In general the dry matter intake of conserved forage as silage or hay is lower than that of the fresh material (Bines, 1979). Campling (1966) observed a lower intake of silage than of hay made from the same crop when offered alone but this difference largely disappeared when supplementary concentrates were offered.

Method of feeding

The effect on intake of changing the ratio of roughage to concentrates in the diet can be expressed as the substitution rate. This is defined as the decrease in roughage dry matter intake (kg) per kg of added concentrate intake. Its effect depends among other things on the energy requirement of the cow, its physiological state, the frequency of feeding, the digestibility and physical form of the forage and the amount of concentrates (Van der Honing, 1975). Where the quality of the basal diet is poor and especially where it has a low protein content, addition of a small amount of concentrates will even raise roughage intake unless the protein content of the concentrates is also low. The substitution rate increased with the increase of the digestibility of the roughage and for hay and silage it ranges between 0.2 and 0.6 (Rijpkema and Steg, 1975; Van der Honing, 1975). The substitution rate for ad libitum herbage feeding is about 0.4 - 0.6 over the range of 2-4 kg concentrates (Meijs, 1981). Van der Honing (1975) reviewed values of about 0.8 - 1.0 for ground roughage.

The substitution rate increases with a higher level of concentrates (Rijpkema and Steg, 1975), the total dry matter intake usually decreases when more than 60-70% of diet is concentrates. Some long roughage in the ration is necessary for the normal functioning of the rumen. Ekern (1972b) showed, in an experiment with two concentrate levels per kg of produced FCM, a decrease in the substitution rate with the increase of the stage of the lactation. However, the lactation stage was confounded with the concentrate level. The substitution rate during the lactation appeared dependent on the concentrate level in the dry period before calving.

Wilson and Flynn (1974), cited by Bines (1979), suggested that 6 hours per day ad libitum access to feed is probably adequate for stall-fed animals to maximize their intake of silage. Freer and Campling (1963) found an increase of the hay intake when cows had 24 hours access to it instead of 5 hours. Balch and Campling (1969) and Zemmelink (1980) described the influence of the quantity of offered material on the intake by ruminants.

According to Kaufmann (1976) an increase in the number of meals of concentrates per day increases the intake and rumen fermentation activity.

Palatability and smell

Several researchers have postulated that palatability and smell may influence the roughage intake (Baile and Forbes, 1974). However, these factors have not been examined in great detail and it is difficult to quantify their effects but it is likely that, as with other mammals, they do play a role in the selection of feed by ruminants (Rohr, 1977).

2.1.3 Animal factors

The feed intake of a dairy cow is dependent on many factors peculiar to the animal itself e.g. growth, fattening, milk production, pregnancy, size, age, genetic potential. The relations between the various factors will be described in chapter 2.4 and this chapter will be confined to a general description of the influence of the physiological state of the dairy cow (lactation and pregnancy) and the genetic differences.

Pregnancy

Two opposing effects influence feed intake during pregnancy. The slightly increased demand for nutrients for the development of the foetus would increase the intake. At the end of pregnancy however, the volume of the rumen is reduced by the foetus and associated tissues. In the dairy cow the stage of lactation is confounded with that of pregnancy and therefore most research on the effect of pregnancy is limited to the dry period. Curran et al. (1970) and Journet and Rémond (1976) reported a decline in intake of 0.2 kg dry matter per day per week during the last six weeks before calving. Journet and Rémond (1976) observed considerable differences between diets in the level of intake and the intake, decreased more rapidly during the last week of pregnancy.

Early lactation

The feed intake increases more slowly than the milk production (energy output) in early lactation. In the literature three possible reasons are mentioned:

1. It may be necessary that fat deposited within the abdomen before calving must be mobilized before rumen fill can be maximized (Bines, 1976b).
2. A slow hypertrophy of the alimentary tract after parturition as was suggested by Tulloh (1966).
3. The rate of metabolism in both rumen and tissues has to adapt to the new situation (higher demand for nutrients), but this takes time.

Bines (1976b) concluded on the basis of literature and his own research that the time of maximum intake of feed lies between the 5th and 36th week of the lactation with an average of 16 weeks. The time between maximum milk production during the lactation and maximum feed intake is dependent on the age and physiological state of the animal and the ration composition. An increase in the quantity of concentrates in the ration decreases the difference in time (Coppock et al., 1974; Bines, 1976b; Journet and Rémond, 1976).

Later lactation

In several experiments the dairy cows were fed according to their milk production and this implies that the amount of concentrates was dependent on the milk production level. The time during the lactation with the maximal energy intake and the shape of the energy curve over the lactation is dependent on the feeding system. Brown et al. (1977) reported a clear decrease in the energy intake during the lactation after the maximum intake, but the cows were offered concentrates according to the level of milk production. Østergaard (1979) offered a fixed concentrate level during the lactation (weeks 1-36) and observed a comparatively constant energy intake level in the second part of the lactation. The same was found for the ad libitum intake of feeds with fixed concentrate to forage ratios (Broster et al., 1978).

Genetic differences

A large number of experiments have been done on the effect of feed quality or feeding level on the feed intake, however only a few have been designed to estimate genetic differences. Within the experiments with genetic inferences there existed a variation between experiments in feeding ration and period of measuring during the lactation. In most studies forages were fed to appetite and concentrates according to milk production.

Legates et al. (1956), cited by Miller et al. (1972), reported significant differences between Ayrshire, Guernsey, Jersey and Holstein cows in hay consumption per unit body weight (grain provided 40% of the maintenance requirement). Hooven et al. (1971) observed differences between Holsteins and Jerseys. Oldenbroek and Van Eldik (1980) reported differences in roughage intake between Dutch Red and White, and Friesians (Holstein and Dutch). In these two experiments the cows were fed concentrates according to milk production.

Lamb et al. (1977) reported a coefficient of variation among progeny groups of 5.0% for the total dry matter intake during the lactation (ad libitum system) on a roughage ration without concentrates. For a ration with ad libitum roughage and 1 kg concentrates per 3.5 kg milk a coefficient of 7.3% was found. A second comparable experiment with higher concentrate levels per ration showed lower coefficients of variation among progeny groups.

Stone et al. (1960) observed a repeatability of weekly forage dry matter consumption of 0.70 for Holstein cows. Mather (1959) summarized the literature and arrived at the following repeatabilities for forage consumption per 454 kg body weight: month-to-month in same year, 0.54; year-to-year, 0.37. Relations between feed consumed, total- and part-lactation were investigated by Hooven et al. (1972) on the basis of 425 first lactations. Coefficients of correlation between estimated net energy (ENE) consumed in adjacent periods ranged from 0.75

to 0.91 while the values between the 10 part-lactation measurements of ENE consumed and total lactation ranged from 0.51 to 0.87 (highest values in mid-lactation).

The estimations of the heritabilities of the feed intake ranged between 0.1 and 0.4 (Gray et al., 1967; Miller et al., 1972; Hooven et al., 1972). These estimations were greater than zero, indicating that a portion of the total variation in feed intake is controlled by additive genetic effects. The variations in estimates is caused by the nature of the characteristic, the ration and the number of individuals used.

2.2 Milk production and components

The milk yield and composition of milk are affected by many factors. They can be divided into two broad areas namely physiological and environmental. The physiological factors are governed in part by the inheritance of the animal and in part by such factors as age, number of lactation and pregnancy (e.g. Dommerholt, 1975). The feeding level, the season and the herd are examples of environmental factors.

In a normal situation the lactation curve of a dairy cow shows a rapid increase in the milk production immediately after parturition reaching its peak production approximately 30-50 days after parturition (Bines, 1979). Peak milk production plays an important role in determining lactation milk yield (Broster, 1972). The rate of decline in yield after calving (persistency) is clearly influenced by pregnancy (Auran, 1974).

There is a general inverse relationship between milk production and milk protein and milk fat percentages. These percentages decrease in early lactation; are at a low point during the peak of lactation and then gradually increase towards the end of lactation (Politiek, 1957).

2.2.1 Animal factors

Milk production increases with the age of a cow and the maximum is reached at an age of about 6-8 years. The effect of age on test-day yield decreased progressively with days after parturition (Dommerholt, 1975). The calving interval has, in general, a positive relation with the lactation yield. The depressive effect of the pregnancy on the milk production starts 60-150 days after conception (Auran, 1974). This depends on the stage of lactation and the lactation number.

Dommerholt (1975) investigated the milk records of 4000 cows and observed a coefficient of variation for milk production at 30 days lactation of 23% and this increased slowly to about 26% at 190 days and then towards 32% at 270 days. The influence of season, age and herd decreased as the lactation progressed. At the beginning a model with these effects explains about 69% of the variation and this decreases to about 49% at the end of the lactation. The cumulative total production had a coefficient of variation of 21.6% and the three effects mentioned explained 69% of the variation.

Differences between breeds in milk yield and components were reviewed by e.g. Turton (1981). Heritabilities of yields and percentages of milk components in the first lactation were reviewed by Maijala and Hanna (1974) and Miller et al. (1981) and these are on average in field conditions: milk yield 0.25; fat yield 0.25; protein yield 0.25; fat percentage 0.50 and protein percentage 0.45. Maijala and Hanna (1974) reviewed a repeatability for milk production of 0.49 between lactations and for fat percentage 0.69. Dommerholt (1975) calculated correlation coefficients between test-day yield and total lactation. These were highest in mid-lactation (about 0.85) and higher in the first months of lactation than at the end.

The phenotypic correlation coefficients between milk yield and percentage fat and between milk yield and percentage protein were -0.20 and -0.19 respectively (Maijala and Hanna, 1974). The correlation coefficient between the two components was estimated to be 0.49.

2.2.2 Environmental effects

This review will be confined to the most important environmental effect, namely feeding level. The milk production response to feeding level and changes of feeding level is dependent among others on stage of lactation, length of feeding period and production potential of the cows. The milk production of a dairy cow is not only dependent on the actual energy supply but also on the feeding level during the previous period. Therefore both short-term and long-term effects had to be considered by comparing the effects of several rations or feeding levels.

Dry period

The dry period has an influence on the redevelopment of the mammary gland tissue and the replenishment of body reserves. Broster (1971) had reviewed the literature concerning relationships between prepartum feed intake and subsequent production. He concluded that the amount of feed prepartum was without effect in comparisons between "moderate" and "high" levels and when postpartum feeding was generous. A low feeding level (a fall or a small gain in liveweight before calving) had a negative influence on the milk production postpartum. Ekern (1972a) investigated the effect of two feeding levels (82-90 MJ ME or 99-111 MJ ME) but did not observe differences in milk production. Lodge et al. (1975) reported the results of an experiment with eighteen cows with two feeding levels prepartum (494 kJ ME or 889 kJ ME per body weight to the 0.75 power) and observed no difference in milk production on an ad libitum feeding system.

Lactation

The effect of level of feeding during lactation has been studied by many researchers (e.g. reviews of Broster, 1972 and Wiktorsson, 1979). In these studies a distinction can be made between experiments during some weeks of the lactation, experiments during total lactation and multiple lactation studies. In these investigations several levels or distributions of concentrates over the lactation were compared:

- Different levels of concentrates were fed according to the actual milk production with a fixed amount or ad libitum roughage.
- Different fixed levels of concentrates during the lactation with fixed or ad libitum roughage.
- Different fixed ratios of concentrates to roughage (fixed or ad libitum).

Broster et al. (1969) reported a high response to an increased fixed feeding level during the first 9 weeks of the lactation in an experiment with heifers. The heifers were fed during these weeks two fixed levels one being the requirement of a heifer with 20 kg milk the other being 75% of this standard. In these 9 weeks of lactation this resulted in a milk production difference of 161 kg milk and over the total lactation 533 kg (short- and long term effect). After 9 weeks the cows at each level were rerandomized to either a high or a low level of feeding. The results indicated that the response in milk yield for the same amount of feed is dependent on the foregoing feeding level (treatment high-high versus high-low 168 kg; treatment low-high versus low-low 58 kg). Broster and Thomas (1981) concluded in a review that in fixed feeding regimes the short-term response in milk output to concentrate input is directly related to current yield and the long-term effect is mainly influenced by the feeding level during the experimental period and the plane of nutrition in the residual period.

Ekern (1972a) studied normal and high levels of concentrates given according to milk production. During the experimental period of 28 weeks of lactation the cows consumed 5.06 - 5.44 and 5.82 - 6.09 MJ ME per kg FCM above maintenance requirement. No significant response in milk yield was observed. Østergaard (1979) compared 8 fixed strategies of feeding concentrates independent of the current yield. These were characterized by different patterns of feeding 3 different total amounts of concentrates. The total concentrates fed during the 36 weeks of lactation were: 1134 kg, 1512 kg and 1865 kg. The roughage was ad libitum with a fixed amount of roots, dried pulp and molasses (7.4 kg dry matter per day). During the rest of the lactation the cows were fed according to milk yield and body condition. The distribution of the concentrates over the lactation within a level did not influence the milk production. The average milk yields for the groups low, medium and high were 5657 kg, 6062 kg and 6388 kg FCM respectively (43% heifers per group). These 3 levels were compared with a group of cows which were fed according to milk production with total lactation yield of 5772 kg FCM. Østergaard (1979) observed an influence of the pattern of feeding distribution on the persistency but no influence of the level on this characteristic. Broster and Thomas (1981) suggested, referring to Johnson (1977), that the ability of changes in persistency to compensate on peak yield is a function of the feeding level in relation to cow potential.

As just mentioned the milk production is influenced by both short- and long-term effects. Therefore it is desirable to study cows over several lactations. Wiktorsson (1971, 1979) had studied multiple lactations. Wiktorsson (1971) compared three levels of feeding different amounts of energy per kg milk during two experimental lactations. The results from these lactations indicated that the cows on both treatments seemed to adapt their yields to the new feeding levels. The changes in milk production occurred during the first of the two lactations. Wiktorsson (1979) presented the results of a simular experiment with two feeding levels during two successive lactations. The results were comparable with the previous experiment. After these two experimental lacatations the individuals got the same feeding level. The low level of feeding in earlier lactations had a negative effect on the milk yield during the first part of the lactation, while the total production over 305 days did not differ significantly between groups when the same feeding level was used.

Oldham and Sutton (1979) have discussed the effect of the concentrates to roughage ratio on the milk fat percentage. More than about 70% concentrates in the dry matter decreased the fat percentage. Underfeeding had a negative influence on the protein percentage of the milk (Rook, 1976).

2.3 Live weight change

Changes in live weight of lactating cows result from a combination of growth, change of alimentary tract fill, pregnancy and alternate deposition and subsequent catabolism of body reserve tissues. Even though body reserves may subsequently be catabolized to provide metabolites for milk secretion, this process is inherently less efficient than the direct utilization of nutrients for milk production (Van Es and Van der Honing, 1979). Moe et al. (1971) indicated that body tissue changes may not be accurately reflected by live weight changes.

Huth and Smidt (1979) observed, in an experiment with 304 cows, an average body gain from service to date of calving of 127.6 kg. Miller et al. (1969) studied the body weights of 1004 Holstein cows. They observed the greatest change in live weight during the first lactation. The effect of the stage of lactation ranged from -37 to +46, or a total of 83 kg. These values for second and following lactations were -26 to +45 and -17 to +34 respectively.

In an experiment where hay and concentrates were available ad libitum (Lodge et al., 1975), cows which had been fed at the maintenance level before calving weighed less at calving than cows that had been given 1.8 times maintenance. The former group showed no net loss of body weight during the first 16-weeks' period of the lactation and the cows fed at the higher level before calving lost 62 kg in that period.

A more generous plane of nutrition in early lactation benefitted current body weight change, either reducing losses or increasing gains, depending on the trend in the experiment (Broster and Thomas, 1981). A low feeding level had the reverse effect but after a change in level the individuals tried to regain the lost tissues. Wiktorsson (1971, 1979) showed that in multiple lactation experiments the main changes in live weight caused by the feeding level applied occurred during the first year.

2.4 Relationship between milk production, feed intake and live weight change

2.4.1 Introduction

At the initiation of lactation, marked alterations in the general partitioning of nutrients and metabolism of the whole animal must occur to accommodate the demands of the mammary gland. Lactogenesis in ruminants is attended with metabolic changes such as increased lipolysis, gluconeogenesis and glycogenolysis, mobilization of protein reserves and increased absorption and mobilization of minerals (Bauman and Currie, 1980). According to these reviewers these metabolic changes are perhaps the most pronounced examples of homeorhesis. Within species, they can result in a deficiency of nutrients by the combined effects of feeding level, feed intake capacity (2.1.3) and genetic potential for milk production. This deficiency can be compensated by a reduction in body reserves. Bauman and Currie (1980) underlined the importance of diverting nutrients from the feed and body reserves to meet the needs of pregnancy and lactation. Within dairy cattle there is a variation in genetic potential for milk production. Selection for greater production increases the requirement for nutrients. These can be supplied by a higher feed intake and/or higher mobilization of reserves.

Milk production decreases with the progress of the lactation and under normal conditions (365 days calving interval) the decrease is intensified by the new pregnancy. At the end of pregnancy the nutrient requirements are about 75% greater than in a non-pregnant animal (Bauman and Currie, 1980). In general there is no lack of nutrients for milk production in the second part of the lactation and the animal will try to replenish reserve tissues to reach an equilibrium at a certain physiological state (Baumgardt, 1970). Genetic differences exist in the division of nutrients between milk production and reserve tissues (differences in priorities).

Several researchers have quantified the relation between milk production, feed intake and live weight losses and these have been studied under several feeding conditions. The review will be confined to some extensive studies on ad libitum feeding systems, namely: 1. Feeding concentrates according to requirements and ad libitum roughage 2. Feeding concentrates independently of requirements.

2.4.2 Feeding concentrates according to requirements

This feeding system is based on energy balance studies in which the utilization of the several nutrients for milk production and maintenance are estimated. In most studies the individuals were offered ad libitum roughage and limited concentrates. The concentrate level per individual was determined on the basis of the difference between the requirement for milk production and maintenance and the estimated average intake from roughage. Thus milk production was the determining factor on which feed was adjusted.

Hooven et al. (1972) and Miller et al. (1973) reported an extensive investigation into the relations between milk production, feed intake and live weight with this feeding system. This research was based on 425 first lactations (Hooven et al., 1972) or 548, 536 and 211 first, second and third lactations respectively (Miller et al., 1973)(overlap of material). Table 2.1 presents the range of the correlation coefficients per stage of lactation because these were calculated in both studies per 30 days lactation. The correlation coefficients with live weight were from Miller et al. (1973) and were based on 3 lactations. The other results were those of Hooven et al. (1972). The correlation coefficients between FCM and feed intake increased with increasing lenght of the lactation. The average live weight per stage of the lactation has a low correlation coefficient with milk yield and feed intake.

Table 2.1. Phenotypic correlation coefficients between FCM (kg) or milk yield (kg), feed intake (ENE), live weight (kg) and gross efficiency* in three parts of the lactation (Hooven et al., 1972, Miller et al., 1973).

	FCM/ Intake	Milk/ Live weight	FCM/ Efficiency	Intake/ Live weight
weeks 1-13	+0.15 - +0.50	-0.03 - +0.11	+0.78 - +0.85	+0.31 - +0.36
weeks 14-30	+0.57 - +0.70	-0.16 - -0.08	+0.77 - +0.82	+0.25 - +0.30
weeks 31-42	0.70 - +0.73	-0.23 - -0.19	+0.82 - +0.98	+0.21 - +0.22
	Intake/ Efficiency	**Live weight/ Efficiency**		
weeks 1-13	-0.38 - -0.15	-0.29 - -0.13		
weeks 14-30	-0.09 - +0.24	-0.42 - -0.34		
weeks 31-42	+0.30 - +0.43	-0.48 - -0.45		

* Gross efficiency = ratio FCM yield to feed intake (kg $Mcal^{-1}$)

Miller et al. (1972) calculated on the basis of a limited amount of material, namely 548 daughter-dam pairs, the phenotypic and genetic correlation coefficients on total lactation results (table 2.2). The genetic correlation coefficients between grain consumption and milk production was +1.0 due to the precise allocation of grain according to each cow's production. Genetic and phenotypic correlation coefficients between forage consumption and milk yield were positive but much lower. Forage consumption was negatively related to gross feed efficiency. By varying the ratio of forage to grain the feeding regime increased the variation in yield among cows.

Table 2.2. Phenotypic (first line) and genetic correlation coefficients between feed consumption and other total lactation traits (Miller et al., 1972).

Trait	Concentrates (ENE)	Roughage (ENE)	Energy intake (ENE)
FCM (kg)	+0.83 ± 0.02 +1.00	+0.10 ± 0.05 +0.32 ± 0.31	+0.72 ± 0.02 +0.82 ± 0.02
Live weight change* (kg)	-0.48 ± 0.04 -0.95 ± 0.42	+0.08 ± 0.05 +0.26 ± 0.19	-0.28 ± 0.04 -0.43 ± 0.24
Concentrates (ENE)		-0.23 ± 0.05 +0.33 ± 0.20	+0.58 ± 0.03 +0.84 ± 0.03
Roughage (ENE)			+0.66 ± 0.03 +0.80 ± 0.05
Gross efficiency** (kg ENE^{-1})	+0.74 ± 0.02 +0.90 ± 0.02	-0.32 ± 0.04 -0.11 ± 0.25	+0.17 ± 0.05 +0.50 ± 0.07
Live weight (kg)	-0.18 ± 0.05 -0.21 ± 0.18	+0.49 ± 0.04 +0.93 ± 0.01	+0.41 ± 0.04 +0.44 ± 0.07

* Live weight change between start and end of lactation
** Gross efficiency = Ratio FCM yield to energy intake

Broster (1972) reviewed the literature and noted that several workers found a negative correlation between body weight change and milk production. Politiek and Vos (1975) observed in first lactation cows a negative correlation coefficient between milk production and live weight change in the first 100 days of lactation (-0.55). Wood et al. (1980) observed a partial correlation coefficient between milk yield during the period of a negative energy balance and live weight loss, with live weight after calving held constant, of -0.18 for Friesians and -0.55 for Ayrshires. The period of negative energy balance was estimated on the live weight change. The coefficient between milk yield during the first 20 weeks of the lactation and live weight after calving was +0.56 for Friesians and +0.76 for Ayrshires.

2.4.3 Feeding concentrates independently of requirements

Feed is made the independent factor and is expressed in absolute amounts independent of the milk production. Examples of such feeding regimes are: 1. Fixed ratio of concentrates to roughage. 2. A fixed concentrate level with ad libitum roughage. Broster (1976) described the general relation between feed intake, milk yield and live weight change dependent on the genetic potential of the cow. The partitioning of the nutrients over the several body functions and the supply of nutrients is dependent on the individual and the physiological state of the animal. On this feeding regime feed intake and milk production are not confounded in contrast with the regime of feeding to requirements.

Østergaard (1979) compared 8 fixed strategies of feeding concentrates independently of the current milk yield with a control group fed concentrates according to milk production. However, he did not describe the relations between the characteristics in that extensive material (total number: 298 cows). Grieve et al. (1976) reported the correlation coefficients between characteristics on a feeding regime with a fixed concentrates to roughage ratio (n=49 first lactations) (first 180 days of lactation 60:40 and the rest of the lactation 40:60). Intake of dry matter during the total lactation, days 91 to 180, and days 181 to 305 was correlated with lactation yield of solids-corrected milk and the coefficients being +0.81, +0.78 and +0.82 respectively (table 2.3). The first part of the lactation has a much lower correlation coefficient. Feed intake was also correlated with gross efficiency and this phenotypic correlation coefficient was much higher than in the results of Miller et al. (1972).

Table 2.3. Correlation coefficients between dry matter intake and lactation traits (Grieve et al., 1976).

	Dry matter intake period (days)			
	1-90	91-180	181-305	Total
305 days SCM* yield	+0.31	+0.78	+0.82	+0.81
Body weight post partum	+0.28	+0.28	+0.15	+0.27
Body weight loss**	-0.28	+0.29	+0.16	+0.10
Body weight end lactation	+0.17	-0.10	-0.12	-0.04
Gross efficiency***	+0.12	+0.63	+0.68	+0.62

* SCM = Solids corrected milk

** Body weight loss post partum to peak lactation

*** Efficiency = Ratio total lactation SCM to total dry matter intake (kg kg^{-1})

2.5 Genotype-ration interaction

2.5.1 Introduction

The performance (the phenotype) of an animal is a function of the genotype and the environment and a possible non-additive relationship between these two effects.

The differences between genotypes may be dependent on the environment.

Several workers have reported on the genotype-environment interaction within species among breeds, strains or families. The research on the importance of the interaction was stimulated by Hammond (1947). He suggested: "The highest improvement of a trait by selection will be reached in the environment that is necessary for the fullest expression and the superiority of a genotype in this environment will be kept in an other environment". However, Falconer and Latyszewski (1952) demonstrated an interaction between genotype and level of nutrition for growth in mice and Fowler and Ensminger (1960) in pigs. They stated that the genes affecting the character in the two environments were not the same.

Some examples of environments are: climate, nutrition, housing, age, sex, year and season. This section will be confined to the importance of the interaction between genotype and level of nutrition or type of ration in dairy cattle.

2.5.2 Methods of detecting the presence of interaction

The testing of an interaction is possible in a situation in which at least two genotypes are tested in at least two environments. The genotype may be represented, for example, by progeny groups, monozygous twins, or breeds. The chance of obtaining an interaction will increase with the increase of the genetic variation (Syrstad, 1976).

The variance analysis is that according to Pani and Lasley (1972), one of the most usual ways for detecting a genotype-environment interaction. However, a statistically significant interaction may be caused by ranking differences of the genotypes between environments or by the differences between genotypes in the two environments (pseudo-interaction)(figure 2.1). These differences may be caused by genetic and/or environmental effects.

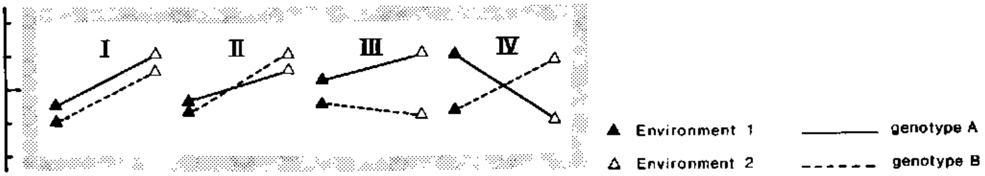

Fig. 2.1. A classification of genotype-environment interactions (Minkema, 1968)
I : No ranking change, no significant interaction
II : Ranking change, no significant interaction
III: No ranking change, significant interaction
IV : Ranking change, significant interaction

Falconer and Latyszewski (1952) considered the phenotypic expression in the two environments as two different characteristics and calculated the genetic correlation between these two characteristics. The genetic correlation can also be estimated from the direct and correlated responses in selection.

2.5.3 Results with dairy cattle

Results of the experiments with progeny groups and monozygous twins were reviewed. The review was confined to temperate zones and no references to experiments with different breeds (dairy and/or dual purpose) were found in the literature.

Progeny groups of sires

The experiments with progeny groups can be divided into experiments with groups on several rations and on field data.

Richardson et al. (1971) performed an experiment with 228 daughters (heifers) of 13 Jersey sires which were divided into groups on a roughage ration (ad libitum) or a ration with roughage ad libitum and 1 kg concentrates per 3 kg of milk. The first group produced about 19% less fat corrected milk and the interaction between sire and ration had a significance level between 0.10 and 0.05. The interaction for the ratio total net energy to FCM was significant which might be the result of the level of concentrates being determined by the level of production. The ranking of the sires on the two rations for FCM were similar but there were a few clear shifts, namely from two groups of daughters of bulls selected from New Zealand (9 to 5 and 12 to 2).

Lamb et al. (1977) presented the results of two experiments. Data were from 289 complete first lactations of Holstein cows, including 150 daughters of 10 sires in trial I and 139 daughters of 8 sires in trial II. The two rations for trial I were alfalfa hay ad libitum and alfalfa hay ad libitum plus 1 kg concentrates per 3.5 kg FCM. In trial II, the rations were alfalfa hay ad libitum plus 1.4 kg concentrates per day and alfalfa hay ad libitum plus 2.1 kg concentrates per 3.5 kg FCM above 4.5 kg per day with a minimum of 10.9 kg concentrates per day for the first 6 weeks and 2.7 kg per day thereafter. Between the two rations of the first experiment there existed a difference in coefficient of variation for FCM production (higher on the concentrate ration). The difference between the two rations in the two experiments for FCM was approximately 29% and 28%. The interaction of sire - ration affected ($P \leq 0.05$) FCM, ratio FCM to digestible energy intake and fat yield in trial I. In trial II no significant interactions were found. When the daughters of a New Zealand bred sire were removed from experiment I, no significant interactions remained.

Since the regular progeny testing of sires was introduced, several studies have been made on the importance of genotype-environment interaction on the ranking of progeny-tested sires. The nutrition difference is probably the most important factor in the variation between herds within a region. The interaction may be expressed by the herd - progeny group of a sire or by the genetic correlation between production in pairs of levels and these analyses were carried out by several researchers on milk recording data.

A review of the results was presented by Freeman (1975), Syrstad (1976), Wiggans and Van Vleck (1978), Ibrahim (1979) and Danell (1982). In general the interaction component was small (0-4% of the total variation, or a genetic correlation between 0.8-1.0). A clear exception were the results of Mao and Burnside (1969), which grouped the herds in a series of environmental factors. Only the interaction between progeny group (sire) and amount of concentrates given in summer was significant and genetic correlations were determined between 0.54 and 0.79. Many researchers showed a higher variance between and within progeny groups on the high level herds.

Monozygous twins

An interaction between genotype and environment may be estimated through a difference in environment between the twins. It is necessary for testing the interaction in a variance analysis to have pairs on the same treatment. Rindsig and Freeman, cited by Freeman (1975), divided 129 monozygous twins over two rations. Half of the twins were not so allocated but were available for comparison. The low nutrition level consisted of ad libitum roughage and 0.167 kg concentrates per kg FCM and the high level of ad libitum roughage and 0.5 kg concentrates per kg FCM. No significant interaction was determined for production traits. The coefficient of correlation between members of monozygous pairs was estimated as 0.71. The reviews of Pani and Lasley (1972), Freeman (1975) and Syrstad (1976) showed that the few experiments with dairy cattle monozygous twins on different rations did not indicate significant interactions for milk production characteristics.

3 MATERIALS AND METHODS

3.1 Materials

3.1.1 Introduction

Review of the literature shows that the importance of the genotype-ration interaction on production traits in dairy cattle was studied in some experiments within a breed (e.g. progeny groups, monozygous twins). Reports of experiments with different breeds (dairy, dual-purpose) in temperate zones were not found in the literature. Nevertheless it is probable that the chance of obtaining an interaction will increase with an increase in the genetic variance. As mentioned in the general introduction (1) the importance of the use of different breeds in a genotype-ration experiment has increased with the exchange of semen between countries. A comparison between Dutch Friesians and crossbreds between Friesian subpopulations was carried out on the experimental farm of the Agricultural University (Politiek et al., 1982). Dairy cows descended from the Dutch Friesian (DF) population and the crossbreds between Holstein- (HF) and Dutch Friesians (as well HFxDF as HF x (HFxDF)) from that experiment were used in this project. These two groups had the greatest contrast for milk production (DF - HFxDF: -822 kg milk in the first lactation - Politiek et al., 1982) and were defined as the genotypes in this genotype-ration experiment.

Most studies on milk production and feed intake were carried out on a feeding regime with concentrates given according to milk production. The variation on production traits was confounded with the concentrate level. The dairy cows in this project were offered a fixed level of concentrates during the lactation (two levels) with ad libitum roughage. The variation in milk yield may have been caused by e.g. a variation in roughage intake, body change or utilization of nutrients. The Dutch Friesians and the crosses between Holstein- and Dutch Friesians were allocated over two rations namely a low and a high concentrate level with ad libitum roughage. The contrast in concentrate level between rations was chosen in such a way that a difference in the regulation mechanism of the feed intake was possible (2.1.1).

The short- and long term reactions of the individuals were studied during two experimental lactations as was the dry period between these two lactations. The original plan of the project was to study the effect of the ration in the first lactation on the traits in the second lactation by changing half the number of the cows within a subpopulation. The involuntary culling during and at the end of the first experimental lactation was higher than was expected. Therefore all the cows were changed from the ration of the first to the second experimental lactation. The differences between ration contrasts in the two lactations could be studied and it was to be expected that the carry-over effect would be greater than in the alternative (a situation with two experimental lactations without ration change).

The experimental lactations were extended over a period of 40 weeks. No data were gathered in the period between week 40 of the first experimental lactation and the dry period (8 weeks before calving) but the ration was checked and all the cows were offered the same ration in the dry period.

This project started in 1979 on the experimental farm of the Agricultural University ("Ir. A.P. Minderhoudhoeve" - East Flevoland).

The following abbreviations were used:

DF	- Dutch Friesians
HF	- Crosses between Holstein Friesian and Dutch Friesian
Roughage	- Ration with a low concentrate level and ad libitum roughage
Concentrate	- Ration with a high concentrate level and ad libitum roughage
Experiment I_1	- First experimental lactation (total number: 91)
Experiment I_2	- First experimental lactation of the cows with a second experimental lactation (total number: 64)
Experiment II	- Second experimental lactation (total number: 64)

3.1.2 Animals

The first experiment started with about 100 cows but this number was decreased by involuntary culling in the two experiments and the dry period. Full lactation data were presented from 91 cows in the first experiment and 64 cows in the dry period and second experiment. The allocation of cows over the genotypes, rations and experiments are presented in table 3.1. "Normal" indicates that the same concentrate level was offered to all the individuals with ad libitum roughage in the dry period.

Table 3.1. The allocation (including numbers) of the cows over the genotypes, rations and experiments.

Genotype	Experiment I	Dry period	Experiment II
DF	Roughage (n=23)	Normal (n=18)	Concentrate (n=18)
DF	Concentrate (n=22)	Normal (n=16)	Roughage (n=16)
HF	Roughage (n=23)	Normal (n=17)	Concentrate (n=17)
HF	Concentrate (n=23)	Normal (n=13)	Roughage (n=13)

The cows were allocated over the rations within a genotype before the first experiment. The allocation criteria were:

- Date of calving
- Milk production (including components) first lactation
- Live weight (including some body measurements) at the beginning of the first lactation
- Lactation number (2, 3 and more than 3)
- Generation (first or second for the HF group).

The unadjusted averages per genotype-ration group are presented in table 3.2. The culling before and during the first experiment and the environmental effects on production characteristics in the first lactation could have influenced the correctness of the allocation. However an analysis of the variance of these characteristics of the cows used (total n=91) in the first lactation and the lactation before the first experiment did not show a significant ($P > 0.05$) ration effect.

Table 3.2. Live weight and some body measurements after calving at the first lactation and milk production (incl. components) in the first lactation per genotype-ration group.

	DF-Roughage (n=23)		DF-Concentrate (n=22)		HF-Roughage (n=23)		HF-Concentrate (n=23)	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Trait								
Live weight (kg)	502	39	502	38	512	37	521	41
Pelvic height (cm)	130.3	3.5	131.1	2.9	135.1	3.3	136.0	4.0
Hearth girth (cm)	190.3	8.7	188.7	6.3	189.8	6.3	191.4	6.2
Milk production (kg)	4990	710	4860	531	5799	709	5737	712
Fat (10 g kg^{-1})	4.35	0.28	4.24	0.28	4.01	0.29	3.93	0.19
Protein (10 g kg^{-1})	3.36	0.16	3.39	0.18	3.29	0.13	3.27	0.14

The involuntary culling after the first experiment, during the dry period and the second experiment was mainly caused by fertility problems and mastitis (table 3.3). The insemination of the cows was started 60 days after calving and the cows were culled because of fertility problems when the time between calving and conception was more than 180 days. The total number of involuntary culling ranged between 5 and 10 over the four genotype-ration groups.

Table 3.3. The reasons and numbers of involuntary culling after the first experiment per genotype-ration group.

	DF-Roughage	DF-Concentrate	HF-Roughage	HF-Concentrate
Reason				
Fertility problems	2	5	4	6
Mastitis and other udder problems	1	1	1	2
Remainder	2	-	1	2

Every disease during this project was recorded when it was diagnosed by the veterinarians of the Central Veterinary Institute in Lelystad. Table 3.4 reviews the incidence of the several diseases per experiment and per genotype-ration group. The total numbers per experiment are presented, which included repeated measurements in the several weeks of the lactation. However, within any one week it was considered as one treatment. During the project a "measuring week" was defined as being from Thursday to Thursday. A tendency existed for a difference between rations in the number of treatments for mastitis and, in the first experiment, for sole ulcer (table 3.4). The numbers of treatments for sole ulcer were 22 and 45 respectively for the combined roughage and combined concentrate groups in the first experiment. The number of cows with sole ulcer during the lactation were, for the roughage and concentrate group in the first experiment, 17 and 26 respectively and in the second experiment 10 and 18. This underlined the ideas of Weaver (1979) on the influence of the feeding level on this disease. Some cows of the roughage group had been treated because of grass-tetany. This only happened at the beginning of the first experiment because after that time the magnesium level in the concentrates was increased for this group.

Table 3.4. Health disturbances, per experiment (I, II) and per genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
Trait	I	II	I	II	I	II	I	II
Retentio secundinarum	2	1	2	2	4	4	-	-
Endometritis	1	1	7	2	3	1	1	-
Mastitis	-	2	6	3	3	1	8	8
Other udder diseases	-	1	2	1	3	1	9	3
Sole ulcer	10	7	20	10	12	7	25	9
Phlegmona interdigitalis	1	3	3	3	3	-	3	2
Other foot and leg diseases	10	11	16	9	4	3	6	5
Milk fever	3	1	1	1	5	-	2	2
Grass-tetany	6	-	-	-	5	-	-	-
Indigestion	-	1	2	-	1	1	3	-
Other diseases	2	-	-	-	1	-	-	-

The cows were kept in a cubicle stall during the whole experiment and offered preserved roughage. The individual roughage intake was recorded over a period of one week every 3 or 4 weeks and this was carried out in a tying stall.

3.1.3 Rations

The rations contained ad libitum roughage (residues of approximately 10% of the amount offered) and the amounts of concentrates were restricted to the treatment. The roughage and concentrates were offered separately. The time of access was the whole day for the roughage and for the concentrates it was dependent on the level. A level of 4 kg or less was divided over two periods (morning and late afternoon) and a higher level was divided over four or more periods depending on the level.

Concentrates

The cows within a genotype were allocated to either a low concentrate (Roughage group) or a high concentrate (Concentrate group) ration. The total amounts of concentrates (including standard deviation) per cow, experiment and concentrate step are shown in table 3.5. Some variation between cows for the concentrate intake occurred because not all of the offered concentrates was eaten (mainly concentrate groups) and also because of the definition of a measuring week (3.1.2). The concentrates were divided over the lactation in three steps per ration. These periods generally corresponded with three physiological stages of the lactation (e.g. Bines, 1976b). An exception was the first three weeks of the lactation of the concentrate groups (figure 3.1). The concentrates were offered independently of the individual milk production.

During the dry period before the first experiment the concentrate level was the same for all the cows, namely week 8-6 before calving no concentrates, week 6-4 1 kg, week 4-2 2 kg and 2 weeks before calving until calving 3 kg concentrates per day. Between the two experiments these levels were: 8-6 weeks before calving no concentrates and between week 6 and date of calving 1 kg concentrates. In this period the same level was offered for the whole time so that the level of roughage intake throughout this period was not confounded with the concentrate level. When the cows were still lactating after 40 weeks lactation in the first experiment and before the dry period they were offered 1 kg concentrates per day.

Table 3.5. Means and standard deviations (s.d.) of the total concentrate intake (kg) per experiment (I, II), period and genotype-ration group.

Period (weeks)	1-12		13-28		29-40		1-40	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I								
DF-Roughage	269	6	222	0	86	0	573	7
DF-Concentrate	854	32	968	23	506	10	2304	47
HF-Roughage	266	8	222	0	86	0	570	7
HF-Concentrate	845	32	967	32	507	12	2291	46
Experiment II								
DF-Roughage	265	5	222	0	86	0	569	5
DF-Concentrate	871	22	986	33	512	14	2345	43
HF-Roughage	266	7	222	0	86	0	570	7
HF-Concentrate	845	41	978	32	515	2	2315	62

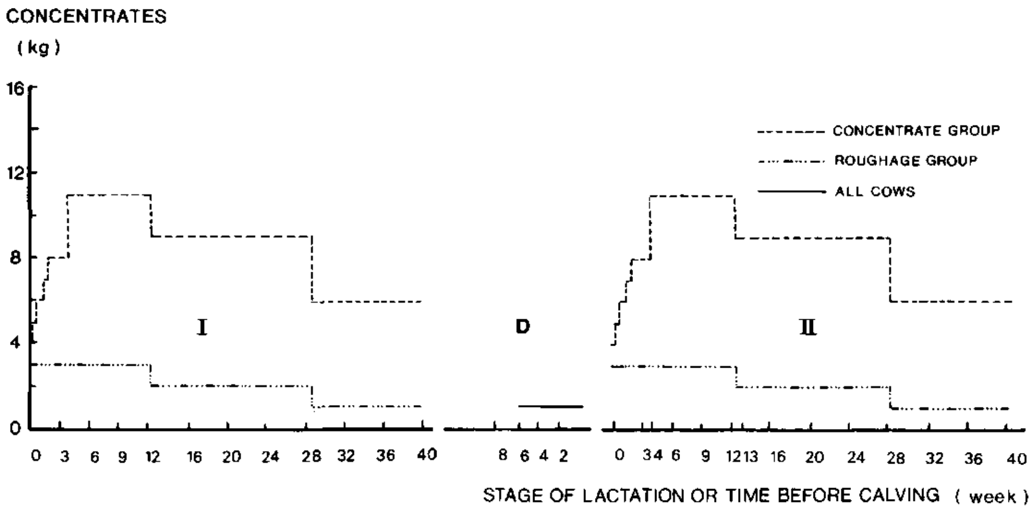

Fig. 3.1. The concentrate levels per experiment (I, II) and the dry period (D) per ration.

The estimated feeding value of the concentrates was 940 VEM (1 VEM = 6.904 kJ net energy) and 120 grams digestible crude protein per kg. However, the ration groups had different mineral contents in the concentrates which was further increased after some problems with grass-tetany. The following mineral levels were found in thirteen samples of the concentrates over the two experiments (after increasing MgO-level):

	Concentrate group	Roughage group
CaO $(g\ kg^{-1})$	16.9 ± 2.8	28.6 ± 1.5
MgO $(g\ kg^{-1})$	8.4 ± 1.6	22.6 ± 3.2
P_2O_5 $(g\ kg^{-1})$	12.0 ± 1.1	24.9 ± 2.1

The other elements per kg concentrates were comparable for the two rations and the difference in mineral content was caused by dicalcium phosphate and magnesium oxide. There were some changes in the ingredients of the concentrates which were caused by market conditions.

Roughages

The roughage was offered ad libitum accepting residues of approximately 10% of the amount offered (5-15%). The results showed a difference between rations, however, the average refusal for the roughage group was the lowest. A higer feed refusal can imply more selection possibilities (Zemmelink, 1980) and therefore it is possible that the difference between rations was underestimated.

During the first experiment the cows were offered hay but as a result of the wet summer of 1979 it was not possible to preserve sufficient grass as hay for the second experiment. Therefore after the first experiment the hay was replaced by grass silage.

Some minerals were analysed from a representative sub-sample of bulked samples over four weeks (a constant proportion). The testing procedures were described in "Voorlopig overzicht analysemethodieken" (Bedrijfslaboratorium voor grond- en gewasonderzoek, 1978). The average figures (g kg^{-1}) in the first and second experiment for CaO, MgO and P_2O_5 were 8.6 (± 1.1) and 10.5 (± 0.3), 2.6 (± 0.2) and 3.1 (± 0.3), 8.7 (± 1.3) and 9.5 (± 1.2) respectively.

3.1.4 Characteristics and frequency of measuring

Roughage intake

In general measuring individual roughage intake is laborious and needs special equipment. It was therefore impossible to record the individual intake every day. The roughage intake was determined for individual cows over a period of a week every 3 or 4 weeks during the lactation. In such measuring weeks the cows were housed in a tying stall. The first 3 days of the week were used for adaptation and during the following 4 days the individual intake was recorded. The measuring weeks during the two experiments were the following lactation weeks: 3, 6, 9, 12, 16, 20, 24, 28, 32, 36 and 40. In the second experiment weeks 4 and 13 were also measured because of the concentrate change after week 3 for the concentrate group and after week 12 for both groups. Because of insufficient equipment measurements were impossible in week 29. The roughage intake was recorded individually in the dry period during weeks 6, 4 and 2 before calving.

A representative sample in duplicate was taken every week of the hay offered and, for the silage, four duplicates were taken because of the higher within and between day variations in moisture content in comparison with hay. The samples were analysed for dry matter content, crude fiber, crude protein and ash content (Bedrijfslab. voor grond- en gewasonderzoek, 1978). The in-vitro digestibility of the roughage was determined in the laboratory of the dept. of Animal Nutrition. The Tilley and Terry (1963) method was used with the modification of Van der Koelen and Dijkstra (1971).

Appendices 1 to 5 show the means and standard deviations of the constituents of the roughage per measuring week, per experiment and per genotype-ration group. No significant differences existed between the four groups for the several characteristics within a week. The dry matter content (%) in the hay ranged between 81.6 and 84.1 and for the silage period between 36.8 and 47.0. The quality of the hay decreased at the end of the first experiment. The variation in standard deviations over the several weeks might be caused by the differences between batches of hay. A seasonal variation in measurement for individuals at the same stage of lactation was inherent in the design of the experiment.

In the first experiment the feed refusals were recorded once a day per individual and a proportional sample each week was tested for dry matter content. During the dry period and the second experiment the refusals were determined once every two days. The roughage dry matter intake per individual per day within a week was based on the average difference between roughage dry matter offered and refused during four days.

Energy intake

The energy intake per individual per day within a week was calculated from the dry matter intake and the energy content of the ration (roughage and concentrates). The energy concentration of consumed forage was possibly underestimated due to the assumption that the composition of consumed and refused forage was the same.

The net energy content per kg roughage dry matter was based on the following formula (Van Es, 1978):

$NE\ (kJ\ kg^{-1}) = 0.6\ [1 + 0.004\ (q-57)]\ \times c \times ME$

- The value NE predicts the amount of net energy in milk at a feeding level suitable for a production of 15 kg milk, in which c (= 0.9752) is the correction factor to convert the metabolizable energy (ME) at the maintenance level of feeding to the ME at this particular feeding level.
- $ME\ (kJ\ kg^{-1}) = (3.4\ D_O + 1.4\ D_{XP}) \times 4.184$

  $D_O\ (g\ kg^{-1})$ = digestible organic matter (in-vitro method)

  $D_{XP}\ (g\ kg^{-1})$ = digestible crude protein and this was calculated according to the C.V.B. (1977).
- $q = 100 \times ME \times GE^{-1}$

  Gross energy (GE) of forages was assumed to be 18410 kJ per kg dry matter

(Van Es, 1978).

The calculated net energy (NE) was expressed in Dutch feed units for lactation (VEM); one VEM unit equals 6.904 kJ NE.

The average and standard deviations of the energy content (VEM) per kg roughage dry matter per week, experiment and genotype-ration group are presented in appendix 6. This characteristic did not show a significant ($P > 0.05$) difference between genotype-ration groups within a week. However, this characteristic clearly showed a variation over the weeks.

The estimated feeding value of the concentrates was 940 VEM (1 VEM = 6.904 kJ NE).

Milk production and components

The milk production and components were recorded on one day per week. The milk components analyses were done according to the methods of the Central Milk Recording Organisation. The milk fat was tested by means of the Milco Tester Automatic (light dispersion method) which was standardized with the Gerber-method. The Amino black (colour binding) method was used for the determination of the milk protein and this method was standardized with the Kjeldahl method.

Live weight

The live weight of all the individuals was recorded before and after a measuring week in both experiments. It was also determined the second day after calving. In this way 23 and 25 measurements respectively were made, in the first and second experiment, during the lactation. In the dry period the individuals were weighed one week before this period, at the start of the dry period and before and after the three measuring weeks. The time of measuring during the day was between 13.00 and 15.00 hours.

The difference between energy intake and requirements for maintenance and milk production

The energy requirement for maintenance and milk production was expressed as net energy for lactation. The requirement for maintenance ranges between 450-500 kJ ME per unit metabolic weight ($W^{0.75}$) per day and this implies in Dutch feed units approximately 42.4 VEM (Van Es, 1978). One kg fat corrected milk (FCM) needs 442 VEM (3054 kJ NE) (Van Es, 1978). Both requirements are expressed on a milk

yield level of 15 kg because the energy intake applies to this level. The total requirement had to be corrected for higher or lower feeding levels and was calculated with the following formula (Benedictus, 1977; Van Es, 1978):
VEM d^{-1} = (42.4 $W^{0.75}$ + 442 FCM)(0.9752 + 0.00165 FCM).

The FCM in this equation is calculated from the formula: FCM = (0.4 + 0.15 Milk Fat percentage) x Milk Yield. The accuracy of this equation for estimation of the energy milk output is dependent on the underlying correlations between the several milk components (Tyrrell and Reid, 1965). The concentrate levels of the two rations in our experiment had a different effect on the milk components at the beginning of the lactation (4.2.2). A multiple regression of milk energy on fat and protein percentage in the milk was calculated on the basis of 270 balance trials with dairy cows (Van der Honing, 1981). The data were derived from dairy cows in the first part of lactation and which were offered long forage and concentrate dependent on the milk yield. The following equation resulted:
Fat Protein Corrected Milk (FPCM) = (0.349 + 0.107 Milk Fat percentage + 0.067 Milk Protein percentage) x Milk Yield. This equation assumes a fixed relationship between these two components and the milk lactose percentage. The equation for the total energy requirement per day used in the analysis was as follows: VEM d^{-1} = (42.4 $W^{0.75}$ + 442 FPCM)(0.9752 + 0.00165 FPCM). In that way it was possible to calculate the energy needs for maintenance and milk production, and also the difference between energy intake and requirement.

3.2 Statistical methods

3.2.1 Introduction

The analysis was started with the separate characteristics in accordance with the purposes of this study. In addition the relations between the traits were analysed. The analysis was divided into three steps:

a. Cumulative periods
b. Measuring weeks
c. Characterizing of the characteristics over the lactation.

The analysis was carried out within an experiment because of the confounding effects between year, kind of roughage, lactation number and carry-over effects from the first to the second experiment. On the assumption that these effects had only level changes, it is possible to compare the contrasts in the two experiments. This gives an impression of possible carry-over effects.

3.2.2 Cumulative periods

This first step shows a general impression of the several effects within a cumulative period. These periods corresponded with the concentrate steps over the lactation and generally with the physiological stages of the lactation. The periods were weeks 1-12, 13-28 and 29-40 respectively. The characteristics per period were based on the average of the measuring points within that period.

The data were analysed by the least squares methods (Harvey, 1977) with the following models:

$$y_{ijklmn} = \mu + g_i + r_j + l_k + s_l + p_m + \text{two-way interactions} + e_{ijklmn} \quad \text{(Model I)}$$

y_{ijklmn} = the characteristics of the n^{th} cow with genotype i, ration j, lactation number k, season l and days open class m.

μ = overall mean

g_i = effect of i^{th} genotype (i = 1,2)

r_j = effect of j^{th} ration (j = 1,2)

l_k = effect of k^{th} lactation number (k = 1,3) (in the second experiment k = 1,2)

s_l = effect of l^{th} season (l = 1,4)

p_m = effect of m^{th} days open class (m = 1,4)

e_{ijklmn} = error term

- The lactation numbers were divided in the first experiment into 3 classes: lactations 2, 3 and more than 3. The second experiment had two classes: lactations 3 and more than 3.
- The seasonal effect was confounded between season of calving and measuring and this was divided in (calving season): December-January, February, March and April-May.
- The days open effect in the lactation analysed was divided into four groups: less than 82 days, 82-110 days, 111-145 days and more than 145 days between calving and conception.

Model I was used for testing the interactions between main effects. These results were taken into account in the interpretation of the analysis of a simplified model (model II) without interactions. For the purposes of this study an exception was made for the genotype-ration interaction.

$$y_{ijklmn} = \mu + g_i + r_j + l_k + s_l + p_m + (gr)_{ij} + e_{ijklmn} \quad \text{(Model II)}$$

symbols: see model I
$(gr)_{ij}$ = the interaction between i^{th} genotype and j^{th} ration.
The interaction effect was estimated by the difference between the sums of the diagonaal subclasses (Mather and Jones, 1958): [(HF-Concentrate + DF-Roughage) - (HF-Roughage + DF-Concentrate)] .

3.2.3 Measuring weeks

The second step gives more detail information about the several effects during the lactation. The analysis was confined to the measuring weeks for intake and this meant, in the first and second experiments, 11 and 13 weeks respectively, and 3 weeks in the dry periods between these experiments.
The characteristics used were calculated as follows:

- Intake: The average recorded intake per day (roughage or energy) within a week.
- Milk production and components: The average of the measuring week (week t), week t-1 and week t+1 was calculated.
- Live weight: The average of the recorded weight at the beginning and the end of the measuring week was calculated.
- Live weight change: The difference between the averages of two measuring weeks.
- Difference between energy intake and energy requirements for maintenance and milk production: The calculation was based on the foregoing characteristics.

The data in the 27 measuring weeks were analysed with the same models as the characteristics in the cumulative periods (model I and II).

One of the conditions for testing the effects in an analysis of variance are the homogeneous variances in the several subcells. Scheffé (1959)(cited by Snedecor and Cochran, 1967) had studied the effect of unequal variances in the subcells on the chance of an error decision. His conclusion was that heterogeneous variances in subcells have only a small effect on the chance of an error decision in the situation of comparable numbers in the subcells.

3.2.4 The characterizing of the characteristics over the lactation

The analyses per measuring week within an experiment supplied 11 or 13 repeated testings of main and interaction effects. This number of testings can be decreased by the characterizing of traits over the lactation by some parameters. A model was developed for the live weight curve over the lactation. Further, this model was applied to the other energy requirement and intake traits (energy intake, fat protein corrected milk).

The live weight curve during the lactation can be written as the following general equation:

f (live weight) = f (age) + f (lactation) + f (pregnancy)

- f (age) = $A - q_1 t_3^{-1}$

  A = mature live weight

  q_1 = correction parameter of the mature live weight for age

  t_3 = age (days)

- f (lactation) = $\alpha t_1^{n} e^{-\beta t_1}$ (Wood, 1967)

  α = level parameter

  β and n = parameters to describe the shape of the curve

  t_1 = number of days lactation

- f (pregnancy) = $q_2^3 (t_2 - q_3)^3$ (Hugget and Widdas, 1951; cited by Taylor, 1980)

  q_2 and q_3 = parameters of pregnancy

  t_2 = number of days pregnant.

The estimation of parameters of a function was done by the least squares method included in the computer program BMDX85 (Dixon, 1973). The assumptions of this method were described by Daniel and Wood (1971). The model was reduced according to the results (non-converge), the adaptation of the pregnancy function by Taylor (1980) and the biological interpretation of the parameters. The following model was used:

$$y_{it_2t_1} = p_1 + p_2^3 (t_2 - 50)^3 + p_3 t_1 p_4^{-1} e^{(1 - t_1 p_4^{-1})} \quad \text{(Model III)}$$

$y_{it_2t_1}$ = characteristic (e.g. live weight) of cow i on normal scale dependent on the stage of pregnancy (t_2) and the stage of lactation (t_1).

t_2 = number of days pregnant

t_1 = number of days lactation

p_1 = the level of the characteristic

p_2 = pregnancy parameter

p_3 = maximum increase or decrease of the characteristic during the lactation

p_4 = time during the lactation with the maximum or minimum of the characteristic.

The live weight, energy intake and FPCM curve over the lactation were fitted per individual with this model. The four genotype-ration groups were compared on the basis of the four parameters per individual. This analysis was confined to the first experiment.

3.2.5 Coefficients of variation and correlation

Possible differences between genotype-ration groups in variation of traits and coefficients of correlation within and between characteristics were of interest in this study. However, the traits were affected by some known and unknown effects. Known effects were lactation number, season and days open and the characteristics were adjusted for these effects within a genotype-ration group (Model IV). One of the unknown effects was the genetic potential. The adjusted variations give a comparison of the relative genetic effects on different genotype-ration groups assuming no other systematic unknown effects.

$y_{klmn} = \mu + l_k + s_l + p_m + e_{klmn}$ (Model IV)

symbols: see model I

y_{klmn} = the characteristic of the n^{th} cow with lactation number k, season l and days open class m

e_{klmn} = error term.

4 RESULTS

This chapter summarizes the results of the two experimental lactations and the dry period between these two experiments. The separate characteristics, feed intake, milk production and live weight change are described in the first part. In the description a distinction is made between cumulative periods, the relations between periods and the pattern of the characteristics over the lactation. The second part of this chapter summarizes the relations between the production characteristics.

The effects of treatments (e.g. ration and genotype) were analysed by analysis of variance and tested at a significance level of $P \leq 0.05$. The levels of significance of the coefficients of correlation are indicated by asterisks. The levels used and the asterisk notation assigned to each are $P \leq 0.05$ *, $P \leq 0.025$ **, $P \leq 0.01$ ***.

4.1 Feed intake

4.1.1 Energy intake

4.1.1.1 Cumulative periods

The averages and standard deviations of the total energy intake per genotype-ration group, experiment and period are presented in table 4.1. These results were not adjusted for environmental effects. The standard deviations in the first period (weeks 1-12) were comparable for the four groups but they were different for the rations in the second and third periods of the second experiment. In spite of the lower energy intake level the roughage ration showed in most cases a greater standard deviation than the concentrate ration.

The total energy intake per period was analysed with model I and this resulted in only one significant ($P \leq 0.05$) two-way interaction in the third period of the second experiment. This interaction was not important in the other periods. The results of the analysis with model II, which included the effects of genotype, ration, lactation number, pregnancy, season and the interaction between genotype and ration, accounted for 74 to 90% of the total variation (R^2) in total energy intake, independent of the stage of lactation and the experiment (table 4.2).

Table 4.1. Means and standard deviations (s.d.) of the total energy intake (kVEM) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40	
	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I						
DF-Roughage	1189.80	121.14	1508.28	168.73	872.71	128.28
DF-Concentrate	1488.19	102.46	1871.57	88.30	1112.49	114.32
HF-Roughage	1245.25	107.27	1515.86	122.66	837.29	115.19
HF-Concentrate	1563.52	113.58	1954.75	118.06	1144.03	120.91
Experiment II						
DF-Roughage	1117.19	74.51	1397.22	137.68	905.60	112.98
DF-Concentrate	1580.45	98.92	1958.43	98.01	1175.73	74.11
HF-Roughage	1172.86	69.98	1562.33	145.50	977.26	110.74
HF-Concentrate	1579.85	90.26	1962.39	81.07	1228.29	70.70

Table 4.2. Analysis of variance on the total energy intake (VEM) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40	
Source	df	SS $\times 10^8$	P	SS $\times 10^8$	P	SS $\times 10^8$	P
Experiment I							
Total	91	1742541.5		2715462.0		922215.3	
μ	1	1507398.9		2327376.7		783823.4	
Genotype	1	180.0	.199	415.5	.061	262.9	.022
Ration	1	22072.9	.000	32064.4	.000	13627.1	.000
Lactation	2	1200.2	.005	830.3	.032	723.0	.001
Days open	3	204.3	.594	109.5	.813	82.9	.634
Season	3	665.7	.111	3325.6	.000	7336.5	.000
Genotype * Ration	1	5.5	.822	33.6	.591	54.8	.289
Remainder	79	8466.5		9083.1		3801.8	
R^2 (%)		74.8		82.5		87.1	
Experiment II							
Total	64	1256830.9		1968328.9		765878.7	
μ	1	864917.5		1366822.8		542182.2	
Genotype	1	82.5	.264	447.2	.075	703.5	.003
Ration	1	24349.6	.000	26433.1	.000	11150.3	.000
Lactation	1	17.4	.606	8.3	.805	0.9	.912
Days open	3	108.2	.646	680.4	.184	18.7	.968
Season	3	889.4	.006	237.4	.629	1301.2	.001
Genotype * Ration	1	194.8	.089	398.2	.093	3.5	.828
Remainder	53	3429.6		7191.4		3862.8	
R^2 (%)		90.2		85.5		77.0	

The genotype-ration interaction had the highest level of significance in the first and second periods of the second experiment (P = 0.089 and 0.093). In both experiments the influence of the genotype increased with the stage of lactation. According to the design the ration effect was highly significant. The lactation effect was significant in the first experiment and this was caused by the cows with a second parity in the first experiment. The effect of season was variable and the clear seasonal effect in weeks 29-40 of the first experiment can be explained for the greater part by the variation in offered roughage (appendix 6).

Table 4.3. Least squares constants of the effects on the average energy intake (VEM d^{-1}) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40	
Source	I	II	I	II	I	II
Mean	15190	15190	15167	15263	11736	12817
DF-Roughage	-1937	-2676	-1891	-2781	-1638	-2136
DF-Concentrate	+1589	+2413	+1467	+2289	+1187	+1315
HF-Roughage	-1646	-2003	-1578	-1818	-1378	-1256
HF-Concentrate	+1993	+2265	+2002	+2308	+1828	+2077
Genotype * Ration	+113	-821	+222	-944	+381	-118
Lactation 2	-648		-436		-544	
Lactation 3	+287	-66	+177	-37	+210	+16
Lactation ≥ 4	+361	+66	+259	+37	+334	-16

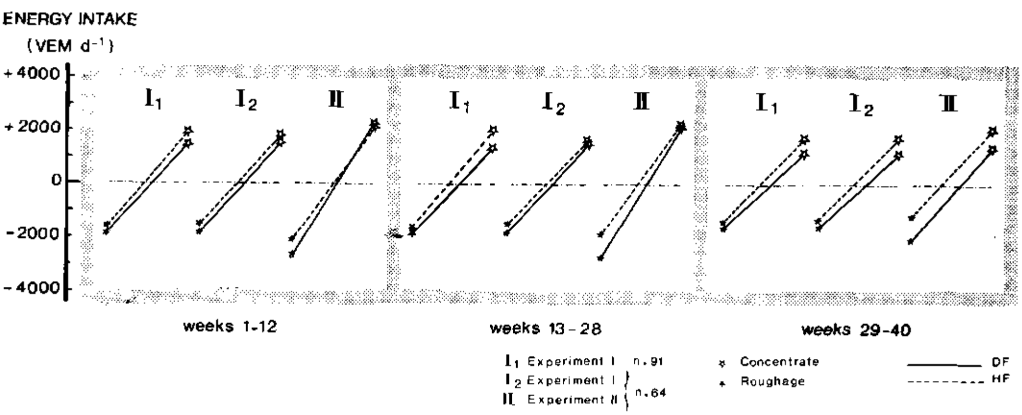

Fig. 4.1. Least squares constants of the energy intake (VEM d^{-1}) per genotype-ration group, experiment and period.

Table 4.3 presents the least squares constants for the ration-genotype groups, the interaction and the lactation number. The overall contrasts (VEM d^{-1}) per period in the first experiment between the DF and HF were -348, -424 and -451 respectively and in the second experiment -263, -460 and -820 respectively.

The concentrate and roughage rations had an overall contrast (VEM d^{-1}) per period in the first experiment of +3583, +3469 and +3016 respectively and in the second experiment of +4679, +4598 and +3392 respectively. The differences between the two experiments may be caused by the change in rations between the two experimental lactations. This effect may also play a role in the difference in genotype-ration interaction between the two experiments. During the first experiment the interaction component was not significant but in all three periods this interaction was positive. This suggest greater difference between genotypes on the high ration. The genotype-ration interaction in the first experiment with the cows that were subjected to a second experiment was quite comparable with the total material (figure 4.1). The interaction term in the second experiment showed that the contrasts between DF and HF were greater on the roughage ration than on the concentrate ration. In the first period of this experiment (II) the difference between DF and HF was -673 VEM d^{-1} on the roughage and +148 VEM d^{-1} on the concentrate ration.

- *Coefficients of variation and correlation*

The coefficients of variation were calculated per period and within a genotype-ration group. The standard deviations were influenced only by the variation in the energy intake from roughage because the concentrate level in the ration was fixed. As described in 3.2.5 the characteristic was adjusted per genotype-ration group for lactation number, season and days open. The coefficients of variation before and after adjustment are shown in table 4.4. In general the coefficients of variation before adjustment were higher in the first than in the second experiment. However, after adjustment there were no clear differences between the experiments. The difference between rations was caused mainly by the difference in fixed concentrate level between rations. The adjusted coefficients of variation for the roughage groups ranged between 4.6% and 9.0% and for the concentrate groups between 2.5% and 5.5%. There were no clear differences between the lactation periods.

The coefficients of correlation between energy intake (adjusted for lactation number, season and days open) in the three periods of the first experiment were higher (table 4.5) for the DF-genotype than for the HF-genotype. The coefficient of correlation between weeks 1-12 and weeks 13-28 were +0.80 and +0.67 respectively for the DF-groups and +0.32 and +0.23 for the HF-groups.

Table 4.6 presents the coefficients of correlation between the adjusted energy intake in the same periods in the two experiments. These relations were calculated from a limited material, namely cows which had been in two experiments. At the beginning of the lactation (weeks 1-12) the coefficients of correlation were not significant for the cows which had a roughage ration in the first experiment and a concentrate one in the second. For the reverse ration change the correlations were higher. The coefficients of correlation in weeks 13-28 between the two experiments were all significant for the four groups (+0.47 to +0.64). A significant coefficient of correlation (+0.40) was found in weeks 29-40 for the DF-group with a roughage ration in the first experiment.

Table 4.4. Coefficients of variation, before (b) and after (a) adjustment, of the total energy intake per period, experiment (I, II) and genotype-ration group.

Period		weeks 1-12		weeks 13-28		weeks 29-40	
		I	II	I	II	I	II
DF-Roughage	b	10.2	6.7	11.2	9.9	14.7	12.5
	a	7.9	4.6	7.3	9.0	7.6	6.0
DF-Concentrate	b	6.9	6.3	4.7	5.0	10.3	6.3
	a	4.5	4.8	2.5	4.5	5.3	5.6
HF-Roughage	b	8.6	6.0	8.1	9.5	13.8	11.3
	a	6.6	5.4	6.3	7.5	5.0	7.3
HF-Concentrate	b	7.3	5.7	6.0	4.1	10.6	6.1
	a	5.4	4.9	3.8	3.8	5.1	5.8

Table 4.5. Correlation coefficients between the adjusted total energy intake in the several periods of the first experiment per genotype-ration group.

Period (weeks)	1-12, 13-28	1-12, 29-40	13-28, 29-40	n
DF-Roughage	+0.80***	+0.41**	+0.55***	23
DF-Concentrate	+0.67***	+0.56***	+0.65***	22
HF-Roughage	+0.32	+0.24	+0.31	23
HF-Concentrate	+0.23	+0.32	+0.23	23

Table 4.6. Correlation coefficients between the adjusted total energy intake in the same periods of the two experiments per genotype-ration group.

Period (weeks)	1-12	13-28	29-40	n
DF-Roughage-Concentrate	+0.08	+0.47**	+0.40*	18
DF-Concentrate-Roughage	+0.33	+0.64***	-0.04	16
HF-Roughage-Concentrate	+0.21	+0.53**	+0.12	17
HF-Concentrate-Roughage	+0.65***	+0.64***	+0.02	13

4.1.1.2 Energy intake pattern over the lactation

- *Analysis per week*

The energy intake in the several measuring weeks was analysed with model I. This resulted, beside a possible genotype-ration interaction, in 3 significant ($P \leq 0.05$) two-way interactions in the eleven weeks in the first experiment, no significant interaction in the three weeks of the dry period and one significant interaction in the thirteen weeks of the second experiment. These two-way interactions were not systematic and so all the weeks were analysed with model II.

The results (figure 4.2) show a maximum energy intake during the lactation for the concentrate group of about 18500 VEM d^{-1} and, for the roughage group, about 14000 VEM d^{-1}. On the high ration there was a clear influence of the concentrate change after week 28 on the energy intake. The energy intake in the dry period (1 kg concentrates) ranged between 9500-10500 VEM d^{-1} with a small not significant difference between the groups.

The energy intake in the second experiment was lower in the roughage group but higher in the concentrate group than in the first experiment. Because of this the contrast between rations was higher in the second experiment than in the first experiment (on average, over the weeks, a difference of -780 VEM d^{-1}). The effect of the ration in the first experiment was not significant in the dry period. The roughage groups had a longer time of underfeeding (including total deficiency) than the concentrate groups and the average live weight of the cows in the roughage groups was lower at the end of the lactation than the average live weight at the beginning of the lactation. It was not necessary or possible in the dry period to recover the difference in live weight between rations due to the feeding level in the previous lactation.

The genotype contrast in the eleven weeks of measurements in the first experiment was 498 VEM d^{-1}; in the three weeks of the dry period 267 VEM d^{-1} and in the thirteen weeks of the second experiment 526 VEM d^{-1}. The contrast was very regular but at the end of the second experiment the contrast increased. In the two experiments the genotype effect was significant but not in the dry period. The DF-group with a concentrate ration in the first experiment had the lowest energy intake in the dry period.

In summary the interaction between genotype and ration was not significant for the several weeks during the lactation and the dry period. However, in the first experiment and in the dry period the interaction was systematically positive and

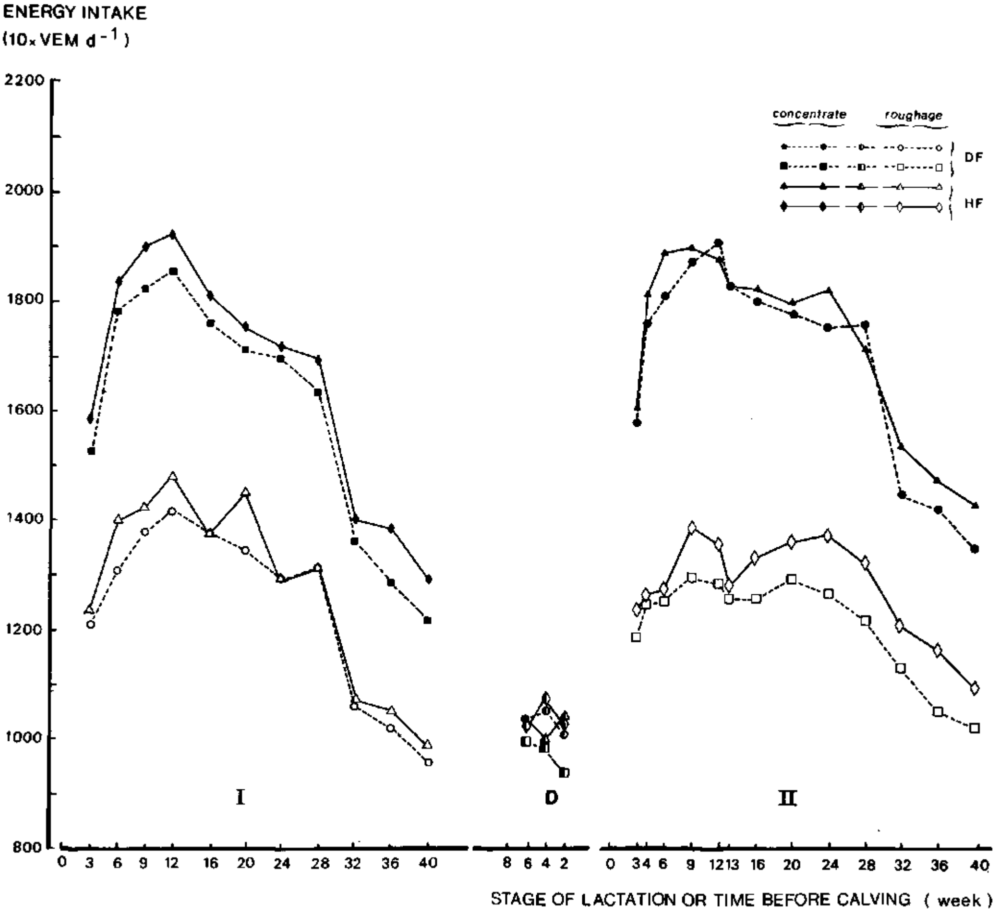

Fig. 4.2. Least squares means of the energy intake (VEM d^{-1}) per genotype-ration group, and experiment (I, II) or dry period (D).

in the second experiment negative. This implies that in the first experiment and in the dry period the contrasts between genotypes were greater on the concentrate ration than on the roughage and in the second experiment the reverse.

- *Energy intake curve over the lactation*

The energy intake of the individual cows during the lactation was characterized in the first experiment by model III. This model used as parameters the level of energy intake, the stage of lactation with maximum energy intake, the maximum increase of energy intake during the lactation and a pregnancy parameter. The differences between groups were tested by the Student-Newman-Keuls method (Snedecor and Cochran, 1967). The following elements are shown in table 4.7:

- Variance and relations between error terms: There were differences between genotypes in the average total variance of the eleven measurements over the lactation. The HF-groups demonstrated a greater total variance and within the genotypes the total variance of the roughage groups was lower in comparison with the concentrate groups. The average residual variance was clearly different for the rations and this variance was 2.094 and 1.703 for the roughage and concentrate rations respectively. The average residual standard deviation for the different groups was: DF-Roughage 1585, DF-Concentrate 1214, HF-Roughage 1915 and HF-Concentrate 1390 VEM d^{-1}. The average squared multiple correlation coefficient (R^2)(%) was 71.5 with a difference between the rations (the average of the roughage and the concentrate groups was 63.4% and 79.6% respectively). The independence of the error terms was tested with the Durbin-Watson test (1951). The model fitted the energy intake during the lactation with an average Durbin-Watson per genotype-ration group in the range with no possible conclusion about autocorrelation (P = 0.05).
- Values of the parameters: The difference between rations for the level of energy intake was self-evident (8.213 and 10.870 kVEM d^{-1}). There was a tendency for a greater variance on the roughage ration. The time during the lactation with the maximum energy intake was not significantly different for the four groups (on average:day 93). The concentrate steps had probably a clear influence on the time for all the four groups. The latest measurement during the first concentrate step was on day 88 and the first day of measuring in the next step was day 112. The roughage groups had a greater standard deviation by comparison with the concentrate groups which might have been caused by the small concentrate change after week 12 of the lactation. The maximum energy intake during the lactation was different for the rations (roughage groups: 14.631 kVEM d^{-1} and concentrate groups: 18.988 kVEM d^{-1}) and small differences existed between HF- and DF-genotypes (within roughage: 0.664 kVEM d^{-1} and within concentrate: 1.120 kVEM d^{-1}).

Table 4.7. Mean parameters and standard deviations (s.d.) of the fitted energy intake (kVEM) curve over the lactation per genotype-ration group (same character: not significantly different - P = 0.05).

	DF-Roughage		*DF-Concentrate*	
	mean	s.d.	mean	s.d.
Total variance	4.705[a]	2.330	5.695[ab]	2.246
Residual variance	2.513[ab]	1.655	1.474[a]	1.087
R^2 (%)	63.2[a]	15.1	79.8[b]	14.6
Durbin-Watson	2.62[a]	0.44	2.51[a]	0.48
Level (p_1)(kVEM)	8.489[a]	2.231	10.656[b]	1.737
Time (p_4) (d)	105.9[a]	47.1	92.0[a]	16.6
Max. incrase (p_3)(kVEM)	5.810[a]	2.382	7.772[a]	1.650
Pregnancy (p_2)	-0.0049[a]	0.0118	-0.0091[a]	0.0082
Max. energy intake(kVEM)	14.299[a]	1.347	18.428[b]	0.753
	HF-Roughage		*HF-Concentrate*	
	mean	s.d.	mean	s.d.
Total variance	6.531[b]	2.459	7.152[b]	2.588
Residual variance	3.294[b]	1.908	1.931[a]	0.996
R^2 (%)	63.5[a]	15.4	79.4[b]	11.9
Durbin Watson	2.58[a]	0.35	2.62[a]	0.52
Level (p_1)(kVEM)	7.936[a]	2.212	11.083[b]	2.111
Time (p_4)(d)	85.9[a]	31.5	88.5[a]	18.7
Max. increase (p_3)(kVEM)	7.027[ab]	2.929	8.465[b]	2.431
Pregnancy (p_2)	-0.0031[a]	0.0174	-0.0053[a]	0.0071
Max. energy intake (kVEM)	14.963[a]	1.091	19.548[c]	1.178

4.1.2 Roughage intake

4.1.2.1 Cumulative periods

The average total roughage dry matter intake per genotype-ration group within a period and an experiment is presented in table 4.8. It shows that there was a difference between rations and the standard deviations within the three periods were in the range 82.8 to 135.6 kg, 72.3 to 176.1 kg and 81.3 to 126.1 kg resp.

The total roughage dry matter intake was analysed with model I and this only indicated a significant ($P \leq 0.05$) interaction between genotype and days open in the third period of the second experiment. This has to be taken into account in the interpretation of the results of model II for that period. The results of the analysis with model II are shown in table 4.9.

Table 4.8. Means and standard deviations (s.d.) of the total roughage dry matter intake (kg). per period, experiment (I, II), and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40	
	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I						
DF-Roughage	1133.2	135.6	1538.9	176.1	1078.1	126.1
DF-Concentrate	834.3	94.8	1143.1	72.3	848.8	102.5
HF-Roughage	1181.8	103.9	1577.2	111.8	1083.3	86.3
HF-Concentrate	935.9	129.5	1248.2	126.2	909.3	111.6
Experiment II						
DF-Roughage	1058.2	84.0	1396.0	140.9	997.5	112.3
DF-Concentrate	920.2	103.5	1192.7	110.7	851.8	81.3
HF-Roughage	1126.9	89.1	1530.7	162.1	1091.4	128.6
HF-Concentrate	938.0	82.8	1208.4	108.7	912.3	85.4

Table 4.9. Analysis of variance on the total roughage dry matter intake (kg) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40	
Source	df	SS × 10^2	P	SS × 10^2	P	SS × 10^2	P
Experiment I							
Total	91	983198.9		1776794.7		895984.4	
μ	1	832306.5		1503397.3		766197.2	
Genotype	1	321.2	.106	591.1	.037	445.3	.014
Ration	1	14949.6	.000	28230.5	.000	9497.2	.000
Lactation	2	1700.2	.002	1904.5	.001	1353.9	.000
Days open	3	53.3	.931	73.9	.904	56.6	.847
Season	3	401.5	.347	1306.4	.024	2784.2	.000
Genotype * Ration	1	73.4	.436	40.2	.581	43.8	.432
Remainder	79	9460.6		10347.1		5534.6	
R^2 (%)		68.6		77.1		71.9	
Experiment II							
Total	64	651192.6		1130802.1		592317.4	
μ	1	475501.3		823386.4		435461.1	
Genotype	1	292.2	.065	559.4	.075	983.4	.003
Ration	1	3907.7	.000	8492.7	.000	2746.4	.000
Lactation	1	107.1	.259	37.4	.641	0.4	.999
Days open	3	166.5	.572	803.9	.206	37.6	.944
Season	3	257.5	.382	213.0	.741	902.8	.036
Genotype * Ration	1	42.2	.477	425.7	.119	25.9	.610
Remainder	53	4365.8		9004.9		5213.9	
R^2 (%)		53.4		58.7		53.0	

This model explained 68 to 77% of the total variation in the first experiment and 53 to 59% in the second experiment. Just as with the energy intake the genotype effect increased with the stage of lactation and the lactation effect was only important in the first experiment. The seasonal effect was significant in the second part of the lactation in both experiments and this might be caused by the greater variation in quality of the offered roughage at the end of both experiments (appendices 1 to 6). The genotype-ration interaction was not significant.

The overall contrasts (kg d^{-}) between DF and HF (table 4.10) ranged from -0.52 to -0.59 in the first experiment, and in the second experiment from -0.50 to -0.97. Ration contrasts were clearly dependent on the experiment and the stage of lactation. In the first experiment these contrasts (kg d^{-1}) were +2.94, +3.26 and +2.52 respectively for the three periods and, in the second experiment, +1.88, +2.23 and +1.68 respectively. The dependence on the stage of lactation might be caused by the concentrate steps. The differences between experiments were not caused by the involuntary culling at the end of the first experiment. The results of the analysis of the first experiment of the individuals which had a second lactation were comparable with the total material (fig. 4.3).

The lactation number contrast was only present between the second and following lactations in the first experiment. This contrast averaged approximately 1 kg d^{-1} over the three periods. The interaction component was not significant, however this component was systematically positive in the first experiment and negative in the second experiment. Figure 4.3 illustrates the interaction for the two experiments and the limited material of the first experiment.

Table 4.10. Least squares constants of the effects on the average roughage dry matter intake (kg d^{-1}) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40	
Source	I	II	I	II	I	II
Mean	11.25	11.20	12.20	11.85	11.60	11.49
DF-Roughage	+1.28	+0.60	+1.43	+0.59	+1.05	+0.27
DF-Concentrate	-1.82	-1.09	-1.95	-1.15	-1.63	-1.25
HF-Roughage	+1.65	+1.28	+1.82	+1.63	+1.47	+1.40
HF-Concentrate	-1.12	-0.78	-1.31	-1.08	-0.88	-0.44
Genotype * Ration	+0.33	-0.37	+0.25	-0.97	+0.33	-0.32
Lactation 2	-0.73		-0.66		-0.74	
Lactation 3	+0.19	-0.16	+0.29	-0.08	+0.31	-0.02
Lactation ≥ 4	+0.53	+0.16	+0.37	+0.08	+0.43	+0.02

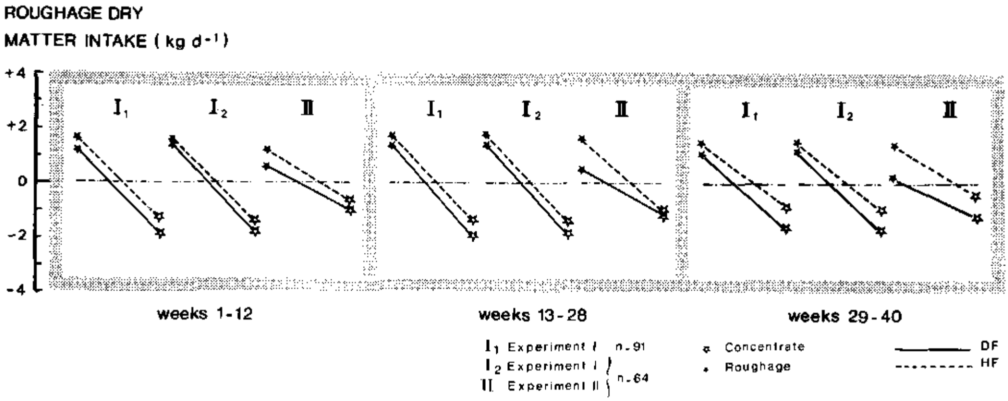

Fig. 4.3. Least squares constants of the roughage dry matter intake (kg d^{-1}) per genotype-ration group, experiment and period.

- Coefficients of variation and correlation

The coefficients of variation of the roughage dry matter intake before and after adjustment are presented in table 4.11. Between the several groups and periods there was a great difference in the influence of the effects of lactation number, season and days open. The coefficients of variation after adjustment ranged from 5.5% to 10.0% and 3.5% to 9.5% for the roughage and concentrate groups respectively. The lowest average coefficient of variation in the first experiment was found in the second period and this was shown most clearly with the concentrate groups. In the first experiment a tendency existed for a higher coefficient for the DF-genotype by comparison with the HF-genotype (on average, over the lactation, 7.9% and 6.9% respectively). The second experiment showed no effect of the stage of lactation. The average level of the coefficients of variation in this experiment was comparable with that in the first experiment.

The coefficients of correlation between the adjusted roughage dry matter intake (table 4.12) in weeks 1-12 and weeks 13-28 were significant for all the four groups. It ranged between +0.57 and +0.86. The DF-groups showed a significant coefficient of correlation between weeks 1-12 and weeks 29-40 of the lactation. In general the coefficients between the several periods were higher for the DF-groups. There were some differences between the coefficients of correlation for total energy intake (table 4.5) and the coefficients for roughage dry matter intake. This difference might have been caused by the variation in roughage quality (energy content) and other environmental effects and not by the concentrate level (fixed).

The coefficients of correlation between the adjusted roughage intake in the two experiments were only significant in the second period for all the four groups (+0.49 to +0.74)(table 4.13). These results were comparable with those for the energy intake (table 4.6). There were no significant coefficients of correlation in the first period for the roughage-concentrate groups and for the concentrate-roughage groups in the third period.

Table 4.11. Coefficients of variation, before (b) and after (a) adjustment, of the total roughage dry matter intake per period, experiment (I, II) and genotype-ration group.

Period		weeks 1-12		weeks 13-28		weeks 29-40	
		I	II	I	II	I	II
DF-Roughage	b	12.0	7.9	11.4	10.1	11.7	11.3
	a	10.0	5.8	7.2	9.4	8.9	5.9
DF-Concentrate	b	11.4	11.2	6.3	9.3	12.1	9.5
	a	8.1	9.6	3.7	7.9	9.2	8.7
HF-Roughage	b	8.8	7.9	7.1	10.6	8.0	11.8
	a	7.3	7.1	5.6	8.2	6.4	7.8
HF-Concentrate	b	13.8	8.8	10.1	9.0	12.3	9.4
	a	8.1	7.8	4.9	7.4	8.8	8.5

Table 4.12. Correlation coefficients between adjusted roughage dry matter intake in the several periods of the first experiment per genotype-ration group.

Period (weeks)	1-12,13-28	1-12,29-40	13-28,29-40	n
DF-Roughage	$+0.86^{***}$	$+0.53^{***}$	$+0.68^{***}$	23
DF-Concentrate	$+0.61^{***}$	$+0.56^{***}$	$+0.72^{***}$	22
HF-Roughage	$+0.57^{***}$	+0.25	$+0.59^{***}$	23
HF-Concentrate	$+0.57^{***}$	+0.14	$+0.44^{**}$	23

Table 4.13. Correlation coefficients between adjusted roughage dry matter intake in the same periods of the two experiments per genotype-ration group.

Period (weeks)	1-12	13-28	29-40	n
DF-Roughage-Concentrate	+0.07	$+0.49^{**}$	$+0.44^{*}$	18
DF-Concentrate-Roughage	+0.32	$+0.74^{***}$	-0.01	16
HF-Roughage-Concentrate	+0.01	$+0.56^{***}$	+0.23	17
HF-Concentrate-Roughage	$+0.54^{*}$	$+0.58^{**}$	-0.01	13

4.1.2.2 Roughage intake pattern over the lactation

- Analysis per week

The average roughage intake in the several measuring weeks was analysed with models I and II. Model I produced no significant interactions in the first experiment and in the dry period. In the second experiment there were four non-systematic significant interactions ($P \leq 0.05$). Two of these interactions corresponded with the interaction in the third cumulative period of the second experiment (4.1.2.1).

The results from model II are shown in figure 4.4. The maximum average roughage dry matter intake for the roughage groups was approximately 14.2 kg d^{-1} in week 20 in the first experiment and 13.2 kg d^{-1} in the same week in the second experiment. The time at which maximum average roughage intake of the concentrate groups occurred was clearly affected by the concentrate steps. In the first experiment the maximum was approximately 11.0 kg d^{-1} and in the following lactation 11.5 kg d^{-1}. The roughage dry matter intake of the concentrate groups was lower in the first experiment than in the second experiment; the roughage groups showed the reverse. The average overall ration contrasts over the several

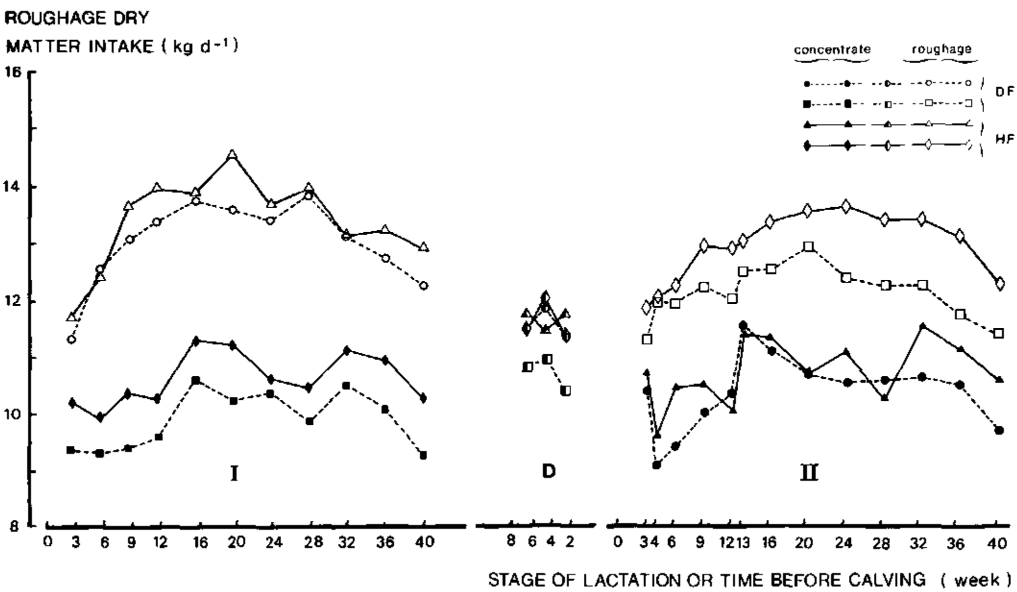

Fig. 4.4. Least squares means of the roughage dry matter intake (kg d^{-1}) per genotype-ration group and experiment (I, II) or dry period (D).

weeks in the first and second experiment were approximately 3 and 2 kg d^{-1} respectively. The contrasts were dependent on the concentrate steps. Just as for the energy intake, there was no significant ration effect in the dry period in spite of the large degree of underfeeding of the roughage groups in the preceding lactation.

The average overall genotype contrasts (DF-HF) over the several weeks in the first and second experiments were -0.52 and -0.58 kg d^{-1} respectively. In the dry period the average contrast was -0.50 kg d^{-1}. In summary the interaction between ration and genotype was not significant. The sign of the interaction component changed from positive in the first experiment and the dry period to negative in the second experiment. This implies that in the first lactation the genotype contrasts were greater on the concentrate ration and in the second experiment on the roughage ration.

4.1.3 Discussion

The individual animals were offered ad libitum roughage and a fixed concentrate level, therefore the variation in feed intake was dependent on the variation in roughage intake (amount and quality). This variation was studied within a genotype-ration group and per concentrate step. The reaction of an animal may be influenced by the environment, the genetic capacity and the physiological state (e.g. stage of lactation). The adjusted coefficients of variation for the roughage intake ranged from 5 to 10 percent. A possible difference in limiting or determining factors of the feed intake between groups did not influence the level of the coefficients. However, the second stage of lactation (weeks 13-28) in the first experiment had a lower coefficient of variation for all the four groups compared with the two other stages of lactation in that experiment. This stage of lactation was the most stable period of the lactation. Table 4.13 also shows the high degree of repeatability of the roughage and energy intake in this period between experiments. Hooven et al. (1972) observed, in a regime of feeding according to production, an increase in the coefficient of variation of the total consumed energy with the increase of duration of lactation. Lamb et al. (1977) reported a difference between the effects of an all roughage ration and a ration with ad libitum roughage and concentrates according to production (2.1.3).

The between genotype contrast was smaller than the within genotype variation. The DF-groups had, on average, a 5 percent lower roughage intake and about 3 percent lower energy intake over the lactations than the HF-groups. The interaction between genotype and ration was not significant and the difference between the sum of the diagonals (3.2.2) was smaller than the genotype contrast. Lamb et al. (1977) used a contrast of 20% digestible energy in one of the trials and obtained essentially the same result for daughter groups within a breed.

The concentrate groups had about 22% lower roughage dry matter intake (kg) and about 21% higher energy intake (VEM) than the roughage groups in the first experiment. During the second experiment the contrast for roughage intake was lower and that for energy intake higher. This carry-over effect of the ration from the preceding lactation is most clearly demonstrated in the first part of the lactation. Perhaps the difference in size of the contrast between the two experiments is influenced by the confounding effects between experiment and lactation number, year and/or kind of roughage. However, in the dry period before the second experiment no effect of the preceding ration was shown. It indicates that, on a fixed concentrate level in the dry period, a difference in underfeeding during lactation is not compensated by a higher roughage intake but only by a higher roughage intake in the first part of the following lactation.

The variation in quality of the roughage is one of the seasonal effects because the season of measuring and calving were confounded. However, in these experiments the animals were kept indoors during the whole period and this may have decreased the influence of the season of calving on production characteristics. The seasonal effects were illustrated by the variance of the components in the roughage given within a measuring period (appendices 1 to 6). The seasonal effect is higher for the energy intake than for the roughage intake.

The patterns of the roughage and energy intake during the lactation were influenced by the concentrate steps (figure 4.4 and 4.2). The short-term reaction of a concentrate change is demonstrated in weeks 4 and 13 of the concentrate groups in the second experiment. The portion of the concentrates in the dry matter intake was dependent on the ration and the stage of the lactation. The parts (%) were around 51, 44 and 34 respectively for the concentrate groups in the three concentrate steps and, for the roughage groups, 17,12 and 7.

The variation within a genotype-ration group was also influenced by the individual substitution rate of roughage by concentrate but this experiment was not suitable for determining these individual reactions. However, the substitution rate between rations within a genotype is shown in figure 4.5. The lower contrast between rations in the second experiment (carry-over effect) was also shown by the substitution rate. In general the replacement increased with the stage of the lactation but this was influenced by the concentrate step. Ekern (1972b), in an experiment with two concentrate levels according to milk production, observed the highest substitution rate in the beginning of the lactation. Figure 4.5

illustrates the opposite and the importance of the physiological state of the animal on the substitution. The difference between genotypes was dependent on the experiment.

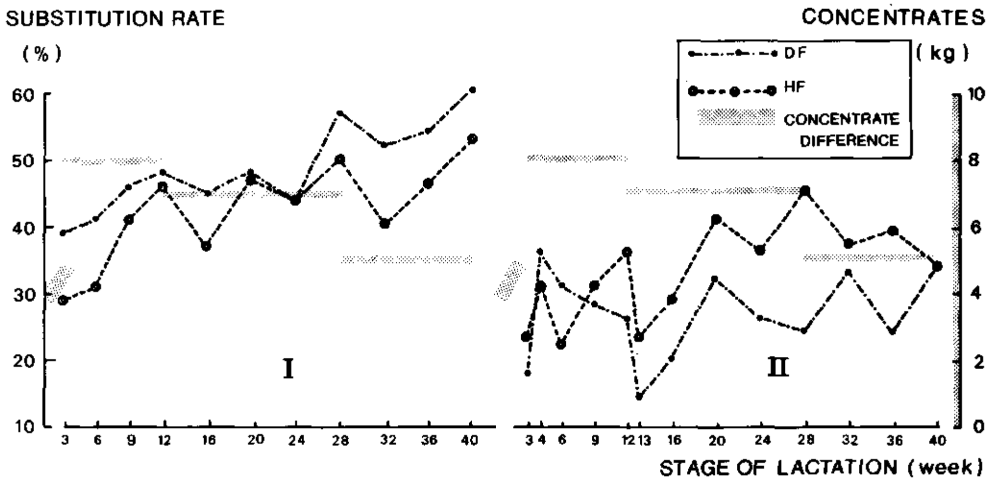

Fig. 4.5. The substitution rate (%) of roughage by concentrates during the lactation dependent on the genotype and the experiment (I, II).

Model III was used for characterizing the energy intake curve over the lactation by four parameters. The results showed a strong influence of the concentrate step and therefore the estimation of the individual intake had a high error. Figure 4.19 illustrates the average curve per genotype-ration group and the general relation with milk output (FPCM) and live weight change during the lactation. The autocorrelation between error terms will decrease in an ad libitum feeding system with a fixed ratio between concentrates and roughage, or a fixed concentrate level during the total lactation.

4.1.4 Conclusions

- The difference between HF- and DF-genotype for roughage and energy intake was significant, with an average over the experiments and rations of about 5 and 3 percent respectively.
- The within genotype-ration group coefficient of variation of the adjusted roughage dry matter intake over the several periods of the lactations averaged approximately 7 percent.

- The ration contrast for roughage intake in the two experiments were approximately 22 and 16 percent respectively.
- A carry-over effect of the ration from the first experiment was demonstrated at the beginning of the second experiment but not in the dry period between these experiments.
- The intake characteristics did not show a significant genotype-ration interaction.
- The correlations between adjacent parts of the lactations were influenced by the genotype (table 4.5 and 4.12).
- The highest repeatabilities between lactations were observed in mid-lactation (energy intake: +0.47 to +0.64; roughage intake: +0.49 to +0.78).

4.2 Milk production and components

4.2.1 Milk production

4.2.1.1 Cumulative periods

Table 4.14 presents the averages and standard deviations of the milk production per period, experiment and genotype-ration group. These results were not adjusted for environmental effects. The standard deviations for the total lactation production (weeks 1-40) were clearly different for the rations in the first experiment and for the genotypes in the second experiment.

Table 4.14 Means and standard deviations (s.d.) of the milk production (kg) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I								
DF-Roughage	2062	316	1817	255	790	127	4668	596
DF-Concentrate	2419	262	2323	375	1078	337	5821	852
HF-Roughage	2257	221	2079	224	861	263	5197	547
HF-Concentrate	2735	275	2664	314	1262	335	6661	815
Experiment II								
DF-Roughage	1981	186	1747	189	824	148	4552	395
DF-Concentrate	2396	240	2349	248	1131	175	5876	529
HF-Roughage	2062	304	2004	327	990	212	5056	725
HF-Concentrate	2468	287	2477	326	1271	281	6216	911

The total milk production per period in the two experiments was analysed with model I. A significant ($P \leq 0.05$) interaction was found only in weeks 1-12 of the second experiment for genotype-season. The results of the analysis with model II for various stages of the lactation are shown in table 4.15. Model II, which included genotype, ration, lactation number, days open, season and the interaction between genotype and ration, accounted for 44 to 62% of the total variance dependent on the experiment and the stage of lactation. In the first experiment the effect of the genotype was significant in all the periods. However, this effect was not significant in the first period of the second experiment. Inherent in the design of the experiment, the effect of the ration was significant in all the periods.

Table 4.15. Analysis of variance on the total milk production (kg) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
Source	df	SS × 10^4	P	SS × 10^4	P	SS × 10^4	P	SS × 10^4	P
Total	91	52221.9		46494.2		10031.5		293265.9	
μ	1	45476.1		39853.9		8036.6		252539.1	
Genotype	1	39.2	.012	154.8	.000	45.6	.012	647.9	.000
Ration	1	402.7	.000	582.8	.000	190.1	.000	3363.6	.000
Lactation	2	96.3	.001	46.3	.065	13.1	.391	371.0	.024
Days open	3	15.7	.456	16.1	.581	39.9	.130	153.2	.365
Season	3	84.3	.004	44.4	.152	65.3	.029	132.5	.431
Genotype*Ration	1	9.9	.201	1.0	.726	2.9	.515	34.4	.398
Remainder	79	469.2		647.1		542.0		3756.3	
R^2 (%)		60.9		61.1		45.2		60.4	
Experiment II									
Total	64	32886.5		30921.6		7673.6		196621.8	
μ	1	22769.9		21521.7		5301.0		137201.9	
Genotype	1	4.2	.421	53.3	.013	39.3	.006	244.1	.021
Ration	1	202.2	.000	377.4	.000	139.0	.000	2064.4	.000
Lactation	1	3.2	.483	4.8	.442	7.4	.215	9.8	.637
Days open	3	14.6	.519	10.8	.717	3.2	.879	50.1	.764
Season	3	30.2	.206	12.9	.660	2.5	.913	40.2	.818
Genotype*Ration	1	1.1	.683	8.6	.305	0.4	.761	21.5	.485
Remainder	53	338.5		424.2		249.6		2296.3	
R^2 (%)		49.8		57.4		44.1		56.1	

The lactation number effect was significant only in weeks 1-12 of the first experiment and, in consequence of that, in weeks 1-40. The seasonal effect was respectively. This ranking of the genotype groups was the reverse of that in the first experiment. At the beginning of the lactation the ration contrast was higher in the first experiment compared with the second experiment. In the second part of the lactation the reverse was true.

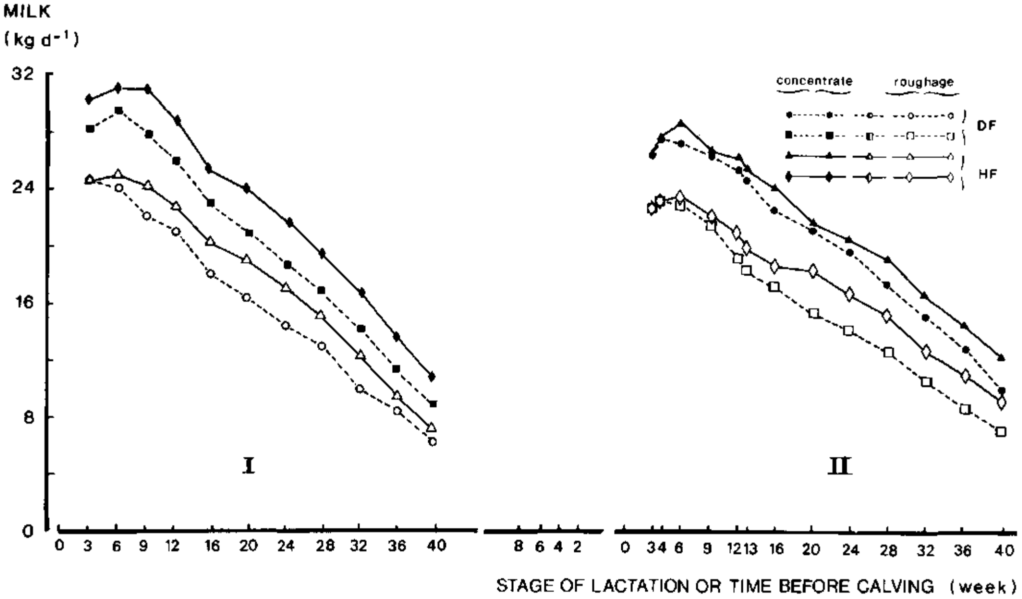

Fig. 4.7. Least squares means of the milk production (kg d^{-1}) per genotype-ration group and experiment (I, II).

The overall contrasts (kg d^{-1}) between genotypes in the first experiment ranged from 0.96 to 2.84 and in the second experiment from -0.17 to 2.19. The average over eleven measuring weeks was 2.02 and 1.38 respectively in the two experiments. Within the roughage ration this contrast (kg d^{-1}) was 1.57 and 1.75 and within the concentrate ration 2.46 and 1.04. The ranking change, of the contrast between genotypes within a ration, from the first to the second experiment may have been caused by the change of ration between the two experiments. The maximum contrast between genotypes during the lactation in the two experiments was observed for the roughage group in week 20 and for the concentrate group in weeks 20 and 28. The interaction between genotype and ration was not significant for the several measuring weeks during the two lactations. However, in the first and at the beginning of the second experiment, the small interaction component was positive and in the rest of the second experiment negative. A positive interaction implies a greater contrast between genotypes within the concentrate ration compared with the roughage ration and a negative component shows the reverse.

4.2.2 Fat and protein percentages

4.2.2.1 Cumulative periods

The average fat percentages per period, experiment and genotype-ration group are presented in table 4.20. The average fat percentage over the total lactation in the first experiment was in the range 3.84 to 4.13 for the four groups. In the second experiment it was between 3.97 and 4.32. There was a tendency for a difference in level between the experiments.

Table 4.20. Means and standard deviations (s.d.) of the milk fat (10 g kg^{-1} d^{-1}) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I								
DF-Roughage	4.25	0.31	3.87	0.28	4.41	0.31	4.13	0.26
DF-Concentrate	4.02	0.29	3.90	0.29	4.39	0.43	4.04	0.25
HF-Roughage	4.13	0.28	3.58	0.32	3.96	0.38	3.88	0.25
HF-Concentrate	3.90	0.24	3.66	0.23	4.12	0.29	3.84	0.19
Experiment II								
DF-Roughage	4.40	0.33	4.15	0.41	4.40	0.33	4.30	0.31
DF-Concentrate	4.23	0.38	4.14	0.22	4.86	0.38	4.32	0.27
HF-Roughage	4.16	0.34	3.75	0.22	4.03	0.35	3.97	0.26
HF-Concentrate	3.89	0.32	3.93	0.32	4.40	0.44	4.01	0.32

The analysis with model I resulted in one significant interaction ($P < 0.05$) between lactation number and days open in the first experiment (weeks 1-12). This interaction was not systematic but had to be taken into account in assessing these two main effects in that period. Model II, which included the genotype, ration, lactation number, season, days open and the interaction between genotype and ration, explained 31 to 49% of the total variation dependent on the stage of lactation and the experiment. The genotype effect was significant in all the periods and the overall contrasts (10 g kg^{-1} d^{-1}) (DF-HF) ranged between +0.11 and +0.40 over the several periods of the lactation (table 4.21, figure 4.8), increasing as the lactation progressed. The genotype contrast over 40 weeks lactation was +0.21 and +0.32 in the first and second experiments respectively.

Table 4.21. Least squares constants of the effects on the milk fat (10 g kg^{-1} d^{-1}) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
Source	I	II	I	II	I	II	I	II
Mean	4.08	4.14	3.75	4.00	4.21	4.43	3.97	4.14
DF-Roughage	+0.15	+0.28	+0.09	+0.16	+0.17	+0.01	+0.13	+0.18
DF-Concentrate	-0.04	+0.02	+0.16	+0.14	+0.17	+0.39	+0.08	+0.14
HF-Roughage	+0.06	-0.02	-0.17	-0.22	-0.25	-0.32	-0.09	-0.16
HF-Concentrate	-0.16	-0.28	-0.08	-0.07	-0.09	-0.07	-0.12	-0.16
Genotype * Ration	-0.03	+0.00	+0.02	+0.17	+0.16	-0.13	+0.02	+0.04
Lactation 2	-0.12		-0.06		+0.01		-0.08	
Lactation 3	+0.10	-0.11	+0.12	-0.05	+0.11	-0.04	+0.11	-0.07
Lactation ≥ 4	+0.02	+0.11	-0.06	+0.05	-0.12	+0.04	-0.04	+0.07

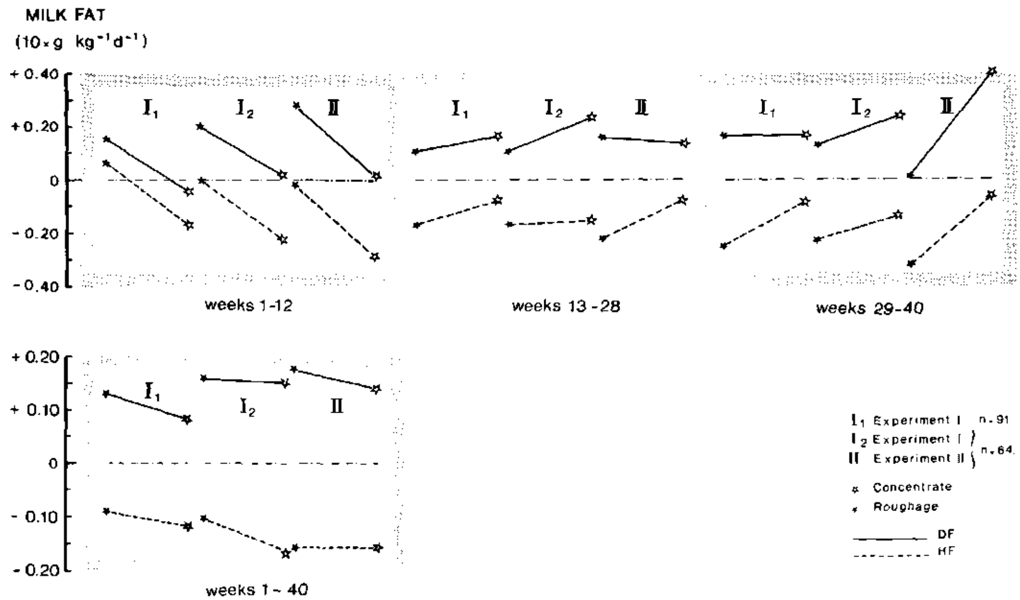

Fig. 4.8. Least squares constants of the milk fat (10 g kg^{-1} d^{-1}) per genotype-ration group, experiment and period.

The ration effect was significant in the first period (weeks 1-12) of both experiments and in weeks 29-40 of the second experiment. The average fat percentage in the lactation (weeks 1-40) did not show a significant ration effect. Obviously the effects at the beginning and the end of the lactation were working in opposite directions. This was clear for the second experiment where the contrast (10 g kg^{-1} d^{-1}) between roughage and concentrate in the first period was +0.26 and in the third period -0.32. This contrast over the total lactation in the first and second experiments was +0.04 and +0.02 respectively, which was not significant.

The average protein percentages are shown in table 4.22. For the four groups the range was from 3.17 to 3.34 and 3.12 to 3.36 for the first and second experiments respectively. The percentages increased during the lactation.

Table 4.22. Means and standard deviations (s.d.) of the milk protein (10 g $kg^{-1}d^{-1}$) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I								
DF-Roughage	3.03	0.20	3.37	0.23	3.83	0.27	3.30	0.21
DF-Concentrate	3.17	0.16	3.34	0.18	3.73	0.27	3.34	0.15
HF-Roughage	3.00	0.12	3.19	0.16	3.56	0.25	3.17	0.13
HF-Concentrate	3.07	0.15	3.24	0.18	3.65	0.21	3.24	0.15
Experiment II								
DF-Roughage	2.98	0.12	3.17	0.14	3.60	0.19	3.17	0.12
DF-Concentrate	3.17	0.15	3.33	0.18	3.82	0.27	3.36	0.16
HF-Roughage	2.93	0.16	3.14	0.15	3.45	0.17	3.12	0.14
HF-Concentrate	3.11	0.14	3.26	0.15	3.59	0.25	3.26	0.13

The results of model I did not show a significant two-way interaction between the main effects on the protein percentage. The analysis of variance with model II explained 23 to 33% of the variance in the first experiment and 29 to 46% in the second. The average protein percentage over the lactation in the first experiment was significantly influenced by the genotype effect but, this was not significant in the second experiment. The overall total lactation contrasts (DF-HF)(10 g kg^{-1} d^{-1}) were +0.08 and +0.05 respectively (table 4.23, figure 4.9). These contrasts for weeks 1-12, 13-28 and 29-40 were +0.05 and +0.04, +0.12 and +0.04, +0.13 and +0.18 in the first and second experiments respectively. The highest contrasts were found at the end of the lactation.

Table 4.23. Least squares constants of the effects on milk protein (10 g kg^{-1} d^{-1}) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
Source	I	II	I	II	I	II	I	II
Mean	3.05	3.06	3.27	3.23	3.67	3.62	3.24	3.23
DF-Roughage	-0.06	-0.06	+0.06	-0.05	+0.11	-0.01	+0.01	-0.06
DF-Concentrate	+0.11	+0.10	+0.06	+0.09	+0.02	+0.18	+0.07	+0.11
HF-Roughage	-0.05	-0.12	-0.08	-0.07	-0.09	-0.16	-0.06	-0.10
HF-Concentrate	+0.00	+0.08	-0.04	+0.03	-0.04	-0.02	-0.02	+0.05
Genotype * Ration	-0.12	+0.04	+0.04	-0.04	+0.14	-0.05	-0.02	-0.02
Lactation 2	-0.01		-0.01		-0.03		-0.01	
Lactation 3	+0.07	-0.00	+0.06	-0.02	+0.06	-0.04	+0.06	-0.01
Lactation ≥ 4	-0.06	+0.00	-0.05	+0.02	-0.04	+0.04	-0.06	+0.01

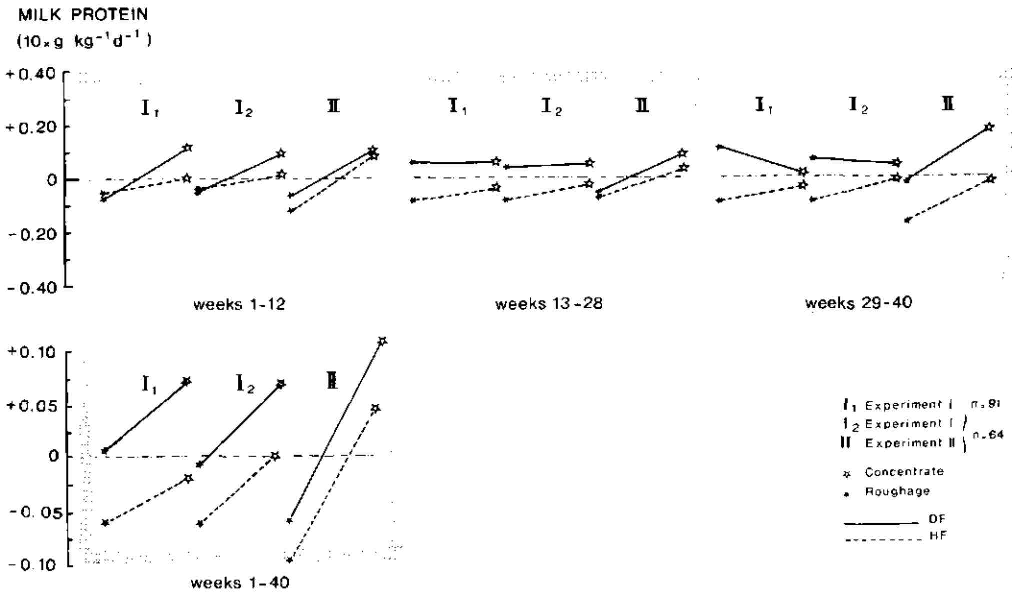

Fig. 4.9. Least squares constants of the milk protein (10 g kg^{-1} d^{-1}) per genotype-ration group, experiment and period.

In the first experiment the ration effect was only significant in weeks 1-12 with a contrast (10 g kg^{-1} d^{-1}) between roughage and concentrate of -0.11. This effect was significant in all the periods of the second experiment and these contrasts were -0.18, -0.12 and -0.17. The average protein percentage over the lactation was only influenced significantly by the ration effect in the second experiment (-0.16). The genotype-ration interaction was not significant.

- Coefficients of correlation between periods

The coefficients of correlation between the fat and the protein percentages in the several periods and the total lactation are presented separately in table 4.24. These correlations were adjusted for the lactation number, season and days open. The coefficients of correlation for the average fat percentage between weeks 1-12 and the total lactation for the four genotype-ration groups ranged between +0.59 and +0.91. These values were +0.80 and +0.94 for the average protein percentage. The second period had, on average, a higher correlation (fat percentage: +0.86 to +0.91, protein percentage: +0.92 to +0.95). The third period (weeks 29-40) was comparable with the first period.

Table 4.24. Correlation coefficients for adjusted milk fat and for protein between the several periods of the first experiment per genotype-ration group.

	Fat percentage			Protein percentage			
Period (weeks)	1-12, 1-40	13-28, 1-40	29-40, 1-40	1-12, 1-40	13-28, 1-40	29-40, 1-40	n
DF-Roughage	+0.91***	+0.91***	+0.76***	+0.94***	+0.94***	+0.81***	23
DF-Concentrate	+0.73***	+0.87***	+0.66***	+0.80***	+0.94***	+0.85***	22
HF-Roughage	+0.59***	+0.88***	+0.64***	+0.82***	+0.92***	+0.72***	23
HF-Concentrate	+0.69***	+0.86***	+0.77***	+0.94***	+0.95***	+0.80***	23

Table 4.25. Correlation coefficients for adjusted milk fat and for protein between the same periods of the two experiments per genotype-ration group.

Period (weeks)	1-12	13-28	29-40	1-40	n
Fat percentage					
DF-Roughage-Concentrate	+0.34	+0.53**	+0.50**	+0.44*	18
DF-Concentrate-Roughage	+0.27	+0.71***	+0.67***	+0.61***	16
HF-Roughage-Concentrate	+0.34	+0.80***	+0.65***	+0.70***	17
HF-Concentrate-Roughage	+0.13	+0.53*	+0.65***	+0.43	13
Protein percentage					
DF-Roughage-Concentrate	+0.44*	+0.34	+0.41*	+0.44*	18
DF-Concentrate-Roughage	+0.49*	+0.70***	+0.60**	+0.66***	16
HF-Roughage-Concentrate	+0.44**	+0.59***	+0.63***	+0.56***	17
HF-Concentrate-Roughage	+0.13	-0.00	+0.47	+0.06	13

The coefficients of correlation between the adjusted average fat and the average protein percentages in the total lactation for the first and second experiments varied between +0.41 and +0.70 for the fat and +0.06 and +0.66 for the protein. The lowest values were found for the HF-group with a concentrate ration in the first experiment and roughage in the second. Weeks 1-12 showed the lowest coefficients of correlation between the two experiments in comparison with the other periods (table 4.25).

4.2.2.2 Milk components pattern over the lactation

- *Analysis per week*

Data from the eleven weeks of measuring feed intake during the first experiment and the thirteen weeks of the second experiment were analysed with models I and II. The components per week were the average of the measuring week (week t of lactation), week t-1 and week t+1.

Model I, which included five effects and the two-way interactions between these effects, resulted in one significant two-way interaction in both experiments for fat percentage as well as a possible interaction between genotype and ration. On the basis of these results the data were analysed with model II. Figure 4.10 shows the least squares estimates for the four genotype-ration groups in several weeks of the lactation. In some weeks there was a significant interaction between ration and genotype.

After calving the fat percentage decreased and reached a minimum at about week twelve of the lactation. At the beginning of the lactation there was a contrast between the rations in both experiments. The fat percentage decreased more slowly on the roughage ration than on the concentrate ration. However, in the second part of the lactation the increase of the fat percentage was comparable for both rations in the first experiment but, in the second experiment, the increase on the roughage ration was slower than on the other ration. The contrast (10 g kg^{-1} d^{-1}) between roughage and concentrate ration in the several lactation weeks ranged, in the first and second experiments, from -0.15 to +0.30 and -0.32 to +0.33 respectively.

In both experiments the level of the fat percentage was dependent on the genotype. The contrasts between genotypes increased with the increase of the stage of lactation. These contrasts ranged from +0.02 to +0.44 and 0.00 to +0.52 in the first and second experiments respectively.

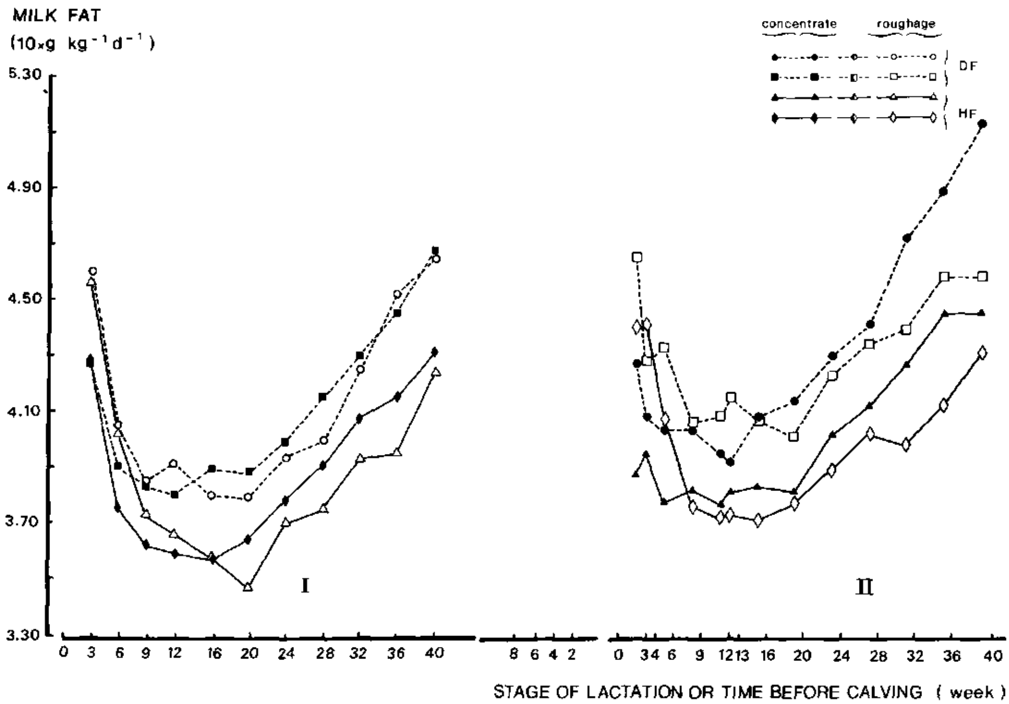

Fig. 4.10. Least squares means of the milk fat (10 g kg^{-1} d^{-1}) per genotype-ration group and experiment (I, II).

In addition to a possible genotype-ration interaction the analysis of the protein percentage with model I resulted in the first experiment (eleven weeks) in four significant interactions, namely in weeks 32, 36 and 40. The two-way interactions were genotype - season (2x) and ration - lactation (2x). In the second experiment there were no systematic significant two-way interactions. By analysing the material with model II the presence of the interactions at the end of the first experiment had to be considered. The least squares estimates (model II) of the four genotype-ration groups at the end of the first experiment may have been influenced by these interactions.

In both lactations the genotype contrasts (DF-HF) increased during the lactation (figure 4.11). For the ration contrasts (roughage-concentrate) there was the opposite reaction in the first experiment during the lactation. In the second experiment the contrasts existed for the whole of the lactation.

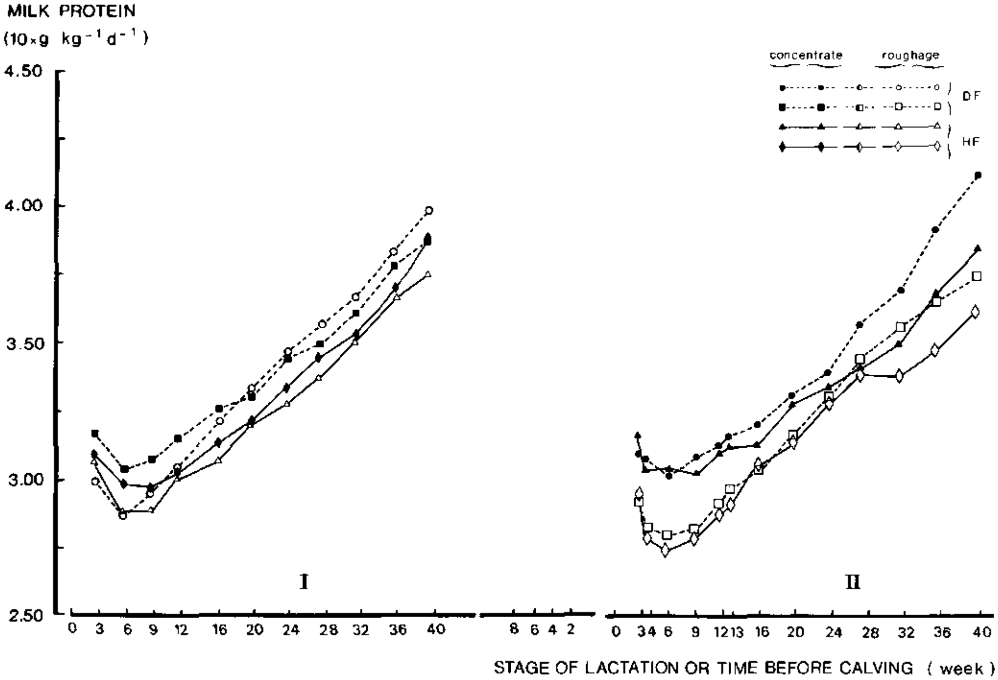

Fig. 4.11. Least squares means of the milk protein (10 g kg^{-1} d^{-1}) per genotype-ration group and experiment (I, II).

4.2.3 Fat protein corrected milk

The manner of calculation of the fat protein corrected milk (FPCM) is presented in chapter 3.1.4. The regression fitted the energy per kg milk on the two most important energy components in the milk (fat and protein). This trait was used for the calculation of the energy requirement and this subchapter will give some brief information about FPCM, the underlying characteristics having been discussed in the preceding subchapters.

4.2.3.1 Cumulative periods

Tables 4.14, 4.20 and 4.22 give information about the components of the FPCM on the several periods of the two experiments per genotype-ration group. Model II, which includes the effects of genotype, ration, lactation number, season, days open and the interaction between genotype and ration, accounted for 45 to 64% of the total variance (table 4.26), dependent on the experiment and the stage of lactation. The genotype effect was only significant in weeks 1-12 and weeks 13-28 of the first experiment. The estimated overall genotype contrasts in daily FPCM yield (DF-HF)(kg d^{-1}) in the two experiments in the three periods were -1.22 and -0.41, -1.85 and -1.03, -1.40 and -1.36 respectively (table 4.27). The contrasts for this characteristic were smaller than those for milk production (4.2.1.1). The contrast of the total lactation in the first and second experiments was -430 (7.7%) and -199 kg (3.7%) respectively.

Table 4.26. Analysis of variance on the total fat protein corrected milk (kg) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
Source	df	SS × 10^4	P	SS × 10^4	P	SS × 10^4	P	SS × 10^4	P
Experiment I									
Total	91	50892.2		43361.9		10869.5		271736.0	
μ	1	44324.0		37181.3		8705.3		234078.7	
Genotype	1	22.2	.047	78.5	.001	25.5	.061	338.8	.004
Ration	1	336.0	.000	593.8	.000	218.2	.000	3158.2	.000
Lactation	2	122.5	.000	39.7	.052	6.6	.628	336.8	.014
Days open	3	14.5	.450	16.1	.479	32.5	.214	129.8	.333
Season	3	74.9	.005	36.5	.138	73.5	.020	123.8	.354
Genotype*Ration	1	5.0	.338	0.7	.748	3.9	.461	21.1	.455
Remainder	79	429.3		509.3		560.3		2964.7	
R^2 (%)		59.0		63.5		44.8		61.9	
Experiment II									
Total	64	32802.4		30494.1		8774.0		190057.4	
μ	1	22567.4		21184.6		6015.8		132036.8	
Genotype	1	1.2	.677	19.5	.103	19.2	.056	58.3	.230
Ration	1	165.4	.000	426.4	.000	202.2	.000	2175.8	.000
Lactation	1	12.8	.179	1.9	.603	6.0	.280	0.2	.999
Days open	3	10.9	.666	5.2	.864	1.0	.976	27.1	.877
Season	3	24.6	.323	8.4	.756	1.1	.975	43.9	.775
Genotype*Ration	1	1.9	.602	7.2	.318	1.7	.559	28.7	.398
Remainder	53	366.4		375.6		266.6		2096.2	
R^2 (%)		44.5		60.9		48.5		58.2	

The ration effect was significant in all the periods in both experiments and the estimated overall contrasts (Concentrate-Roughage)(kg d^{-1}) in the three periods were +4.42 and +3.86, +4.72 and +4.97, +3.82 and +4.56 respectively. At the beginning of the second experiment the contrast between the concentrate and roughage groups were lower than in the first experiment, however at the end of the lactation the reverse was observed. The contrast of the total lactation in the first and second experiments was +1220 (20.3%) and +1259 kg (21.2%) respectively. The genotype-ration component (table 4.27) was systematically positive in the first experiment and negative in the second one. This was not caused by the involuntary culling at the end of the first experiment (figure 4.12).

Table 4.27. Least squares constants of the effects on the total fat protein corrected milk (kg) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
Source	I	II	I	II	I	II	I	II
Mean	2344	2196	2147	2128	1039	1134	5387	5313
DF-Roughage	-229	-177	-359	-371	-198	-266	-775	-800
DF-Concentrate	+119	+207	+152	+257	+80	+152	+345	+601
HF-Roughage	-169	-169	-170	-185	-123	-117	-445	-459
HF-Concentrate	+278	+141	+377	+301	+241	+231	+874	+658
Genotype * Ration	+99	-74	+36	-142	+86	-70	+199	-248
Lactation 2	-187		-105		-19		-301	
Lactation 3	+35	-51	+13	+20	-26	+35	+24	+6
Lactation ≥ 4	+152	+51	+92	-20	+44	-35	+277	-6

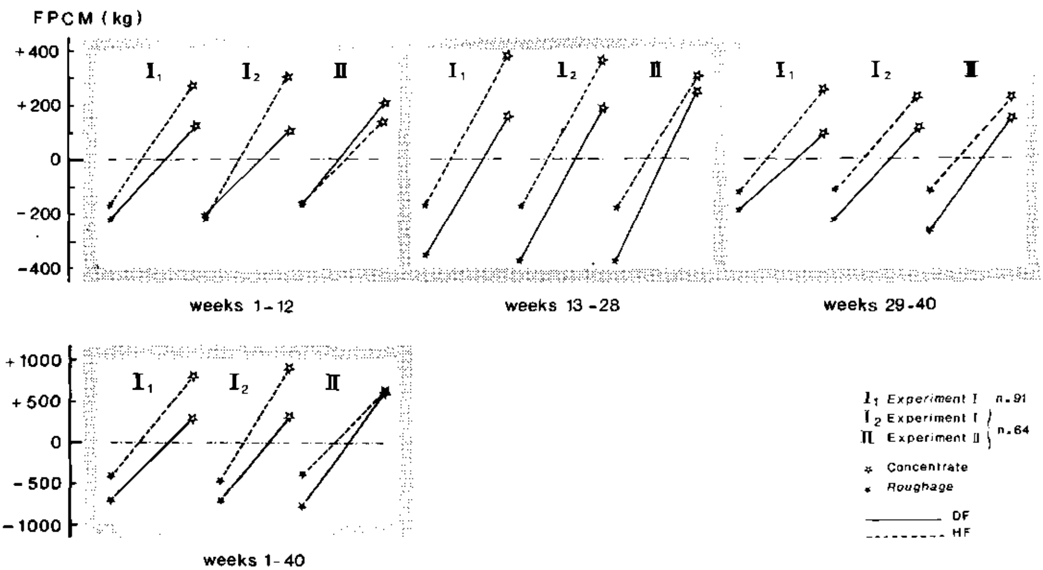

Fig. 4.12. Least squares constants of the fat protein corrected milk (kg) per genotype-ration group, experiment and period.

4.2.3.2 Fat protein corrected milk pattern over the lactation

- *Analysis per week*

The estimated least squares means (model II) per genotype-ration group over the two experimental lactations are presented in figure 4.13. During the first experiment the overall contrast (kg d^{-1}) between concentrate and roughage at the beginning of the lactation was +4.22, reached its peak at week 9 (+5.78) and finished at the end of this experiment at +3.57. In the second experiment the greatest contrast was found in week 12 (+5.83) having started at +2.95. The contrast in week 40 of this experiment (+4.16) was higher than in the first experiment.

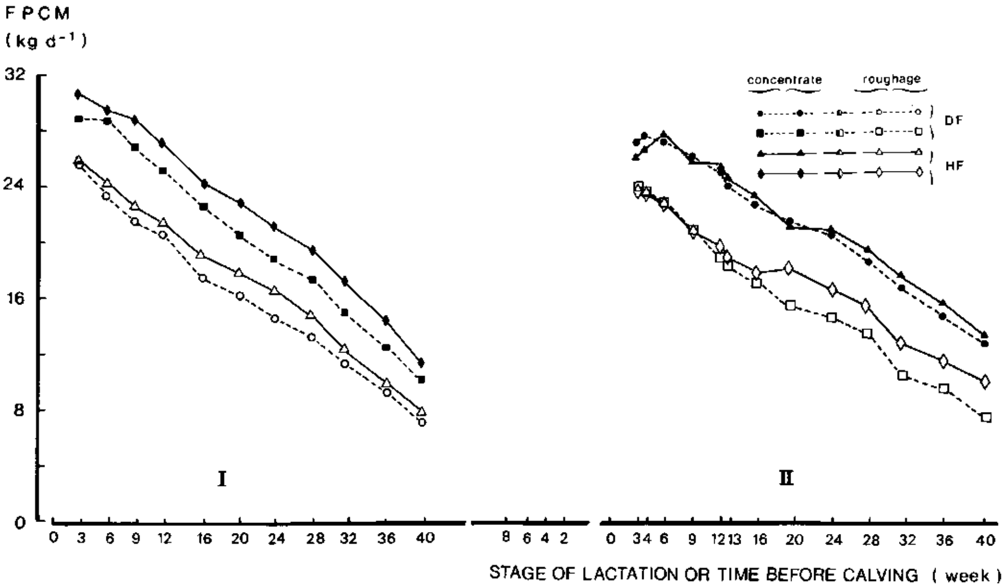

Fig. 4.13. Least squares means of the FPCM (kg d^{-1}) per genotype-ration group and experiment (I, II).

The estimated contrasts (kg d^{-1}) between DF and HF ranged, in the first and second experiments, from -2.08 to -0.80 and -1.60 to +0.94 respectively. The greatest values were found in weeks 24 and 28 respectively. These contrasts for FPCM were smaller than those for milk production.

- *Fat protein corrected milk curve*

The FPCM per individual cow was characterized on the basis of forty measurements during the lactation (one day every week) with model III. FPCM was used because this characteristic was a means of calculating the energy requirement for milk production (including the components). However, the same model (III) was also used for milk production and the results of these two characteristics were quite comparable. Model III included the following parameters: level of FPCM production, time of maximum FPCM production, maximum increase of FPCM production during the lactation, and an adjustment parameter for pregnancy. Table 4.28 presents the results of the fitted curve per genotype-ration group in the first experiment.

Table 4.28. Mean parameters and standard deviations (s.d.) of the fitted fat protein corrected milk curve over the lactation per genotype-ration group (same character: not significantly different - P = 0.05).

	DF-Roughage		*DF-Concentrate*	
	mean	s.d.	mean	s.d.
Total variance	33.16[a]	16.58	36.82[a]	23.26
Residual variance	4.09[a]	2.19	4.96[ab]	2.52
R^2 (%)	87.0[a]	7.6	84.7[a]	8.3
Durbin-Watson	1.26[a]	0.44	1.60[b]	0.54
Level (p_1) (kg)	13.51[a]	2.20	16.42[ab]	4.16
Time (p_4) (d)	33.6[a]	11.2	38.4[a]	9.4
Max. increase (p_3)(kg)	12.09[a]	3.14	12.77[a]	5.34
Pregnancy (p_2)	-0.0187[a]	0.0093	-0.0178[a]	0.0082
Max. production (kg)	25.60[a]	3.88	29.19[b]	3.27
	HF-Roughage		*HF-Concentrate*	
	mean	s.d.	mean	s.d.
Total variance	44.35[a]	21.10	43.17[a]	20.20
Residual variance	7.08[ab]	4.65	6.02[ab]	2.53
R^2 (%)	83.9[a]	8.8	84.6[a]	8.6
Durbin-Watson	1.16[a]	0.31	1.57[b]	0.50
Level (p_1)(kg)	14.92[ab]	2.57	18.67[b]	3.39
Time (p_4)(d)	32.5[a]	7.2	39.1[a]	8.7
Max. increase (p_3)(kg)	12.75[a]	3.42	13.63[a]	3.26
Pregnancy (p_2)	-0.0210[a]	0.0184	-0.0154[a]	0.0029
Max. production (kg)	27.67[b]	2.80	32.30[c]	3.23

- Variance and relations between error terms: There was a tendency for a difference to exist between genotypes and within genotypes, between rations in the average total variance. The average magnitude of the residual standard deviation per genotype-ration group was: DF-Roughage 2.02, DF-Concentrate 2.23, HF-Roughage 2.66 and HF-Concentrate 2.45 kg d^{-1}. The DF-groups had a lower residual deviation than the HF-groups. The squared multiple correlation coefficient (R^2)(%) was comparable for the four groups and the average ranged from 83.9 to 87.0%. The FPCM production curve per individual was fitted on 40 measurements during the lactation. The relations between error terms were tested with the Durbin-Watson (1951) test. The roughage ration had, on average, a fitted function with a positive autocorrelation. This was caused by an overestimation in the first part of pregnancy and an underestimation in the last stage of lactation. The model characterized the FPCM production for the concentrate groups on average with a Durbin-Watson test (P = 0.05) in the range with no possible conclusion about autocorrelation.

- Values of the parameters: The level of FPCM production ranged from 13.51 to 18.67 kg d^{-1} over the four groups. The Student-Newman-Keuls method (Snedecor and Cochran, 1967) distinguished the following homogenous subsets: DF-Roughage, HF-Roughage and DF-Concentrate; HF-Roughage, DF-Concentrate and HF-Concentrate. The average time from the start of lactation at which the maximum yield of FPCM was obtained was determined for each individual group. Over the fours these averages ranged from 32.5 to 39.1 days. Peak milk production was found some days later (40.9 to 47.0) with this model. No significant difference existed between the four groups in increase of FPCM production during the lactation (12.09 to 13.63). The production peak was highest with the HF-concentrate group and lowest with the DF-roughage group.

4.2.4 Relation between milk production and components

The coefficients of correlation between the milk production traits were calculated on the adjusted traits per genotype-ration group and per period of the first experiment. The adjustments were for season, days open and the lactation number effect.

The coefficients of correlation between milk production and fat percentage ranged in the three periods over the four groups from -0.31 to +0.15 , -0.66 to -0.28 and -0.26 to +0.04 respectively (table 4.29). It indicated that most negative values were found in the middle of the lactation and showed also a difference between genotypes. The DF-groups had the highest absolute values. The coefficients of correlation between these two traits for the total lactation were -0.37, -0.74, -0.33 and +0.01 for the DF-Roughage, DF-Concentrate, HF-Roughage and HF-Concentrate respectively. Protein percentage and milk production were negatively correlated and the highest values were found in the first period of the lactation (weeks 1-12). Similarly to the coefficient of correlation between milk and fat percentage, there existed a difference between the groups of genotypes; the coefficients in the total lactation were, for the four groups: -0.38, -0.41, -0.24 and -0.11 respectively. Table 4.29 illustrates clearly the influence of the milk production characteristic on the calculated FPCM production. The correlation between milk production and FPCM ranged between +0.95 and +0.99. A significant positive correlation between fat and protein percentage was found only in the middle and at the end of the lactation and the correlations in the total lactation were, for the four groups; +0.34, +0.36, +0.48 and +0.30 respectively.

Table 4.29. Correlation coefficients between adjusted milk production, FPCM and milk components per period and genotype-ration group.

	milk/ fat %	milk/ protein %	milk/ fpcm	fat %/ protein %	fat%/ fpcm	protein %/ fpcm
Weeks 1-12						
DF-Roughage	-0.24	-0.43**	+0.95***	+0.20	+0.05	-0.32
DF-Concentrate	-0.31	-0.69***	+0.95***	-0.09	-0.02	-0.70***
HF-Roughage	-0.18	-0.41*	+0.96***	+0.10	+0.07	-0.29
HF-Concentrate	+0.15	-0.26	+0.96***	+0.21	+0.41*	-0.11
Weeks 13-28						
DF-Roughage	-0.49***	-0.28	+0.97***	+0.37*	-0.28	-0.12
DF-Concentrate	-0.66***	-0.42*	+0.98***	+0.58***	-0.50***	-0.26
HF-Roughage	-0.28	-0.29	+0.95***	+0.61***	+0.03	-0.05
HF-Concentrate	-0.28	-0.25	+0.96***	+0.42***	-0.03	-0.07
Weeks 29-40						
DF-Roughage	-0.10	-0.48**	+0.97***	+0.62***	+0.13	-0.28
DF-Concentrate	-0.26	-0.23	+0.99***	+0.68***	-0.15	-0.12
HF-Roughage	+0.04	+0.00	+0.99***	+0.59***	+0.19	+0.10
HF-Concentrate	-0.12	-0.32	+0.99***	+0.59***	+0.03	-0.22

4.2.5 Discussion

The variation in milk production in a dairy population depends on animal and environmental effects (2.2). The variation in feeding levels is one of the most important factors of the between herd variation within a breed, but the feeding regime (allocation over the individuals and distribution during the lactation) within a herd has also a clear influence on the degree of variation of the total and part lactation milk yield within a herd (Hooven et al., 1972; Lamb et al., 1977; table 4.14 - experiment I). The coefficients of variation during partial and total lactation were comparable for the four genotype-ration groups (table 4.17) but these results were lower than the observed coefficients in a feeding system with concentrates given according to milk production.

The contrast between genotypes (over rations) in total milk production was comparable in the first experiment (594 kg, 10.1%) with the adjusted coefficients of variation within a genotype-ration group. The second experiment showed a lower contrast (407 kg, 7.2%) which was possibly caused by a different carry-over effect on milk yield for the two genotypes of the ration used in the preceding lactation. The observed contrasts between genotypes were smaller than the contrasts of the adjusted data of the first lactation (3.1.2)(813 kg, 14.3%) and the last lactation before the experiments (974 kg, 15.2%). These results were obtained before the experiments and the cows were fed concentrates according to milk production.

During the lactation the comparative milk production contrasts between genotypes increased (table 4.16) and the greatest absolute differences were found in week 20 of the lactation (figure 4.7). This implies a difference between genotypes in persistency under these feeding circumstances. The same was found for fat protein corrected milk (the energy equivalence of milk) but the contrasts were about 3 percent smaller. Østergaard (1979) did not find within a breed any effect of the strategy of concentrates distribution during lactation on the total lactation yield but the peak production and persistency were dependent on the strategy. Broster and Thomas (1981) suggested in a review that the amount of compensation is dependent on the cow's potential in relation to the feeding level. The experiment with two genotypes on two feeding levels indicated that the lower peak yield contrast between genotypes was not quite compensated by a greater persistency.

The comparative importance of the ration effect also increased during the lactation and the contrasts over the total lactation were 20.2 and 20.4 percent respectively (1259 and 1227 kg) in the two experiments. These total lactation yield contrasts agreed with the contrasts for the fat protein corrected milk. However, as a result of the difference in milk fat to milk protein ratio between the rations during the lactation, the contrasts were smaller in the early stages of the lactation compared with the milk production but at the end the reverse was the case.

Distinct underfeeding (a low concentrate level) corresponded with a low protein percentage and a slower decrease of the fat content at the beginning of the lactation compared with a higher concentrate level (figure 4.9 and 4.11). The reaction of an individual to the protein content in the period of underfeeding was independent of the fat content within a genotype-ration group and this was in contradistinction to the rest of the lactation (table 4.29). An interaction between stage of lactation and ration is shown in figure 4.9. Although the roughage groups had a lower milk yield and concentrate level than the concentrate groups, the fat percentage was lower in the second part of the lactation.

Besides the fat and protein content in the milk, lactose was determined in the second experiment. The results showed a significant ration effect on the average lactation lactose percentage (least squares estimates: DF-Roughage 4.59, DF-Concentrate 4.63, HF-Roughage 4.54, HF-Concentrate 4.66 (10 g kg^{-1} d^{-1})).

The repeatability between the two experiments determined the reaction of the individuals in two different rations. This is a type of genotype-ration interaction. However, the ration effect was confounded with the carry-over effect of the preceding lactation, the year effect, the kind of roughage and/or lactation number effect. The results showed comparable repeatabilities at the beginning of the lactation (4.19) for the four genotype-ration groups that were clearly higher than those observed by Østergaard (1979). The reaction of the individual within a genotype on the total lactation yield was quite different for the two genotypes.

4.2.6 Conclusions

- The overall genotype contrasts (DF-HF) in the two experiments were for total milk production -594 (10.1%) and -407 kg (7.2%) respectively, for milk fat +0.21 and +0.32 (10 g kg^{-1} d^{-1}) for milk protein +0.08 and +0.05 (10 g kg^{-1} d^{-1}) and FPCM -430 (7.7%) and -199 kg (3.7%).
- The overall ration contrasts (Concentrate-Roughage) in the two experiments were for total milk yield +1259 (20.2%) and +1227 kg (20.4%) respectively, for milk fat -0.04 and -0.02 (10 g kg^{-1} d^{-1}), for milk protein +0.05 and +0.16 (10 g kg^{-1} d^{-1}) and FPCM +1220 (20.3%) and +1259 kg (21.2%).
- The within genotype-ration group coefficient of variation on the total lactation milk yield was on average about 10 percent (table 4.17).
- The milk production and the components did not show a significant genotype-ration interaction.
- A carry-over effect of the ration in experiment I was demonstrated in the beginning of the second experiment (smaller contrast) but it was eliminated at the end of the lactation.

- The repeatabilities between lactations were different for the genotypes (table 4.19).

4.3 Live weight and body weight change

4.3.1 Cumulative periods

The average live weight and the change in weight was calculated within a concentrate step and the development of the body weight was characterized by both of these criteria. The first experiment had eleven measuring weeks and the cows were weighed at the beginning and end of these weeks. In addition, they were weighed on the second day after calving. In this way 23 measuring points per cow were obtained over the lactation. The average live weight per period was calculated on the basis of the points within that period (weighed for days). The live weight change per period was calculated as the difference between the live weight on the second day after calving and the average of the last measuring week or the difference between the average of the first and last measuring weeks of the period. The same method was used in the second experiment.

Table 4.30 shows the average live weight in the two experiments per period and genotype-ration group. In the first experiment the level was influenced by the ration and in the second experiment this happened after the first period. The roughage groups in the first experiment had a lower standard deviation than the concentrate groups.

Table 4.30. Means and standard deviations (s.d.) of the average live weight (kg) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40	
	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I						
DF-Roughage	554.9	48.6	537.6	39.9	561.7	43.2
DF-Concentrate	588.4	58.4	591.4	61.3	619.4	61.8
HF-Roughage	570.5	49.3	558.7	45.0	581.1	51.1
HF-Concentrate	619.2	62.1	612.7	63.1	640.0	66.6
Experiment II						
DF-Roughage	580.6	39.1	560.7	34.6	579.4	39.4
DF-Concentrate	582.8	41.2	595.8	51.6	622.1	54.7
HF-Roughage	593.5	42.8	580.8	51.3	598.9	60.5
HF-Concentrate	597.8	51.8	612.9	52.9	645.1	54.0

Table 4.31. Means and standard deviations (s.d.) of the live weight change (kg) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40	
	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I						
DF-Roughage	-69.9	37.1	+11.5	27.3	+29.7	19.8
DF-Concentrate	-30.1	23.5	+19.7	15.2	+29.4	18.1
HF-Roughage	-59.1	37.8	+14.6	22.4	+27.1	23.7
HF-Concentrate	-38.1	31.1	+17.8	21.3	+31.7	21.4
Experiment II						
DF-Roughage	-75.0	19.6	+ 9.0	19.8	+21.6	35.8
DF-Concentrate	-17.0	27.4	+21.5	12.5	+23.6	20.0
HF-Roughage	-67.1	35.4	+15.7	20.3	+10.4	29.9
HF-Concentrate	-17.2	20.2	+34.1	18.5	+28.6	17.3

The live weight change during the lactation was influenced by the ration and the ration in the preceding lactation (experiment II)(table 4.31). In the second and third periods of the lactation (weeks 13-28 and 29-40) the live weight change was positive for all the groups.

The average live weight per period was analysed with model I, which resulted in no significant two-way interactions. Model II explained between 42 and 48% of the total variation in the first experiment and, in the second, between 34 and 39% (table 4.32) dependent on the stage of lactation. The ration effect in the first experiment was significant in all the three periods and the overall contrasts (kg) between roughage and concentrate groups were -45, -59 and -65 respectively (table 4.33). However, at the beginning of this experiment (I)(second day after calving) there existed a ration effect which could not have been caused by the ration because the same ration was offered to all cows before calving. This ration contrast (-27 kg) was caused by the allocation of the cows over the groups. After correcting for this error the differences (kg) were approximately -18, -22 and -38 respectively. The range over the lactation indicated an increase of the contrast during the lactation.

The limited number of cows whose lactations were the subject of two experimental lactations did not show a significant ration effect at the beginning of the first experiment and the contrast (kg) in the three periods in the first experiment were -34, -47 and -50 respectively (figure 4.14). In the second experiment the ration effect was not significant in weeks 1-12. This was caused by the carry-over effect of the ration in the preceding experiment. The contrasts (kg) between roughage and concentrate were +1, -29 and -41 respectively (table 4.33).

Table 4.32. Analysis of variance on the average live weight (kg) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40	
Source	df	SS $\times 10^2$	P	SS $\times 10^2$	P	SS $\times 10^2$	P
Experiment I							
Total	91	312666.9		304006.2		331591.0	
μ	1	270719.9		262849.2		285937.6	
Genotype	1	46.7	.160	42.3	.174	36.0	.223
Ration	1	427.8	.000	735.1	.000	861.5	.000
Lactation	2	603.6	.000	421.7	.000	502.8	.000
Days open	3	58.5	.475	130.5	.131	193.2	.051
Season	3	15.8	.877	19.3	.836	31.3	.727
Genotype * Ration	1	0.1	.999	12.2	.465	15.6	.421
Remainder	79	1828.9		1778.5		1881.8	
R^2 (%)		41.9		44.9		48.2	
Experiment II							
Total	64	222772.5		223290.9		242388.0	
μ	1	158164.8		157746.3		172196.6	
Genotype	1	26.0	.193	45.3	.139	69.0	.093
Ration	1	0.0	.999	118.8	.018	230.6	.003
Lactation	1	243.9	.000	245.9	.001	229.9	.003
Days open	3	85.6	.140	49.5	.487	71.8	.394
Season	3	29.8	.578	27.8	.710	73.4	.384
Genotype * Ration	1	18.7	.268	6.0	.586	14.5	.436
Remainder	53	793.6		1061.8		1250.2	
R^2 (%)		34.0		35.2		38.8	

The genotype effect was never significant in the several periods of both experiments. The estimated non-significant overall contrasts (DF-HF)(kg) in both experiments for the three periods were -16 and -14, -16 and -18, -14 and -22 respectively. At the beginning of the first experiment (second day after calving) this contrast was also not significant. Table 4.32 shows a significant lactation number effect in both experiments in all the three periods. In the first experiment this was caused by the cows in their second and by those in the third or later parities and the contrasts (kg) between these two groups in the three periods were -59, -45 and -51 respectively. The significant effect of lactation number in the second experiment was caused by the contrast between the third and following parities.

At the end of the first experiment the days open effect was significant. The interaction component was zero or negative in the first experiment and, in the following experiment, positive but never significant.

Table 4.33 Least squares constants of the effects on the average live weight (kg) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40	
Source	I	II	I	II	I	II
Mean	579	581	571	581	595	607
DF-Roughage	-30	-0	-41	-20	-43	-26
DF-Concentrate	+15	-12	+25	+2	+30	+4
HF-Roughage	-14	+2	-18	-9	-21	-15
HF-Concentrate	+31	+13	+33	+26	+35	+36
Genotype * Ration	0	+23	-15	+13	-17	+21
Lactation 2	-38		-29		-32	
Lactation 3	+26	-22	+24	-23	+27	-22
Lactation ≥ 4	+13	+22	+4	+23	+6	+22

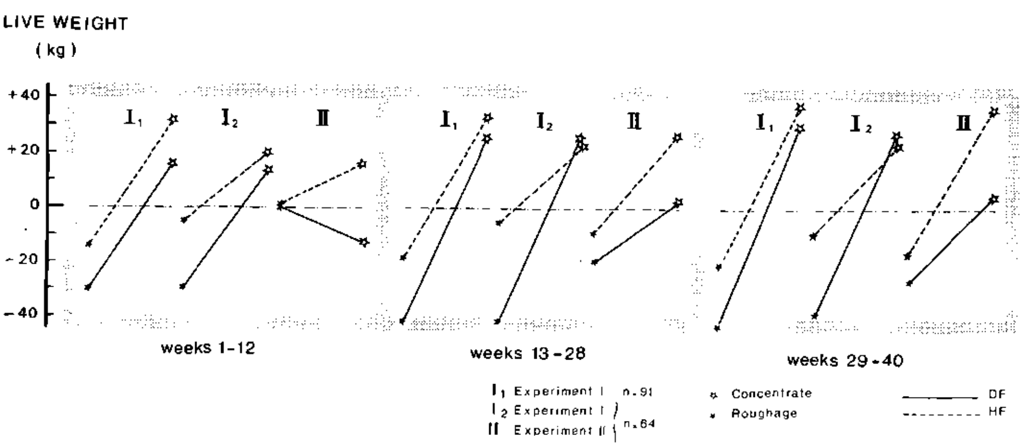

Fig. 4.14. Least squares constants of the live weight (kg) per genotype-ration group, experiment and period.

The results of the analysis with model II of the average live weight change per period and experiment are presented in table 4.34 and 4.35. Only in weeks 13-28 of the first experiment did model I result in five significant (P ≤ 0.05) two-way interactions and one interaction in weeks 1-12 of the second experiment. For these two periods the estimation of some main effects was dependent on the level of another main effect. Model II explained between 14 and 34% of the total variance in the first experiment and, in the second experiment, between 32 and 59%.

In both experiments the genotype effect was not significant ($P \leq 0.05$). The ration effect was significant in period I (weeks 1-12) for both experiments and, in the following periods, only in the second experiment. The overall contrast (kg) between roughage and concentrate in the two experiments for the three periods was -29 and -55, -8 and -14, -1 and -14 respectively.

Table 4.34. Analysis of variance on the live weight change (kg) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40	
Source	df	SS	P	SS	P	SS	P
Experiment I							
Total	91	340476.2		66057.9		117358.2	
μ	1	209201.4		18275.1		72488.3	
Genotype	1	558.6	.454	41.6	.766	65.6	.656
Ration	1	17479.2	.000	1236.4	.108	39.3	.729
Lactation	2	8475.3	.017	954.6	.366	982.3	.229
Days open	3	5306.1	.155	1975.8	.247	7543.5	.000
Season	3	6409.2	.098	2284.8	.190	4176.6	.008
Genotype * Ration	1	2611.0	.107	287.8	.436	129.5	.531
Remainder	79	77785.2		37002.6		25849.1	
R^2 (%)		33.7		14.3		32.4	
Experiment II							
Total	64	198865.2		51438.3		74370.0	
μ	1	85149.0		18842.7		27518.3	
Genotype	1	590.7	.355	971.5	.075	2.4	.999
Ration	1	41410.0	.000	2490.8	.005	2565.3	.038
Lactation	1	48.6	.790	4.6	.901	0.2	.999
Days open	3	1094.5	.658	538.9	.610	2618.4	.215
Season	3	3709.9	.154	1989.3	.092	9854.0	.002
Genotype * Ration	1	357.5	.471	43.0	.703	927.4	.207
Remainder	53	35951.3		15561.6		30054.1	
R^2 (%)		58.9		36.4		31.8	

In the first period of the second experiment the cows on the roughage ration had comparable live weight changes with those in the same period of the first experiment. The overall least squares mean estimates (kg) were -65 and -70 respectively for the first and second experiments. These estimates (kg) were

-37 and -16 respectively for the concentrate groups and this result shows a tendency towards a difference between the two experiments. In the second period of the lactation (weeks 13-28) the overall least squares mean estimates (kg) for roughage and concentrate groups were in the first experiment +11 and +19 respectively and in the second +13 and +27 respectively. The carry-over effect in the second experiment for the concentrate groups diminished with the stage of lactation.

Table 4.35. Least squares constants of the effects on the live weight change (kg) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40	
Source	I	II	I	II	I	II
Mean	-51	-43	+15	+20	+30	+24
DF-Roughage	-23	-33	- 5	-10	- 0	- 3
DF-Concentrate	+17	+27	+ 6	+ 2	- 2	+ 3
HF-Roughage	- 6	-22	- 3	- 4	- 1	-11
HF-Concentrate	+12	+28	+ 1	+12	+ 3	+11
Genotype * Ration	-22	-10	- 7	+ 4	+ 6	+16
Lactation 2	+16		+ 3		- 1	
Lactation 3	- 6	- 1	+ 3	+ 0	- 4	+ 0
Lactation ≥ 4	-10	+ 1	- 5	- 0	+ 5	- 0

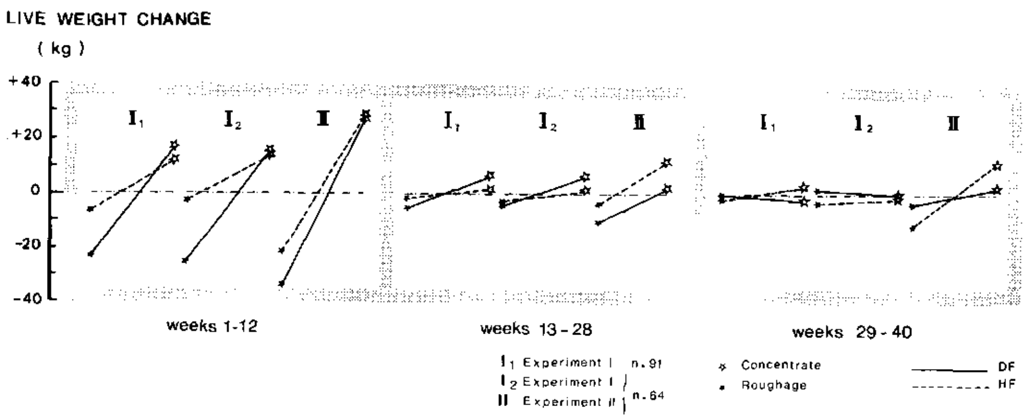

Fig. 4.15. Least squares constants of the live weight change (kg) per genotype-ration group, experiment and period.

The effect of parity was only significant (P ≤ 0.05) in period I (weeks 1-12) of the first experiment. This was caused by the difference between second and following lactations. The genotype-ration effect was not significant (P ≤ 0.05) in any of the periods. However, this component had at the beginning of the lactation a negative sign and at the end a positive.

- *Coefficients of variation and correlation*

The variaton of the average live weight per period and genotype-ration group was caused by environmental and genetic effects. Some of the environmental effects were: lactation number, season and days open. This material was adjusted for the known environmental effects within a genotype-ration group. In the first experiment the adjusted coefficient of variation of the four groups ranged in the three periods from 3.5 to 8.3%, 3.9 to 9.0% and 3.5 to 8.9% respectively (table 4.36).

In summary a lower coefficient for the HF-groups and within the genotypes for the roughage group was observed. Clear differences between groups did not exist in the second experiment and the adjusted coefficient of variation of the four groups ranged in the three periods from 5.7 to 7.1%, 5.9 to 7.6% and 5.9 to 8.2% respectively. In this experiment the coefficient for the HF-Roughage group was clearly increased in comparison with the first experiment.

Table 4.36. Coefficients of variation, before (b) and after (a) adjustment, of the average live weight per period, experiment (I, II) and genotype-ration group.

Period		weeks 1-12		weeks 13-28		weeks 29-40	
		I	II	I	II	I	II
DF-Roughage	b	8.8	6.7	7.4	6.2	7.7	6.8
	a	6.9	6.0	5.0	5.9	4.3	5.9
DF-Concentrate	b	9.9	7.1	10.4	8.7	10.0	8.8
	a	8.3	5.7	9.0	6.7	8.9	6.9
HF-Roughage	b	8.6	7.2	8.1	8.8	8.8	10.1
	a	3.5	6.1	3.9	7.6	3.5	8.2
HF-Concentrate	b	10.0	8.7	10.3	8.6	10.4	8.4
	a	6.3	5.9	6.7	7.2	6.8	7.4

Live weight change varied from negative to positive during the lactation. In that situation it was irrelevant to show the coefficient of variation and therefore the standard deviation was only calculated. This deviation was adjusted for lactation number, season and days open within a genotype-ration group. Table 4.37 shows a clear ration effect in the first experiment. In weeks 1-12 of this experiment the DF-Roughage and HF-Roughage had adjusted standard deviations (kg) of 30.1 and 29.6 respectively. The values for the DF-Concentrate and HF-Concentrate were 18.6 and 26.2. However, the extent of live weight change in this period was also influenced by the ration. In the following periods of this experiment the deviations decreased but the tendency towards a difference between rations remained and in these periods there was no ration effect on the level of live weight change. The reaction of the four groups, expressed in adjusted standard deviation for this characteristic, in the second experiment ranged in the first period (weeks 1-12) between 13.0 and 25.0. The DF-Concentrate and the HF-Roughage had the highest values. In the third period a lower adjusted standard deviation for the concentrate groups was observed as in the first experiment.

Table 4.37. Standard deviation, before (b) and after (a) adjustment, of live weight change per period, experiment (I, II) and genotype-ration group.

Period		weeks 1-12		weeks 13-29		weeks 29-40	
		I	II	I	II	I	II
DF-Roughage	b	37.1	19.6	27.3	19.8	19.8	35.8
	a	30.1	13.0	15.9	17.0	14.8	24.0
DF-Concentrate	b	23.5	27.4	15.2	12.5	18.1	20.0
	a	18.6	25.0	9.2	11.0	13.6	16.0
HF-Roughage	b	37.8	35.4	22.4	20.3	23.7	29.9
	a	29.6	25.0	18.4	14.0	17.1	20.0
HF-Concentrate	b	31.1	20.2	21.3	18.5	21.4	17.3
	a	26.2	15.0	15.3	14.1	15.9	16.0

The coefficient of correlation between the adjusted average live weight in weeks 1-12 and 13-28 ranged between +0.80 and +0.99 over the four groups (table 4.38). The same kind of values were found for the coefficients of correlation between the other periods. Live weight change had not such regular and high coefficients of correlation (table 4.38). The significant ($P \leq 0.05$) values were found mainly between weeks 1-12 and 13-28. The DF-Roughage group had a coefficient of correlation of +0.49 which implied a regression coefficient of +0.26 for the estimation of the live weight change in the second period on the first period. For the DF-Concentrate group this regression was -0.41 and for the HF-Roughage -0.23. The coefficient of correlation for the HF-Concentrate was not significant. These coefficients of correlation fluctuated widely over the four groups which indicated a different reaction of the groups. A high mobilization of reserves in the first period within the DF-Concentrate group was connected with a higher reserve deposition in the second period and for the DF-Roughage group the reverse was found. In summary the live weight change at the end of the lactation was not correlated with the change at the beginning of the lactation.

Table 4.38. Correlation coefficients between the adjusted average live weight and live weight change respectively in the several periods of the first experiment.

Period (weeks)	1-12,13-28	1-12,29-40	13-28,29-40	n
Average live weight				
DF-Roughage	+0.91***	+0.82***	+0.88***	23
DF-Concentrate	+0.99***	+0.98**	+0.98***	22
HF-Roughage	+0.80***	+0.69***	+0.86***	23
HF-Concentrate	+0.94***	+0.87***	+0.96***	23
Live weight change				
DF-Roughage	+0.49***	-0.36*	-0.23	23
DF-Concentrate	-0.83***	-0.05	+0.35	22
HF-Roughage	-0.37*	+0.01	-0.34	23
HF-Concentrate	+0.11	-0.04	-0.11	23

The next step in the analysis was the relation between the first and second experiments. The coefficients of correlation are presented in table 4.39. Besides the HF-group that received, in experiment I, the roughage and, in experiment II, the concentrate ration the values for the live weight level ranged between +0.65 and +0.91. The reason for the anomalous behaviour of that HF-group was not clear and the non-significant values ranged over the three periods between +0.23 and +0.38. The coefficients of correlation between the adjusted live weight change were, in general, not significant.

Table 4.39. Correlation coefficients between the adjusted average live weight and live weight change respectively in the same periods of the two experiments per genotype-ration group.

Period (weeks)	1-12,13-28	1-12,29-40	13-28,29-40	n
Average live weight				
DF-Roughage-Concentrate	+0.75***	+0.75***	+0.83***	18
DF-Concentrate-Roughage	+0.76***	+0.66***	+0.65***	16
HF-Roughage-Concentrate	+0.26	+0.23	+0.38	17
HF-Concentrate-Roughage	+0.90***	+0.91***	+0.86***	13
Live weight change				
DF-Roughage-Concentrate	+0.06	+0.35	-0.02	18
DF-Concentrate-Roughage	+0.19	+0.06	+0.59***	16
HF-Roughage-Concentrate	-0.27	+0.09	+0.06	17
HF-Concentrate-Roughage	+0.64***	-0.10	+0.29	13

4.3.2 Live weight pattern over the lactation

- Analysis per week

In both experiments the live weight was determined on the second day after calving and before and after a measuring week. The live weights within a measuring week were averaged and in this way there were twelve measurements per experiment. One week before the dry period the live weight of all the individuals was determined as well as at the time this period started. Besides this, the animals were also weighed before and after a measuring week during the dry period. The live weights per measuring week and around the time of starting the dry period were averaged and this resulted in four averages in that period. The same number of cows was analysed in this period as in the second experiment.

These twenty-eight weeks during and between both experiments were analysed with model II. The analysis of model I did not result in a significant interaction. The least squares means per genotype-ration group within an analysing week are presented in figure 4.16. At the beginning of the first experiment the overall contrast (kg) between the roughage and concentrate groups was -27. This increased over the lactation to -56 in week 6 and -65 in week 40.

The first experiment was also analysed for the limited number of cows that were in the second experiment. The ration effect was not significant at the beginning of this experiment. The estimated non-significant contrast between roughage and concentrate was -7 kg. The contrasts (kg) in the dry period ranged between -44 and -46 and this remained constant during this period. The least squares overall mean of the live weight change between week 9 and week 6 before calving was +22 kg, between weeks 6 and 4, +16 kg and between weeks 4 and 2 +13 kg. It indicated an almost linear relation with the increase of the stage of the dry period.

The cows were weighed two weeks before calving and two days after calving, and between these two points there was a live weight change. The birth weight of the calves was one of the reasons for this change. The least squares means (kg) for the live weight change and the birht weight of the calf were, per group: DF-Roughage -42 and 40, DF-Concentrate -52 and 40, HF-Roughage -43 and 46, HF-Concentrate -50 and 46. There existed a tendency for a ration difference in live weight change (P = 0.08) but not for birth weight (P = 0.77). The genotype effect was only significant for birth weight (P = 0.00) as was the lactation number effect.

At the beginning of the second experiment the overall contrast between roughage and concentrate was positive (two days after calving: +33). This changed in the first weeks from positive to negative and the ration effect was again significant in week 16 of the lactation. After that time it increased with the stage of lactation to -49 kg at week 40.

The genotype effect was never significant in any one of 28 analysing weeks but the overall contrasts (DF-HF)(kg) were always negative and ranged in the first experiment between -10 and -17. This range in the dry period was between -12 and -17 and in the second experiment between -10 and -24. The interactions between genotype-ration were never significant in the 28 weeks. However, in nine weeks of the first experiment and in the four weeks of the dry period the interaction component [(HF-Concentrate + DF-Roughage)-(HF-Roughage + DF-Concentrate)] was negative. This implies a systematic but not significantly greater contrast between genotypes on the roughage ration. The second experiment showed the reverse.

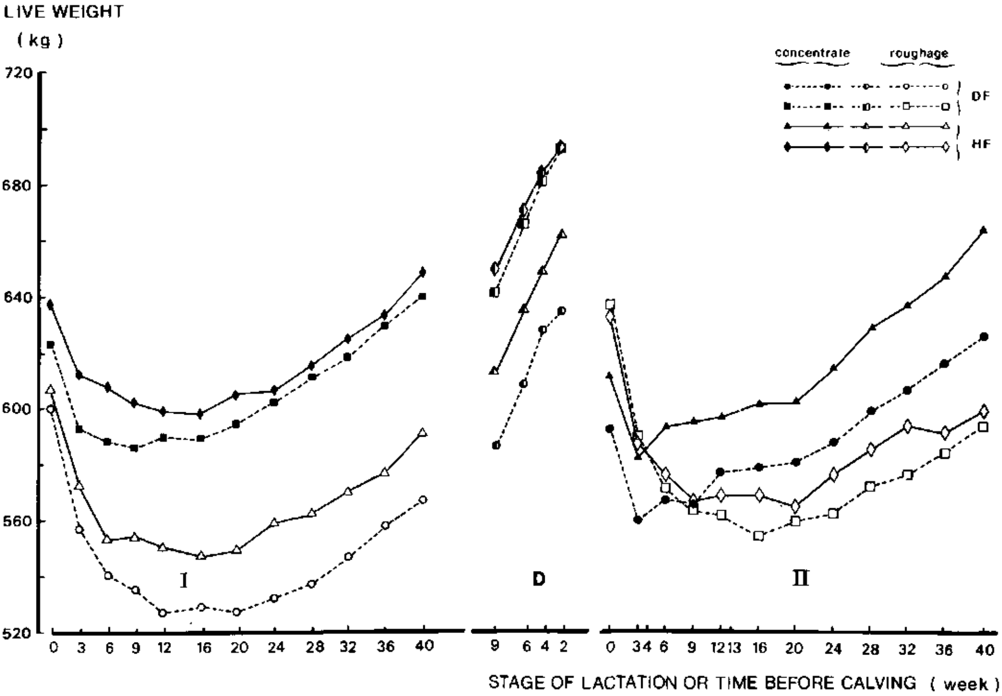

Fig. 4.16. Least squares means of the live weight (kg) per genotype-ration group and experiment (I, II) or dry period (D).

- *Live weight curve over the lactation*

As mentioned in the analysis per week, the live weight was determined 23 times during the lactation. The live weight curve over the lactation was characterized for every individual in the first experiment on the basis of these measurements. Model III fitted the curve and included the following parameters: the level, time of lactation with a minimal live weight, the maximum live weight decrease and a pregnancy parameter. The average parameters and standard deviations per genotype-ration group are presented in table 4.40.

- Variance and relations between error terms: According to the Student-Newman-Keuls test (Snedecor and Chochran, 1967) there were no significant differences between the four subgroups in total variance and the model explained on average, per genotype-ration group, approximately 70% of the variance. The average residual standard deviation per genotype-ration group was: DF-Roughage 12, DF-Concentrate 11; HF-Roughage 14 and HF-Concentrate 14 kg. The relations between the error terms were tested with the Durbin-Watson (1951) test (P = 0.05). The DF-Concentrate had, on average over the individuals, a fitted function with an autocorrelation between error terms in the range with no possible conclusion. The other three groups had, on average over the individuals, no autocorrelation between error terms.
- Values of the parameters: no significant difference between groups was found for the level of the live weight. This ranged between 597 and 642 kg. The time of lactation with minimal live weight was clearly influenced by the ration. The greatest differences were found within the DF-genotype. This time for the roughage and concentrate group of this genotype was day 101 and day 62 respectively. The maximum decrease of the live weight during the lactation was, for the concentrate and roughage groups, 45 kg and 68 kg respectively. The ranking of the groups was the same as for the time of lactation with minimal live weight namely: DF-Roughage, HF-Roughage, HF-Concentrate and DF-Concentrate. The minimal live weight was also clearly influenced by the ration (537 and 585 kg). The pregnancy parameter fitted with the model indicated the increase in live weight by the pregnancy during the period of conception to 40 weeks of lactation. The average values of the live weight change for the four genotype-ration groups on the average calving interval (about 380 days) were: DF-Roughage + 21 kg, DF-Concentrate +39 kg, HF-Roughage +28 kg and HF-Concentrate +28 kg.

A high live weight level was attended by a high maximal decrease of live weight during the lactation (coefficient of correlation ranged between -0.22 and -0.79) but the value for the relation was dependent on the ration (table 4.41). The roughage groups had a higher relation (-0.57 and -0.79). A difference between rations was also found for the coefficient of correlation between level and time. This relation was only significant or weakly significant for the roughage groups (+0.29 and +0.63).

Table 4.40. Mean parameters and standard deviations (s.d.) of the fitted live weight curve over the lactation per genotype-ration group. (same character: not significantly different - P = 0.05).

	DF-Roughage		*DF-Concentrate*	
	mean	s.d.	mean	s.d.
Total variance	656.0^{a}	406.0	520.8^{a}	422.1
Residual variance	139.7^{a}	53.4	113.8^{a}	60.3
R^2 (%)	76.6^{a}	13.5	71.9^{a}	19.5
Durbin-Watson	1.86^{a}	0.55	1.74^{a}	0.57
Level (p_1)(kg)	596.7^{a}	58.1	618.9^{a}	59.6
Time (p_4)(d)	101.2^{b}	50.3	61.5^{a}	25.7
Max. decrease (p_3)(kg)	-71.1^{a}	37.5	-41.2^{b}	20.2
Pregnancy (p_2)	0.0210^{a}	0.0191	0.0259^{a}	0.0153
Min. weight (kg)	525.6^{a}	40.0	577.7^{b}	61.1
	HF-Roughage		*HF-Concentrate*	
	mean	s.d.	mean	s.d.
Total variance	635.6^{a}	388.8	628.8^{a}	405.2
Residual variance	183.0^{a}	156.1	183.7^{a}	102.0
R^2 (%)	69.6^{a}	18.8	67.6^{a}	18.3
Durbin-Watson	1.99^{a}	0.53	1.94^{a}	0.49
Level (p_1)(kg)	611.7^{a}	61.1	642.2^{a}	60.2
Time (p_4)(d)	96.9^{b}	38.7	76.6^{ab}	34.4
Max. decrease (p_3)(kg)	-64.2^{a}	33.9	-49.7^{ab}	26.6
Pregnancy (p_2)	0.0231^{a}	0.0357	0.0231^{a}	0.0049
Min. weight (kg)	547.5^{a}	45.4	592.5^{b}	53.4

Table 4.41. Correlation coefficients between parameters of the fitted live weight curve per genotype-ration group (symbols see table 4.40).

	p_1 p_3	p_1 p_4	p_3 p_4
DF-Roughage	-0.79***	+0.63***	-0.57***
DF-Concentrate	-0.22	-0.29	-0.27
HF-Roughage	-0.57***	+0.29	-0.17
HF-Concentrate	-0.38*	+0.07	-0.65***

4.3.3 Discussion

The live weight of lactating cows changes as a result of an alternate deposition and subsequent catabolism of body tissue during lactation, pregnancy and growth. The live weight change as an indication of the mobilization or deposition of body reserves will be discussed in 4.4.3. The genetic ability to produce milk during early lactation exceeds that of the feed intake to meet requirements for energy. Broster (1976) suggested that this lag is dependent on the genetic potential of the individual and the level of feed intake.

The results described showed a clear ration effect on the live weight change during the first experiment with a maximum decrease of the live weight in the roughage and concentrate groups of 68 and 45 kg respectively. This difference was caused by a longer time and a higher rate of live weight loss during the lactation. This live weight change was positively correlated with the level just after calving within a genotype-ration group but the size was dependent on the ration (table 4.41). Wood et al. (1980) had found the same results as for the concentrate groups. The difference between rations increased with the increase in duration of the lactation and generally within a group there did not exist any relation between live weight decrease and increase during the lactation. The least squares mean estimates of the difference (kg) between week 40 of the lactation and two days after calving of the first experiment was: DF-Roughage -34, DF-Concentrate +16, HF-Roughage -16 and HF-Concentrate +10.

The ration in the first experiment had a significant effect on the level of live weight in the dry period but did not affect the live weight change. It was not possible to compensate for the underfeeding of the preceding period (4.1.4). The carry-over effect was clearly shown in the second experiment. The live weight change in weeks 1-12 in the two experiments were, for the roughage groups, -66 and -71 kg respectively and for the concentrate groups -37 and -16 kg.

These experiments supported the suggestion of Broster (1976) about the influence of the energy intake level on the live weight change. The supposed different live weight change of animals with a different genetic potential for milk production was not observed. The difference between DF- and HF-genotype was not significant nor was the interaction, but figure 4.15 and table 4.40 (p_3 and p_4) show a tendency towards a ranking difference of the genotypes between rations. The DF-genotype had more body reserves (higher score for fatness) at the beginning of the first experiment which might have been useful on the roughage ration.

The live weight change was also influenced by the pregnancy. The change between conception and 264 days pregnancy (latest measuring moment for calving) ranged between 95 and 115 kg over the groups with no significant ration or genotype differences. The four groups had comparable calving intervals (days)(DF-Roughage 394, DF-Concentrate 384, HF-Roughage 373, HF-Concentrate 372). Huth and Smith (1979) observed a live weight change of 105 kg in this period. The ration groups had a different live weight change around calving which may have been caused by e.g. a difference in placenta and foetal membranes and/or rumen fill.

4.3.4 Conclusions

- The maximum decrease in live weight during lactation in the first experiment was influenced by the ration (DF-Roughage -71 kg, DF-Concentrate -41 kg, HF-Roughage -64 kg, HF-Concentrate -50 kg).
- There was no significant genotype effect on live weight change.
- The genotype - ration interaction was not significant for live weight level and change.
- The coefficients of correlation between live weight level and maximum live weight losses (model III) were negative and dependent on the ration (Roughage groups -0.57 and -0.79; Concentrate groups -0.32 and -0.38).
- The live weight change during the lactation was influenced by the ration in the preceding lactation (figure 4.16).

4.4 Difference between energy intake and requirement

4.4.1 Cumulative periods

The basis for calculating the energy requirement per individual cow was described in chapter 3.1.4. This was based on milk production (including components) and live weight (maintenance). The energy intake was described in chapter 4.1.1. In Table 4.42 the total difference between energy intake and the calculated energy requirement ("energy difference") per period, experiment and genotype-ration group is presented. A clear ration effect was shown in both experiments and all the four groups had a negative cumulative energy difference at the end of the first period of the first experiment. This was not shown with the concentrate groups in the second experiment. The absolute energy difference of the roughage groups in weeks 13-28 was smaller in the second experiment than in the first experiment. The highest standard deviations were found in the middle period and the lowest in weeks 29-40.

Table 4.42. Means and standard deviations (s.d.) of the total difference between energy intake and requirement (kVEM) per period, experiment (I, II) and genotype-ration group.

Period	weeks 1-12		weeks 13-28		weeks 29-40	
	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I						
DF-Roughage	-190.46	113.44	+182.19	98.99	+ 92.48	100.44
DF-Concentrate	- 70.18	109.80	+273.29	112.15	+163.69	102.20
HF-Roughage	-224.92	101.55	+ 94.71	106.27	+ 38.53	83.00
HF-Concentrate	-137.86	122.01	+222.46	120.52	+116.00	133.55
Experiment II						
DF-Roughage	-245.35	88.27	- 60.83	160.77	+105.16	81.23
DF-Concentrate	+ 10.47	132.25	+274.20	143.80	+171.67	71.12
HF-Roughage	-210.60	113.14	+ 41.86	135.63	+107.02	98.70
HF-Concentrate	+ 21.21	98.50	+283.63	125.09	+177.17	75.60

Table 4.43. Analysis of variance on the total difference between energy intake and energy requirement (kVEM) per period and experiment (I, II).

Period		weeks 1-12		weeks 13-28		weeks 29-40	
Source	df	SS × 10^3	P	SS × 10^3	P	SS × 10^3	P
Experiment I							
Total	91	3634.1		4798.7		2115.1	
μ	1	2063.2		2704.0		819.1	
Genotype	1	16.9	.229	66.5	.016	10.5	.262
Ration	1	229.4	.000	213.9	.000	111.8	.000
Lactation	2	119.0	.008	15.8	.491	18.6	.328
Days open	3	75.8	.095	66.5	.118	20.1	.489
Season	3	36.2	.375	113.3	.021	281.0	.000
Genotype * Ration	1	6.4	.458	1.7	.691	0.0	.999
Remainder	79	908.7		867.8		648.2	
R^2 (%)		34.9		39.5		44.5	
Experiment II							
Total	64	2272.4		4013.2		1783.2	
μ	1	397.0		1061.2		943.8	
Genotype	1	13.0	.301	46.8	.116	0.5	.776
Ration	1	865.8	.000	1460.2	.000	105.6	.000
Lactation	1	47.3	.051	62.0	.071	0.7	.739
Days open	3	45.3	.295	90.4	.190	7.6	.732
Season	3	12.2	.795	108.7	.128	76.6	.008
Genotype * Ration	1	5.7	.491	19.3	.309	0.4	.801
Remainder	53	603.3		970.5		311.4	
R^2 (%)		62.7		63.4		33.4	

The analysis of the energy difference per period with model I resulted in four significant ($P \leq 0.05$) interactions in the first experiment and no significant interactions in the second experiment. The following significant two-way interactions were found per period in the first experiment: weeks 1-12, season - days open; weeks 13-28, ration - days open and season - days open; weeks 29-40, genotype - days open. These two-way interactions had an effect on the estimation of the main effects with model II. In this study the genotype and ration effects were most important and therefore the previously mentioned non-systematic interactions only appeared in weeks 13-28 and weeks 29-40.

Taking into account the foregoing elements the energy difference was analysed with model II. This model explained between 35 and 45% of the variation in the first experiment and, in the second, between 33 and 63%. The genotype effect was only significant ($P \leq 0.05$) in weeks 13-28 of the first experiment (table 4.43), the overall genotype difference (DF-HF) in this period being +537 VEM d^{-1} (table 4.44). In all the three periods of the first experiment this difference was positive and in the second experiment negative (fig. 4.17).

The ration effect was clearly significant in all the periods, independent of the experiment. However, the overall contrast between rations was higher in the second experiment. The overall contrasts per period (VEM d^{-1})(Roughage-Concentrate) in the two experiments were -1155 and -2790, -896 and -2911, -864 and -1044 respectively. There was a carry-over effect from the first to the second experiment. At the beginning of both experiments the lactation number effect was significant. For this data the relation between energy difference and lactation number was negative. The interaction between genotype and ration was never significant (table 4.43, fig. 4.17).

Table 4.44. Least squares constants of the effects on the average difference between energy intake and requirement (VEM d^{-1}) per period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40	
Source	I	II	I	II	I	II
Mean	-1777	-1024	+1635	+1345	+1200	+1691
DF-Roughage	-505	-1671	-139	-1871	-281	-525
DF-Concentrate	+842	+1342	+676	+1369	+565	+457
HF-Roughage	-650	-1119	-757	-1040	-583	-518
HF-Concentrate	+313	+1448	+220	+1542	+299	+587
Genotype * Ration	-384	-446	+162	-658	+36	+123
Lactation 2	+624		+188		-237	
Lactation 3	-39	+346	-32	-39	+186	-44
Lactation ≥ 4	-586	-346	-157	+39	+51	+44

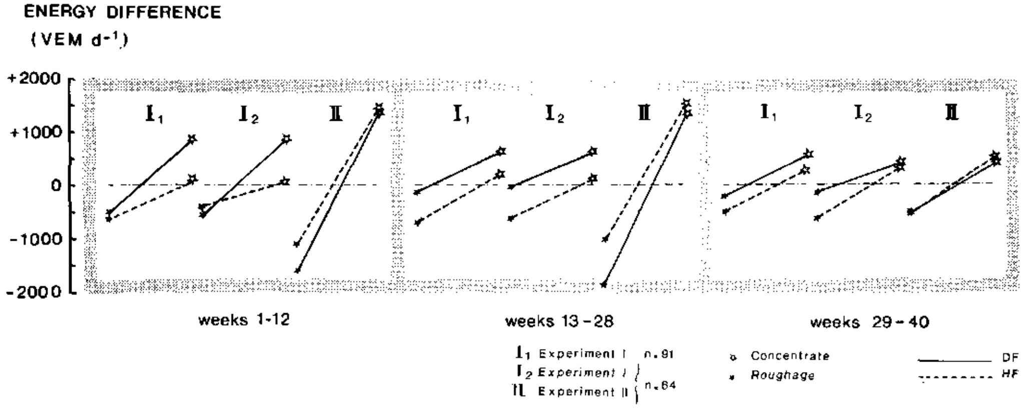

Fig. 4.17. Least squares constants of the difference between energy intake and requirement (VEM d^{-1}) per genotype-ration group, experiment and period.

- *Coefficients of correlation*

The coefficients of correlation were calculated within a genotype-ration group after adjustment for season, days open and lactation number. Within the Dutch Friesian group the coefficient of correlation between the adjusted energy difference in weeks 1-12 and 13-28 was comparable for the two groups (+0.35 and +0.28) (table 4.45). A clear difference between rations was found for the HF-genotype (roughage -0.23 and concentrate +0.60). The coefficient of correlation between weeks 1-12 and 29-40 was only significant for HF-Roughage (+0.53). Between the middle and end of the lactation a positive relation existed for three groups. The HF-Roughage groups had also an aberrant coefficient of correlation (-0.19).

The coefficients of correlation between the same periods in the two experiments (table 4.46) were generally not significant. In the first period these values ranged between -0.20 and +0.43, in the second period between -0.23 and +0.26 and in the last period between +0.27 and +0.57. The highest values were found in the last period.

Table 4.45. Correlation coefficients between adjusted energy difference (intake - requirement) in the several periods of the first experiment per genotype-ration group.

Period (weeks)	1-12,13-28	1-12,29-40	13-28,29-40	n
DF-Roughage	+0.35*	-0.03	+0.38*	23
DF-Concentrate	+0.28	-0.18	+0.57***	22
HF-Roughage	-0.23	+0.53***	-0.19	23
HF-Concentrate	+0.60***	+0.04	+0.35*	23

Table 4.46. Correlation coefficients between adjusted energy difference (intake - requirement) in the same periods of the two experiments per genotype-ration group.

Period (weeks)	1-12	13-28	29-40	n
DF-Roughage-Concentrate	+0.13	+0.02	+0.27	18
DF-Concentrate-Roughage	+0.43**	+0.06	+0.57***	16
HF-Roughage-Concentrate	-0.20	+0.26	+0.31	17
HF-Concentrate-Roughage	+0.25	-0.23	+0.45**	13

4.4.2 Energy difference pattern over the lactation

- Analysis per week

Figure 4.18 shows the least squares mean estimates (model II) of the genotype-ration groups per measuring week within an experiment. Model I resulted in five significant ($P \leq 0.05$) two-way interactions in the first experiment (weeks 9, 16, 20 and 24), in the dry period one (week 4) and two in the second experiment (weeks 3 and 4). However, these interactions were not systematic in the 27 measuring weeks.

The average balance between energy intake and requirements for maintenance and milk production was attained for the concentrate ration in the first experiment between weeks 6 and 9 and for the roughage groups between weeks 9 and 12. In the second experiment this equilibrium state ranged between weeks 3 and 4 and between weeks 13 and 16 respectively.

The overall contrasts (VEM d^{-1}) between rations (Roughage-Concentrate) ranged over the several weeks in the first and second experiments between -2065 and -791 and, -3720 and -699 respectively. In early and mid lactation the ration contrasts were clearly dependent on the experiment. These contrasts were higher in the second experiment. At the end of both experiments the contrasts between rations were comparable.

The concentrate groups after week 28 of both experiments showed a decrease of the energy difference which could have been caused by the decrease in concentrate level (-3 kg). In the first experiment there was also a decrease in the roughage groups which did not occur in the second experiment. This was likely to be caused by the average decrease in energy content of the roughage from week 28 to week 32 in the first experiment (appendix 6).

The same quantity of concentrates was offered to the four groups in the dry period but the roughage groups of the first experiment had, on average, a higher energy difference than the concentrate groups (+491 VEM d^{-1}). In this stage between lactations the overall contrasts (VEM d^{-1}) between genotypes (DF-HF) ranged between -544 and -46. In the first and second experiment these contrasts ranged between -72 and +957 and between -745 and +568 respectively.

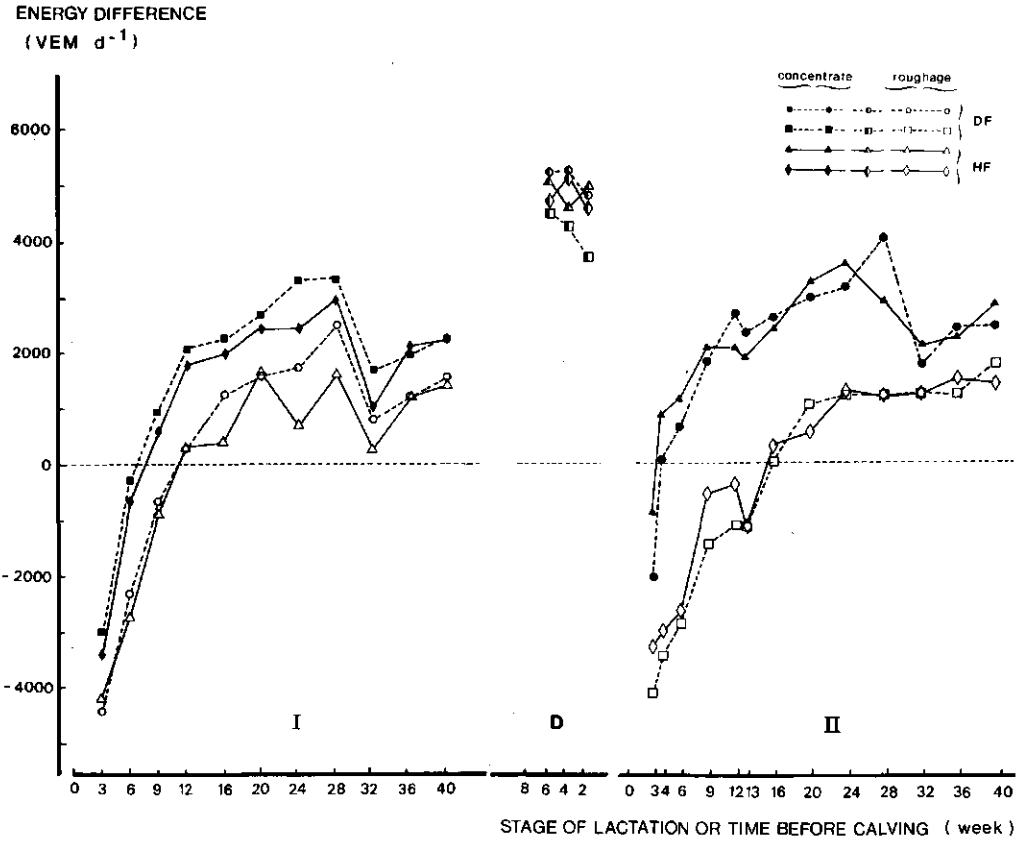

Fig. 4.18. Least squares means of the difference between energy intake and requirement for milk production and maintenance (VEM d^{-1}) per genotype-ration group and experiment (I, II) or dry period (D).

4.4.3 Discussion

The calculated energy difference was based on the energy intake and the estimated energy requirements for maintenance and milk production. It should be emphasized that this figure was subject to random and/or cumulative errors.

Possible reasons for errors could be e.g.:

- Measuring faults e.g. dry matter intake, live weight and milk production.
- Variation in digestibility of the feed consumed. This characteristic was possibly dependent on the ration or genotype or both.
- Variation between animals in net energy requirement per unit metabolic live weight and/or unit milk production.

The chance of cumulative errors indicates the relativity of this characteristic and therefore the discussion will be confined to the general trend which showed a significant ration effect and a difference between rations at the time of reaching energy equilibrium during the lactation.

The inadequacy of energy intake can be overcome by mobilization of body reserves. A surplus of energy intake results in tissue deposition. However, Moe et al. (1971) showed that body tissue changes may not be accurately reflected by live weight changes. For instance the high yielding cow in early lactation has to mobilize body reserves but this is not always shown by a live weight change because e.g. change in rumen fill and/or body fat may be metabolized and replaced by water. Moe et al. (1971) suggested a caloric equivalent of empty body weight change between 21 to 30 MJ (app. 3000-4300 VEM)(corrected for change in rumen fill) per kilogram live weight loss and this quantity can be utilized for milk production with an efficiency of approximately 80-85% (Moe et al., 1971; Van Es and Van der Honing, 1979). The combination of the live weight change per period of the lactation (table 4.31) and the calculated energy difference (table 4.42) resulted, in the first period of the first experiment, in comparable values (table 4.47). Colleau et al. (1979) observed higher values in the first twelve weeks of the lactation and a difference between first and second lactations. The periods with energy surplus or partial lack and surplus showed variable results. The efficiency of deposition of body reserves is lower than the conversion of body reserves in milk production (app. 60 and 80% respectively, Van Es and Van der Honing, 1979) and in late lactation energy is used for pregnancy with a low degree of efficiency.

The coefficient of correlation (adjusted) between energy difference and live weight change for the four genotype-ration groups in the first period (weeks 1-12) ranged between +0.41 and +0.85, in weeks 13-28 between +0.20 and +0.64 and in the third period between +0.06 and +0.79. No close relationship existed and the values were comparable with the results of Østergaard (1979).

This subchapter is confined to the energy difference but Tamminga (1981) emphasized the importance of the proportion of the energy that has to be supplied as protein. However, there is not enough knowledge about the quantity of protein required in the feed as a result of the variation in degradation in the rumen and the production of microbial protein. In spite of the failings of use of digestible crude protein as a measure of the protein requirement of individual cows, which have been described by Tamminga (1979), this criterion (still recommended in the Netherlands) was used in this study for comparing the protein requirements (maintenance and milk production) and intake. The average deficiency for the roughage ration was shown in experiment I in weeks 3 and 6 (app. 20 and 12 percent) and in experiment II in weeks 3, 4 and 6 (app. 8, 4 and 2 percent). The concentrate ration (average) had a deficiency only in week 3 of the first experiment (app. 11 percent). These deficiencies had to be supplied by a mobilization of the body reserves. Tamminga (1981) suggested on the basis of a widely accepted idea, that a contribution from the body reserves is possible in the beginning of the lactation and he suggested on the basis of a personal communication from Van Es that, after a few weeks, it is not more than about 10 percent. It was not possible to conclude whether milk production in early lactation was limited by a lack of protein, energy or both, particularly in the roughage ration, because both factors were involved in the contrasts between rations.

Table 4.47. The difference between energy intake and requirements (milk production and maintenance) per kg live weight change (VEM kg^{-1}), period and experiment (I, II).

	Experiment I			Experiment II		
Period (weeks)	1-12	13-28	29-40	1-12	13-28	29-40
DF-Roughage	2721	15183	3083	3271	*	4780
DF-Concentrate	2329	13665	5644	*	12464	7153
HF-Roughage	3812	6314	1427	3143	2616	10702
HF-Concentrate	3628	12359	3625	*	8342	6109

* a different sign of energy difference and live weight change.

4.4.4 Conclusions

- The difference between energy intake and the requirements for maintenance and milk production was significantly affected by the ration.
- A carry-over effect existed mainly in the first two periods (weeks 1-12 and 13-28) in the second experiment.
- The energy balance during the lactation shift from negative to positive between weeks 6 and 9 and weeks 9 and 12 in the first experiment for the concentrate and

roughage rations respectively. The dates for the second experiment were between 3 and 4, and 13 and 16 weeks (figure 4.18).

- No close relationship between energy difference and live weight change was found.

4.5 Relationship between milk production, feed intake and live weight change

4.5.1 Introduction

The analysis of the separate animal input and output characteristics have been described in chapter 4.1, 4.2 and 4.3. However, these characteristics are not independently effective. The total reaction of the dairy cow is dependent on the genetic potential (e.g. priorities in nutrient distribution), the stage of lactation and the environment (e.g. climate, feeding level and/or distribution during the lactation) and is expressed as a combination of changes in characteristics (2.5).

The description of the relationships between traits is confined to the coefficients of correlation and the multiple regression analyses (Snedecor and Cochran, 1967). These analyses were applied to the energy supply and demand processes in the first experiment, namely fat protein corrected milk yield (FPCM), live weight, live weight change (loss or gain) and energy intake. The multiple regression analysis was used for the study of the relative importance of the independent variables on the variation of the dependent variable. The relative importance was determined by the regression on standarized variables (adjusted for scale) (standard partial regression coefficients). The independent variables are ranked in order of the absolute values of these coefficients. The description in this study is confined to one analysis with FPCM as the dependent variable. The restriction to FPCM as the dependent variable was based on the fact that it was determined in practice. In such a situation it is important to have knowledge about the relative importance of energy intake, live weight change and live weight on the variation in FPCM dependent on the genotype, the ration and the stage of lactation.

4.5.2 Simple relationships

The coefficients of correlation between characteristics were calculated on the basis of data adjusted within a genotype-ration group for the effects of lactation number, season and days open (3.2.5). Table 4.48 presents the results per stage of lactation.

- The fat protein corrected milk was positively correlated with the energy intake and ranged over the four groups and three stages of lactation from +0.26 to +0.75. The roughage groups showed higher coefficients in the first period of the lactation than the concentrate groups. This difference between rations was even more marked for the relationship between FPCM and roughage dry matter intake in that period (Roughage groups: +0.64 and +0.69; Concentrate groups: -0.02 and +0.21). The difference between rations was observed also in the total lactation (weeks 1-40).
- The coefficient of correlation between FPCM and live weight change was, in summary, negative but the size was dependent on the stage of lactation and the genotype-ration group. At the beginning of the lactation a higher fat protein corrected milk production was related to a higher body weight loss but the coefficients showed a range from -0.04 to -0.74 with a difference between rations within the HF-genotype. The third period showed a negative relationship between FPCM production and increase in live weight. A difference between rations was clearly shown in this period. The results of the total lactation (weeks 1-40) showed higher coefficients of correlation for the concentrate groups in comparison with the roughage groups. The values for the latter groups were not significant.
- The average live weight within a stage of lactation was not significantly correlated with FPCM. However, the DF-Concentrate group was an exception in the first two periods of the lactation which might have been caused by the highest ratio of energy intake per kg FPCM. The average live weight also reflected the live weight change during the lactation. This was shown by the coefficients of correlation in the total lactation between FPCM, live weight change and live weight respectively.
- The energy intake and live weight change was only significantly correlated for the DF-Concentrate group in weeks 13-28 and 29-40. The results of the total lactation showed significant values for both concentrate groups.
- The coefficient of correlation between energy intake and the average live weight per period and per genotype-ration group was never significant.
- In summary the coefficients of correlation between average live weight and live weight change ranged over the three stages of the lactation from low positive, negative (mid-lactation) to positive at the end of the lactation. Table 4.48 shows ration differences in weeks 13-28 and 29-40. Table 4.41 showed clearly negative coefficients of correlation between live weight level and maximum live weight losses during the lactation.

Table 4.48. Correlation coefficients between FPCM, energy intake, live weight change and average live weight per period and genotype-ration group.

	FPCM/ Energy intake	FPCM/ Weight change	FPCM/ Live weight	Energy intake/ Weight change	Energy intake/ Live weight	Weight change/ Live weight
Weeks 1-12						
DF-Roughage	+0.66***	-0.41*	+0.18	+0.26	-0.34	-0.63***
DF-Concentrate	+0.27	-0.26	-0.62***	+0.10	+0.10	+0.01
HF-Roughage	+0.63***	-0.04	+0.02	+0.36*	+0.30	+0.25
HF-Concentrate	+0.43**	-0.78***	+0.01	-0.20	+0.30	+0.04
Weeks 13-28						
DF-Roughage	+0.75***	+0.05	-0.16	+0.19	-0.02	-0.40*
DF-Concentrate	+0.66***	-0.27	-0.74***	-0.52***	-0.17	-0.20
HF-Roughage	+0.60***	-0.33	-0.02	+0.16	+0.08	-0.56***
HF-Concentrate	+0.26	-0.21	-0.34	+0.30	+0.05	-0.07
Weeks 29-40						
DF-Roughage	+0.50***	-0.34	+0.32	+0.20	+0.01	+0.32
DF-Concentrate	+0.66***	-0.75***	-0.20	-0.40*	-0.21	+0.57***
HF-Roughage	+0.71***	-0.04	-0.32	+0.06	+0.22	+0.36*
HF-Concentrate	+0.64***	-0.72***	-0.06	-0.17	-0.29	+0.53***
Weeks 1-40						
DF-Roughage	+0.79***	-0.22	-0.02	+0.18	-0.13	-0.47**
DF-Concentrate	+0.57***	-0.47**	-0.78***	-0.43**	-0.12	+0.29
HF-Roughage	+0.77***	-0.19	-0.09	+0.09	+0.29	+0.30
HF-Concentrate	+0.59***	-0.74***	-0.38*	-0.40*	+0.05	+0.32

4.5.3 Multiple regression

A multiple regression analysis was carried out within a genotype-ration group at each stage of lactation. The variables were used on a non-transformed scale. Conrad et al. (1964) and Brown et al. (1977) used variables on the natural logarithmic scale but an analysis with the dependent variable (FPCM) on this scale did not give greater distinction between genotype-ration groups.

The relative importance of the energy intake, live weight change and live weight on the variation of fat protein corrected milk are shown in table 4.49. The energy intake had a positive influence on the variation in FPCM but its importance in all the stages of lactation was clearly dependent on the ration. The roughage groups had higher standard partial regression coefficients than the concentrate groups. The FPCM yield had a negative partial regression coefficient on live weight loss at the beginning of the lactation or live weight gain in the second part. Weeks 1-12 indicated the highest values for the HF-Concentrate group and the lowest values were found for the genotype-ration groups with the greatest or least differences between energy intake and requirements for maintenance and FPCM yield. The standard partial regression coefficients for live weight were generally negative. This trait was, on average, the least important, except for the DF-Concentrate group in the first two periods.

The multiple regression model explained about 67% of the variation over the four genotype-ration groups and the three stages of the lactation.

Table 4.49. The standard partial regression coefficients of fat protein corrected milk on energy intake, live weight change and live weight per genotype-ration group and period.

	Energy intake	Weight change	Live weight	R^2(%)
Weeks 1-12				
DF-Roughage	+0.85	-0.56	+0.12	81.3
DF-Concentrate	+0.38	-0.28	-0.67	59.0
HF-Roughage	+0.76	-0.26	-0.14	48.3
HF-Concentrate	+0.30	-0.72	-0.05	69.2
Weeks 13-28				
DF-Roughage	+0.78	-0.19	-0.22	61.1
DF-Concentrate	+0.45	-0.17	-0.70	86.5
HF-Roughage	+0.76	-0.72	-0.48	70.1
HF-Concentrate	+0.40	-0.36	-0.40	31.9
Weeks 29-40				
DF-Roughage	+0.61	-0.53	+0.21	49.7
DF-Concentrate	+0.44	-0.40	-0.32	79.2
HF-Roughage	+0.98	+0.12	-0.61	78.3
HF-Concentrate	+0.49	-0.51	+0.25	84.3

4.5.4 Discussion

Live weight, fat protein corrected milk and energy intake during the first experiment were characterized with model III and the results are presented in tables 4.7, 4.28 and 4.40. The correctness of the fitted energy intake curve was influenced by the concentrate steps (4.1.1.2). Therefore figure 4.19 shows only the average general trends during the lactation of the three characteristics per genotype-ration group. The values were based on an average calving interval (380 days) in the first experiment of the cows that took part in both the first and second experiments.

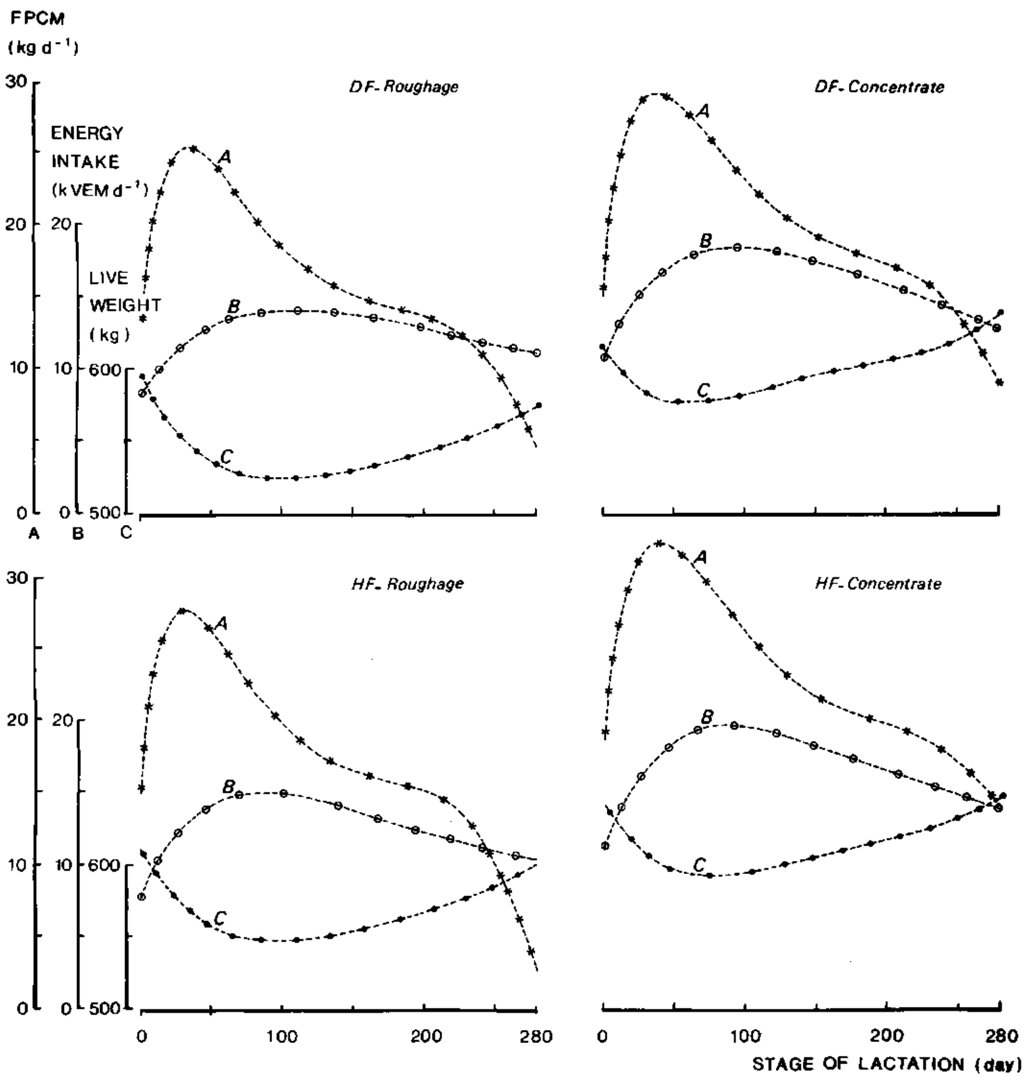

Fig. 4.19. The fitted fat protein corrected milk (kg d^{-1})(A), energy intake (kVEM d^{-1})(B) and live weight (kg)(C) curves during the lactation per genotype-ration group.

Early lactation

FPCM production in early lactation increased faster than the energy intake. The expression of the genetic potential for FPCM production in this stage of lactation is dependent on the energy intake and the live weight (level and weight change). This is not the case when the energy intake is sufficient to meet the requirement for it. The influence of energy intake on FPCM production was greater on the roughage ration than on the concentrate ration. The relationships on the concentrate ration were comparable with the results of Hooven et al. (1972) and Grieve et al. (1976). Both studies were on first lactation cows; the first using a feeding system dependent on milk production and the latter a system independent of requirements. The relationship between milk energy equivalence (FPCM) and energy intake in early lactation on an ad libitum feeding system independent of requirements depends on the roughage concentrates ratio.

In summary the average live weight within a stage of lactation was not correlated with FPCM (table 4.48). Hickman et al. (1971) and Miller et al. (1973) observed the same for cows with comparable lactation numbers. They reported that post partum body weight exerted the greatest influence in spite of the influence of parturition on the live weight. Another approach to the relation between these two characteristics is the use of the level parameters of model III. The coefficients of correlation between the level parameter for live weight and FPCM were: DF-Roughage +0.02, DF-Concentrate -0.70, HF-Roughage +0.10 and HF-Concentrate -0.42 (the four genotype-ration groups). However, these results were in disagreement with the results reported by Wood et al. (1980). They fitted live weight and milk yield during the first 20 weeks of the lactation with the model of Wood (1976)(3.2.4). The reported coefficient of correlation between the two level parameters within adult British Friesian cows was +0.56. Possible reasons for these differences were, among others: length of fitting period, the model III, which is an extended version of the model of Wood (1976), the time of first determining the trait during the lactation, breeds used and rations employed.

Another problem with these level parameters is that the milk production potential is determined not only on the level but also on the expression of the genetic potential above this level during the lactation. The maximum increase of FPCM production was dependent on the decrease of live weight (parameters of model III). The coefficients of correlation for the genotype-ration groups were: DF-Roughage -0.32, DF-Concentrate -0.58, HF-Roughage +0.27, HF-Concentrate -0.58). The significant negative values of the concentrate groups were comparable with the results of Politiek and Vos (1975), and Wood et al. (1980) and the absolute values of the roughage groups were lower.

Later lactation

The energy requirements for milk yield (including components) decreased in the second part of the lactation. The energy intake after energy equilibrium is attained, is probably dependent on the requirements for FPCM, live weight and the restoration of body reserves. Hooven et al. (1972) reported comparable values for the relationship between milk yield and energy intake as the coefficients of correlation mentioned in table 4.48. The significant negative coefficients between FPCM and live weight change were also found in this period of the lactation for the concentrate groups. The importance of the live weight change on the variation of FPCM in the roughage groups was lower than for the concentrate groups in this period of the lactation.

4.5.5 Conclusions

- The relationship between energy intake and milk energy equivalence (FPCM) was more important for the roughage groups than for the concentrate groups.
- The relationship between live weight change and milk energy equivalence (FPCM) was more important for the concentrate groups than for the roughage groups.
- The coefficients of correlation between energy intake and average live weight of a stage of lactation were never significant for the four genotype-ration groups.
- The relationships between energy supply and demand characteristics were dependent on the stage of lactation.
- The coefficients of correlation between the average live weight during the lactation and the total FPCM production were dependent on the ration (Roughage: -0.02 and -0.09; Concentrate -0.78 and -0.38).

5 GENERAL DISCUSSION

The results of the feed intake, production and live weight characteristics have been described in chapter 4 with a discussion at the end of each subchapter. This general discussion will be confined to the following issues regarding these characteristics in dairy cattle.

- Variation of the characteristics in relation to the ration.
- The effects of the change of the ration from the first to the second experimental lactation.
- The pattern of the characteristics during the lactation.
- The milk production to feed input ratio in relation to the characteristics described.
- The genotype-ration interaction.

5.1 Variation of the characteristics in relation to the ration

The variation between individuals in feed intake and production characteristics in part and total lactation is, among other things, dependent on environmental effects. An important environmental effect in the analysis of population data is the herd effect (e.g. Dommerholt, 1975) and this is highly correlated with the feeding level. The influence of the feeding level during the lactation and the distribution of the concentrates over the lactation on the variation of characteristics between individuals within a herd will be discussed.

Milk production. The results of the two experiments described showed a contrast between the two genotypes in the two experiments of -594 (10.1%) and -407 kg (7.2%) respectively. The cows within both genotypes on both rations were fed a fixed concentrate level independent of the milk production. In the preceding lactations the individuals were offered concentrates according to milk yield. The analysis of variance of the preceding lactation and the lactation as a heifer, with a comparable model as for the experiments, resulted in a contrast between genotypes of -974 (15.2%) and -813 kg (14.0%) respectively.

The within genotype-ration group adjusted coefficients of variation in total milk yield of the preceding lactation and the first experiment also showed a difference between the two lactations (table 5.1). Lamb et al. (1977) reported an experiment with progeny groups in which one half of the groups were fed ad libitum roughage and the other half ad libitum roughage with concentrates according to milk production. The coefficients of variation between progeny groups of the two rations were 10.1 and 13.8% respectively.

The allocation of the concentrates over the individuals (dependent or independent of milk production) in feeding systems with ad libitum roughage has an influence on the coefficient of variation in milk yield and is independent of the level of the concentrates. The expression of the phenotypic variation in milk yield is restricted in a system of a fixed concentrate level for the individuals independent of the milk yield. Research is needed to determine the influence of the genetic component in such feeding systems within a population.

The distribution of the concentrates during the lactation had an influence on the persistency of the milk yield (Østergaard, 1979). This implies that the estimation during the lactation of the expected future milk yields of individuals with a different length of lactation has to take into account the average herd level during the lactation.

Table 5.1. Coefficients of variation of the total adjusted milk production per period and genotype-ration group in the lactation before the experiments (B) and the first experiment (I).

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
	B	I	B	I	B	I	B	I
DF-Roughage	13.0	12.2	16.4	11.1	20.9	13.2	14.4	10.4
DF-Concentrate	9.4	8.0	12.8	12.9	24.5	24.7	11.6	11.9
HF-Roughage	12.0	7.3	16.9	9.1	19.7	18.2	14.1	8.5
HF-Concentrate	13.6	8.0	16.9	9.1	21.0	18.2	15.1	9.5

Feed intake. The variation in energy and roughage intake in ad libitum feeding systems is influenced by the ration. Generally individuals were offered ad libitum roughage and concentrates according to milk production. In such circumstances the variation in energy intake between animals depends on:

- variation in milk production,
- variation in roughage intake which is caused in part by the variation in substitution rate of roughage by concentrates.

Both energy intake and roughage intake were confounded with milk yield (e.g. results of Hooven et al., 1972).

Alternatives to study the variation in feed intake characteristics independent of milk yield in ad libitum feeding systems were e.g. a mixed ration of roughage and concentrates and a fixed concentrate level with ad libitum roughage. The former system did not allow the possibility of a variation in roughage intake and, therefore, in substitution rate between individuals. The latter ration gives information about the variation in feed intake resulting from a variation in roughage intake and hence of the substitution rate on a fixed concentrate level.

The experiment described with fixed concentrate levels showed a range of coefficients of variation over the four genotype-ration groups and the three stages of the lactation of between 3.7 and 10.0. The mid stage of the lactation in the first experiment showed the lowest values. This stage had the highest coefficients of correlation with the other stages of the lactation and also the highest repeatabilities between experiments. It was the most stable period during the lactation regarding differences between energy input and requirements for maintenance and milk production for all four genotype-ration groups.

Live weight change. Most feeding experiments had planned nutrient intake according to requirements and therefore no live weight change was to be expected. However, such a change was generally observed and may have been caused, among other things, by a deficiency in the nutrient intake at the beginning of lactation and the priority requirement of milk production for energy and/or a physiologically necessary mobilization of body reserves (Bines, 1976b). Table 4.37 shows different variations for the four genotype ration groups during the lactation; the highest values were found on the low concentrate ration. Østergaard (1979) compared several feeding levels and/or regimes but did not mention the variation of the live weight change. The ratio of the price of concentrates to that of roughage in relation to the output returns determined the economic importance of the live weight change. The production of milk through the indirect use of energy via deposition of reserves and mobilization is less efficient than the direct utilization of energy (e.g. Van Es and Van der Honing, 1979).

5.2 The carry-over effects

Most research on short- and long-term effects of a ration change was carried out within a lactation (e.g. Broster, 1972; Wiktorsson, 1979). The effects were dependent on the energy level before and after the ration change, and the stage of lactation. Research on multiple lactations is very scarce. The research described was carried out during two experimental lactations and in the dry period between these two lactations. The carry-over effect can be estimated by the contrasts between rations in the dry period and/or the comparison of the contrasts between rations in the two experiments. The latter is possible on the assumption of no interaction between contrast and nature of roughage and/or year and/or number of lactation. Ad libitum roughage and the same fixed concentrate amount was offered to all the individuals in the dry period. No effect of the ration in the preceding lactation on energy intake and live weight change was observed (figures 4.2 and 4.10) in spite of the fact that the roughage groups had a lower live weight at the end of the lactation than at the start of it. During the first experiment these groups had a longer time and total level of underfeeding during the lactation in comparison with the concentrate groups. No compensation during the dry period by a higher roughage intake was observed. This may have been caused by:

- The desired energy state of the animals having already been reached. However, the concentrate groups had reached a higher live weight so that this reason is doubtful unless the possibility of reaching a certain equilibrium is dependent on the physiological stage of the animal.
- Reduction of the capacity of the rumen by foetus and associated tissues. However, it was assumed that there was a difference between ration groups in total deposition of fat within the abdominal cavity.
- The influence of pregnancy hormones (Forbes, 1977a).

Table 5.2. The least squares contrasts between the rations per period and experiment (I, II) for fat protein corrected milk, energy intake and live weight change.

Period (weeks)	1-12	13-28	29-40	1-40
Fat protein corrected milk (kg d^{-1})				
Experiment I	4.42	4.72	3.82	4.26
Experiment II	3.86	4.97	4.56	4.40
Energy intake (VEM d^{-1})				
Experiment I	3583	3469	3016	3372
Experiment II	4697	4548	3392	4269
Live weight change (kg)				
Experiment I	-29	-8	-1	-38
Experiment II	-55	-14	-14	-83

The carry-over effect of the ration in the preceding lactation was clearly shown at the beginning of the second experiment (table 5.2). At the beginning of this experiment a lower contrast in milk yield was observed which was compensated at the end of the lactation. The contrast in live weight change between rations had increased in the second experiment and this was caused by the smaller live weight decrease of the groups with a ration change from a low to a high concentrate ration. The least squares estimates of the live weight change in the first period of the first experiment were -65 and -37 kg respectively for the roughage and concentrate groups and in the second experiment -70 and -15 kg. Although the concentrate groups in the second experiment were considered to have a greater possibility of showing a live weight decrease because these groups had a lower minimum level in the first experiment (fig. 4.16). This did not occur. Priority for the allocation of nutrients to milk production or the individual energy states of the animals is dependent on the ration, the genotype and the stage of lactation.

5.3 Pattern of the characteristics during the lactation

The feed intake and production traits of the cows were analysed per period and, within a period, per measuring week. The analysis of the measuring weeks (11 weeks in the first experiment and 13 weeks in the second) gives the most information about the movements of effects on the characteristics during the lactation. However, this implies repeated testing of main and interaction effects on correlated data. The procedure of the analyses will be easier and the value of the analyses will increase if it is possible to characterize the pattern of the trait by some parameters that were correlated as little as possible.

This was carried out with model III (3.2.4) on the traits of energy supply and demand. This model contained four parameters namely: level, maximum increase or decrease of the characteristic during the lactation, time during the lactation with the maximum or minimum of the characteristic and pregnancy. This was an extension of the model of Wood (1976). The pregnancy parameter was added and the parameters were changed as regards content so that a biological interpretation was easy. Wood (1976) used parameters to describe the shape of the curve.

The energy intake, fat protein corrected milk and live weight were fitted with model III. The concentrate steps during the lactation had an influence on the energy intake curve. This error will decrease in ad libitum feeding systems with e.g. a fixed ratio between concentrates and roughage, a fixed concentrate level during the lactation, or a system with concentrates fed according to requirements. However, the calculated differences between energy intake and requirements of milk production and maintenance with these fitted curves in the first experiment per period of the lactation were quite comparable with the estimations on the basis of the average for a trait within a period. The similarity was also clearly illustrated in the effect of the ration on the level parameters of milk energy equivalence and energy intake but with no effect on the level of live weight. However, the maximum live weight losses during the lactation and the time during the lactation when this maximum occurred were affected by the ration (table 4.40).

This approach is an addition to the analyses of the several periods of the lactation. The division of the lactation into some fixed periods for all the individuals is a rough approximation to the physiological stages. The time of minimum live weight per individual during the lactation would be better for distinguishing such stages during the lactation. The difference is illustrated by the maximum live weight decrease in the first period of the first experiment for the four groups (-70, -30, -59 and -38 kg respectively) and the unadjusted results of the fitted curves of the four groups (-71, -41, -64 and -50 kg respectively).

5.4 The milk production to feed input ratio

The results described were limited to input and output characteristics, and the difference between energy intake and the requirements for maintenance and milk production. In general the objective of the farmer is to increase the ratio of output to nutritional input (e.g. energy), or the difference between returns and costs. An increase of the feed intake is not always important. It is dependent on the stage of lactation, the use of the increased intake (maintenance, milk production and reserve deposition), the price of the nutritional sources and the milk yield. The following issues will be discussed:

- The "efficiency" in terms of the ratio of fat protein corrected milk yield to energy intake per period of the first experiment.
- The correlation coefficients between efficiency and feed intake and production traits.
- The difference between milk production returns and feed costs.

The efficiency was analysed with model II and table 5.3 presents the least squares mean estimates per genotype-ration group. This characteristic decreased throughout the lactation. This was high in the early part of the lactation due to the catabolism of body reserves. The first part of both experiments showed a significant ration effect which was caused by a difference in live weight change between the rations. In the complete first experiment (weeks 1-40) there was no significant ration effect but the carry-over effect from first to second experiment resulted in a ration effect for the second experiment as a whole. The genotype effect was only significant in the second period of the first experiment and therefore in the total lactation. The observed differences between genotype groups in the other periods for fat protein corrected milk were compensated for the differences in energy intake and the small non-significant differences in live weight.

Table 5.3. Least squares means of the ratio FPCM (kg) to energy intake (kVEM) per genotype-ration group, period and experiment (I, II).

Period	weeks 1-12		weeks 13-28		weeks 29-40		weeks 1-40	
	I	II	I	II	I	II	I	II
Mean	1.72	1.63	1.26	1.25	1.04	1.05	1.34	1.31
DF-Roughage	1.77	1.81	1.20	1.26	1.00	0.97	1.32	1.35
DF-Concentrate	1.63	1.52	1.23	1.21	1.02	1.08	1.30	1.27
HF-Roughage	1.79	1.72	1.30	1.29	1.04	1.05	1.38	1.35
HF-Concentrate	1.70	1.49	1.31	1.23	1.11	1.09	1.37	1.27

The efficiency and fat protein corrected milk had positive, significant coefficients of correlation (table 5.4). These coefficients were calculated within a genotype-ration group on adjusted data (model IV). The correlation between efficiency and FPCM increased during the lactation and a difference between rations existed during the lactation. Hooven et al. (1972) reported values for first lactation cows between those determined in the rations described here.

Table 5.4 shows negative coefficients of correlation between efficiency and energy intake in the first part of the lactation and positive values in the second part. The negative coefficients during the first stage of the lactation were probably a result of the live weight change. The coefficients were comparable with the results of Hooven et al. (1972) and lower than those of Grieve et al. (1976). The former used a feeding system with ad libitum roughage and concentrates according to milk yield and the latter offered a complete ration of roughage and concentrates. The rations used in the experiments described were different from both, as mentioned in the first part of the discussion.

The average body weight for the concentrate groups during the lactation had a significant negative correlation with efficiency. The roughage groups showed lower absolute values. The relations were comparable with the relations between FPCM and live weight (table 4.48) and the difference between the ration groups may have been caused by the difference in the average amount of energy intake in relation to the potential for milk production. Miller et al. (1973) observed values in an experiment with concentrates according to milk yield that were between those determined in the rations described here.

Table 5.4. Coefficiënts of correlation between the adjusted ratio of FPCM (kg) to energy intake (kVEM)(efficiency) and fat protein corrected milk, energy intake, live weight change and live weight per period and per genotype-ration group.

	efficiency/ FPCM	efficiency/ energy intake	efficiency/ live weight change	efficiency/ live weight
Weeks 1-12				
DF-Roughage	+0.72***	-0.05	-0.79***	+0.56***
DF-Concentrate	+0.82***	-0.33	-0.31	-0.67***
HF-Roughage	+0.52***	-0.33	-0.37*	-0.27
HF-Concentrate	+0.80***	-0.19	-0.72***	-0.17
Weeks 13-28				
DF-Roughage	+0.69***	-0.04	-0.12	-0.23
DF-Concentrate	+0.98***	+0.50***	-0.17	-0.80***
HF-Roughage	+0.70***	-0.15	-0.54***	-0.08
HF-Concentrate	+0.91***	-0.15	-0.34	-0.35*
Weeks 29-40				
DF-Roughage	+0.70***	-0.14	-0.52***	-0.04
DF-Concentrate	+0.97***	+0.48***	-0.75***	-0.69***
HF-Roughage	+0.96***	+0.50***	-0.10	-0.35*
HF-Concentrate	+0.95***	+0.39*	-0.80***	-0.68***
Weeks 1-40				
DF-Roughage	+0.69***	+0.11	-0.52***	+0.13
DF-Concentrate	+0.95***	+0.31	-0.39*	-0.85***
HF-Roughage	+0.83***	+0.31	-0.31	-0.39*
HF-Concentrate	+0.95***	+0.32	-0.71***	-0.50***

The efficiency and energy intake over the total lactation were not significantly correlated. However, the economic importance of the energy intake is in the exchange between roughage and concentrates. The importance is dependent on the price ratio per net energy unit between roughage and concentrates. This influence was illustrated (table 5.5) by the least squares mean estimates (model II) of the difference between the milk production returns and feed costs that was dependent on the price ratio of the energy sources. The milk production returns were based on a positive economic value for fat and protein yield (9.62 Dfl. kg^{-1}) and a negative base price for the milk quantity (-0.12 Dfl. kg^{-1}) (Dommerholt, 1979) (Dutch milk price system). A price level of 0.60 Dfl. was assumed for the concentrates per unit net energy (kVEM).

With a price ratio of the energy sources concentrates to roughage of 1 : 1.

- The first experiment showed a significant genotype effect in weeks 13-28. A ration effect was shown in weeks 13-28 and in the total lactation. A significant ration effect in the second experiment was only observed in the last stage of the lactation.
- The total lactation contrasts between genotypes (DF-HF) in the first and second experiments were -106.34 and +55.32 Dfl. respectively and, for the rations (Roughage-Concentrate), -131.19 and -42.19 Dfl.

With a price ratio of the energy sources concentrates to roughage of 2 : 1.

- During the first experiment a significant genotype effect was only observed in the second period of the lactation and the total lactation (weeks 1-40). A significant ration effect was shown in the first period of the second experiment (carry-over effect).
- The total lactation contrasts between genotypes (DF-HF) in the first and second experiments were -141.47 and +6.26 Dfl. respectively and, for the rations (Roughage-Concentrate), +71.80 and +95.86 Dfl.

The comparison of the difference between returns from the milk production and the feed costs of two probably not optimal, but clearly differentiated rations, showed an influence of the price ratio of the energy sources on the economic result.

The importance of feed intake and particularly roughage intake in addition to milk yield and efficiency is dependent on the environmental circumstances in the short- and long-term and the genetic parameters of these characteristics. A number of phenotypic relationships between lactation characteristics (e.g. FPCM - efficiency; efficiency - live weight; energy intake - FPCM) was influenced by the concentrate level and the allocation of concentrates to the individuals. However, knowledge of the genetic parameters is only available for the system of feeding concentrates according to milk production (e.g. Miller et al., 1972). Parameter estimates on different feeding systems and the relationships between characteristics of the performance test of the young bull and his lactating daughters are necessary for the prediction of expected response to selection in different environments.

Table 5.5. Least squares means of the difference (Dfl.) between milk production returns and feed costs per genotype-ration group, period and experiment and for two price ratios of energy from roughage and concentrates.

Period	weeks 1-12		weeks 13-28	
	I	II	I	II
Concentrates: 0.60 Dfl. $kVEM^{-1}$				
Roughage : 0.60 Dfl. $kVEM^{-1}$				
Mean	+472.88	+403.32	+166.09	+166.49
DF-Roughage	+453.66	+462.99	+106.98	+148.91
DF-Concentrate	+465.98	+405.24	+173.53	+179.90
HF-Roughage	+467.76	+401.14	+157.71	+160.15
HF-Concentrate	+504.10	+343.93	+226.14	+176.98
Period	weeks 29-40		weeks 1-40	
Mean	+21.43	+29.12	+660.39	+598.92
DF-Roughage	- 3.63	-21.89	+557.00	+590.00
DF-Concentrate	+17.93	+78.02	+657.43	+663.16
HF-Roughage	+ 7.12	+ 4.37	+632.58	+565.65
HF-Concentrate	+64.29	+55.97	+794.52	+576.87
Concentrates: 0.60 Dfl. $kVEM^{-1}$				
Roughage : 0.30 Dfl. $kVEM^{-1}$				
Period	weeks 1-12		weeks 13-28	
Mean	+726.09	+652.21	+507.85	+509.25
DF-Roughage	+737.12	+724.21	+490.51	+506.20
DF-Concentrate	+679.06	+630.84	+459.28	+490.28
HF-Roughage	+757.71	+679.55	+551.03	+549.32
HF-Concentrate	+730.49	+574.23	+529.98	+491.20
Period	weeks 29-40		weeks 1-40	
Mean	+233.65	+267.44	+1467.59	+1428.88
DF-Roughage	+226.41	+222.94	+1454.02	+1453.34
DF-Concentrate	+200.73	+289.57	+1339.68	+1410.68
HF-Roughage	+244.21	+271.42	+1552.95	+1500.28
HF-Concentrate	+263.25	+285.81	+1523.70	+1351.23

5.5 Genotype-ration interaction

A genotype-ration interaction occurs when the responses among genotypes are not the same on different rations. This kind of interaction is important to breeders and nutritionists. The discussion will be confined to dairy and/or dual purpose breeds in temperate zones.

The experiments described were carried out on a high and a low concentrate ration and with two groups of genotypes with a contrast for milk production. Conrad et al. (1964) and Baumgardt (1970) have suggested that the mechanisms regulating feed intake may vary according to its digestibility. Different genetic backgrounds may be responsible for the regulation mechanisms. The following elements show that the rations used produced different nutritional conditions.

- The roughage groups had, on a total lactation basis, about 21% lower energy intake in comparison with the concentrate groups but about 22% higher roughage intake.
- The range of the digestibility of the total rations was generally too small within a stage of lactation to analyse the suggestions of Conrad et al. (1964) and Baumgardt (1970) accurately. However, analysis of the material of week 6, 9 and 12 of the first experiment gave an impression of some support for their suggestions. As a result of the variation in season of calving there was a variation between cows in long roughage material offered. The feed variable, crude fiber in the dry matter of the roughage, was used instead of the in-vitro digestibility because the latter was determined on average rumen material. The roughage dry matter intake was analysed with a model with the following effects: number of week, the interaction of genotype and number of lactation, individual within the interaction and the linear and quadratic term of the crude fiber (average crude fiber percentage: 28.2 ± 3.0). The results are shown in figure 5.1. The crude fiber percentage was more important in the roughage rations. The curve of the concentrate group had a maximum of 26% crude fiber in the roughage and about 19% in the total ration and this was comparable with the optimal percentage (e.g. Kaufmann et al., 1978).

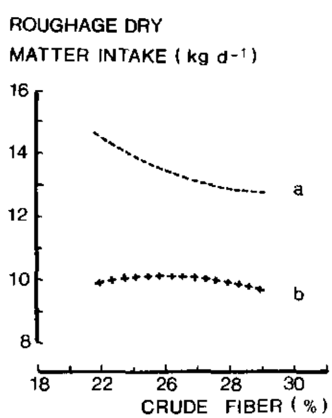

Fig. 5.1. Relation between the roughage dry matter intake and the crude fiber in the roughage dry matter on the high (b) and low (a) concentrate level.

The points mentioned indicate that the different nutritional conditions for both halves of the number of cows within a genotype was as planned.

The two groups of genotypes (Dutch Friesians and crossbreds between Holstein- and Dutch Friesians) had different genetic potentials for milk production. The results of the analysis of variance of the preceding lactation, and the lactation as a heifer of the individuals used in the first experiment, showed contrasts between the two groups of genotypes of 974 (15.2%) and 813 kg (14.0%) (5.1). The cows were fed according to milk yield in those lactations.

The several feed intake, milk production and live weight traits did not show a significant ($P \leq 0.05$) interaction term. Richardson et al. (1971) reported an interaction term in FCM yield which approached significance ($0.10 \leq P < 0.05$) and Lamb et al. (1979) observed a significant interaction in one trial. These interactions were probably caused by the amount of concentrates in the high concentrate groups. This varied between individuals and was dependent on the milk yield.

The literature and the experiments described did not indicate an important genotype-ration interaction. However, periodic trials may be necessary when the apparently unimportant different responses on the several rations accumulate over generations.

SUMMARY

Selection applied to populations of dairy cattle has produced a genetic increase in milk production. This will be increased further in the Netherlands by the introduction of Holstein Friesians. In general the high yielding cow is not capable of taking in enough nutrients to meet the requirements for maintenance and milk production. However the knowledge of the variation in feed intake between animals is limited. It requires detailed observations on each cow.

The variation in feed intake and production characteristics has been studied mostly on feeding regimes with concentrates fed according to milk production. Both characteristics were confounded in that situation. However, feeding systems with concentrates independent of the milk yield, e.g., a fixed concentrate level for all the individuals, and ad libitum roughage shows a variation in milk yield dependent on the variation in roughage intake, mobilization or deposition of body reserves and/or utilization of nutrients.

At present decisions were taken in selection programs on the desirable characteristics of the dairy cow over 10 or 12 years. The present selection is based on performance on a high concentrate level. Environmental circumstances such as nutrient supply (roughage/concentrates) may be changed and the mechanisms for regulating the feed intake may vary according to its digestibility. In addition, the import of semen of Holstein Friesians is increasing in the Netherlands. The Dutch Friesians and the Holstein Friesians show a genetic difference for milk production and the subpopulations were selected in different environmental circumstances. Reports of the importance of a genotype-ration interaction with different dairy breeds in temperate zones were not found in the literature.

This study describes the variation in feed intake (energy and roughage) and production characteristics (milk production and composition, and live weight) for two subpopulations dependent on the ration. The importance of the genotype-ration interaction for these characteristics was also tested. These objectives were studied in an experiment over two successive lactations (experiments I and II) and in the dry period between these two experiments.

The two subpopulations were characterized as Dutch Friesian (DF) and the crosses between Holstein- and Dutch Friesians (HF). In the first experiment the cows were in their second or later lactation. The analysis of the preceding lactation and the lactation as heifers (concentrates fed according to milk yield) resulted in

a contrast between subpopulations of -974 (15.2%) and -813 kg (14.0%) respectively.

The rations contained ad libitum roughage (experiment I - hay; dry period and experiment II - grass silage) and the amount of concentrates was independent of the milk production and restricted to the treatment. A low (Roughage group) and a high concentrate level (Concentrate group) were used in the two experiments. The concentrates were allocated over the lactation in three fixed steps (figure 3.1) and the total concentrate intake per lactation for the roughage and concentrate groups was approximately 570 and 2310 kg respectively. During the dry period all cows were offered ad libitum roughage and, in the last 6 weeks before calving, 1 kg concentrates per day. The carry-over effects from the first to the second experiment were studied on a ration change for all the individuals (roughage to concentrate group and the reverse).

Full lactation data were analysed from 91 cows in the first experiment and these were allocated over the four genotype-ration groups: DF-Roughage 23, DF-Concentrate 22, HF-Roughage 23 and HF-Concentrate 23. The total number in the second experiment and the dry period was 64 (DF-Roughage 16, DF-Concentrate 18, HF-Roughage 17 and HF-Concentrate 13).

Energy and roughage intake. The energy intake was calculated on the roughage and concentrate intake. The roughage dry matter intake was recorded for individual cows on four successive days every 3 or 4 weeks during the lactation and every 2 weeks during the dry period. The roughage offered was analysed weekly for in-vitro digestibility and composition. The concentrate intake was determined daily and the estimated feeding value was 940 VEM kg^{-1} (1 VEM = 6.904 kJ net energy).

The maximum average energy intake for the roughage and concentrate groups was 14631 and 18988 VEM d^{-1}. The energy intake of the roughage groups in the first and second experiments was approximately 3372 (21%) and 4269 VEM d^{-1} (27%) lower than that of the concentrate groups. The carry-over effect was shown in the second experiment but the ration effect of the first experiment was not significant during the dry period. The roughage groups had a longer time and level of underfeeding during the first experiment in comparison with the concentrate groups. A feeding regime with the same concentrate level for all the individuals during the dry period did not indicate compensation by a higher roughage intake. The contrast between rations (Roughage-Concentrate) for roughage dry matter intake in the first and second experiments was 2.9 (22%)(overall mean: 11.7) and 2.1 kg d^{-1} (17%)(overall mean: 11.5) respectively. These results showed that the rations produced different nutritional environments.

The genotype effect was significant ($P \leq 0.05$) only at the end of both experiments and the contrasts between DF and HF groups for energy intake in the first and second experiments were -408 (3%) and -516 VEM d^{-1} (3%) respectively. The contrasts for the roughage dry matter intake were -0.5 (4%) and -0.6 kg d^{-1} (5%) respectively.

The interaction between genotype and ration was not significant ($P > 0.05$) during the two experiments and the dry period. The coefficient of variation (adjusted for number of lactation, season and days open) for roughage dry matter intake during the two experiments was approximately 7% with the lowest values in the mid stage of lactation. This stage had also the highest repeatabilities between the experiments (+0.49 - +0.74 for the four genotype-ration groups).

Milk production and components. The milk production and composition for each cow were determined once a week. The adjusted coefficient of variation for total milk yield (app. 10%) was lower in the first experiment than in the preceding lactation (app. 14%)(table 5.1). The contrasts between the two subpopulations were also smaller. In the first experiment this contrast was 594 kg (10.1%)(overall mean: 5596) and in the second 407 kg (7.2%)(overall mean: 5416) in favour of the HF group. The HF group showed a higher persistency in production during the experiments. However the smaller peak yield contrast combined with greater persistency was still not sufficient to reach the differences expected between genotypes in total yield. The allocation of the concentrates over the cows (dependent or independent of milk production) in feeding systems with ad libitum roughage has an influence on the coefficient of variation in total milk yield. The expression of the differences between subpopulations in total milk yield and the phenotypic variation was smaller in a system of a fixed concentrate level for individuals independent of the milk yield.

The genotype contrasts (DF-HF) (10 g kg^{-1} d^{-1}) in the two experiments were, for milk fat, +0.21 and +0.32 respectively and for milk protein, +0.08 and +0.05. These results caused the contrasts for the milk energy equivalence (FPCM = (0.349 + 0.107 Milk Fat percentage + 0.067 Milk Protein percentage) × Milk Yield) to be smaller than for milk yield (7.7% and 3.7%).

The ration had a clear effect on the milk yield and fat protein corrected milk yield (FPCM) in the two experiments (app. 20% - 1250 kg). As a result of the difference in milk fat to milk protein ratio between the rations during the lactation the contrasts for FPCM were smaller in the early stage of the lactation compared with the milk production, but at the end the position was reversed. The average components over the total lactation were not significantly ($P > 0.05$) affected by the ration. A carry-over effect for milk yield was shown at the beginning of the second experiment but it was compensated at the end (table 5.2).

The genotype-ration interaction was not significant (P > 0.05) for the total lactation milk production characteristics and generally also during the lactation.

Live weight change. The live weight of the individuals during the first experiment was accurately fitted by a model with the following parameters: level, time of minimum live weight during the lactation, maximum live weight losses and a pregnancy parameter. The maximum live weight losses (including variation per group) was clearly influenced by the ration (DF-Roughage -71 kg, DF-Concentrate -41 kg, HF-Roughage -64 kg, HF-Concentrate -50 kg). The cows on the low concentrate level had a greater live weight loss and for a longer time of the lactation than the cows on the high concentrate level. The live weight level and the maximum losses were more highly correlated for the roughage groups than for the concentrate groups (Roughage: -0.79 and -0.57; Concentrate: -0.22 and -0.38).

A carry-over effect was clearly shown in the second experiment. The live weight change in weeks 1-12 in the two experiments were, for the roughage groups, -66 and -71 kg respectively and for the concentrate groups -37 and -16 kg. Differences between ration groups at the end of the first experiment were not compensated in the dry period. The effect of the genotype and the interaction between genotype and ration were small and not significant (P > 0.05) during the experiments.

Difference between energy intake and requirement. This characteristic was based on the energy intake and the requirements for maintenance and milk production. A deficiency in energy existed at the beginning of the lactation. The energy equilibrium in the first experiment was reached between weeks 6 and 9 and weeks 9 and 12 for the concentrate and roughage rations respectively. The second experiment showed a carry-over effect for the time of reaching energy equilibrium. The energy deficiency resulted in a high ratio of FPCM yield to energy input at the beginning of the lactation and the lack had to be compensated by the mobilization of body reserves. No close relationship between live weight losses and the difference between energy intake and requirement was observed. This was in accordance with the literature.

Relationships between production characteristics. The analysis of the relations between characteristics was confined to energy supply and demand processes namely fat protein corrected milk, live weight, live weight change and energy intake. The coefficients of correlation and a multiple regression analysis with FPCM as dependent variable were calculated within a genotype-ration group.

The general relation between live weight, FPCM and energy intake during the lactation in the first experiment per genotype-ration group was presented in figure 4.19. These curves were based on a model with the parameters mentioned in the section on live weight change.

The roughage groups showed a closer relation between FPCM yield and energy intake than the concentrate groups (correlation coefficients total lactation: +0.78 and +0.58). The relation between live weight change and FPCM also showed a difference between the rations but the values of the concentrate groups were higher than those of the roughage groups. In summary the relations were more dependent on the ration than on the genotype. The concentrate level and the allocation of concentrates to individuals have an influence on the relationships. Knowledge of the genetic parameters is only available for systems of feeding concentrates according to milk yield. Parameter estimates on different feeding systems and the relationships between characteristics of the performance test of the young bull and his lactating daughers are necessary for predicting the response to selection in different environments.

In addition to these analyses the coefficients of correlation between these charachteristics and the ratio FPCM to energy intake (efficiency) were presented in the discussion. The efficiency was highly correlated with FPCM (a tendency for a ration difference) but the values for efficiency and energy intake were low. However, the economic importance of the energy intake is in the exchange between roughage and concentrates. This was illustrated by two price ratios per net energy from roughage and concentrates. The same prices for both sources showed a difference between milk production returns and feed costs per cow in favour of the high concentrate ration. A price ratio of 1 : 2 (roughage : concentrates) resulted in the reverse ranking of the two rations.

SAMENVATTING

De sterke toename van de melkproduktie per koe in melkveepopulaties gedurende de laatste 10 jaren is hoofdzakelijk een gevolg van een verbeterde voeding en de toepassing van efficiënte selectiemethoden. Het gebruik van Holstein Friesians in de Nederlandse zwartbontpopulatie zal deze vooruitgang versterken. Gemiddeld is de hoog produktieve melkkoe aan het begin van de lactatie niet in staat om voldoende voedingsstoffen op te nemen voor de totale behoefte. De kennis met betrekking tot de variatie in voeropname tussen dieren is echter beperkt. Het bestuderen van dit kenmerk per koe vraagt veel arbeid en een aangepaste accommodatie. Dit in tegenstelling tot bijvoorbeeld het kenmerk melkproduktie.

De variatie in voeropname- en melkproduktiekenmerken is meestal bestudeerd onder voedingsomstandigheden waarbij krachtvoer naar produktie werd verstrekt. De genoemde kenmerken zijn dan verstrengeld. Een voedingssysteem met bijvoorbeeld een vast krachtvoerniveau voor alle dieren en ad libitum ruwvoer vertoont deze verstrengeling niet. De variatie in melkproduktie wordt dan veroorzaakt door verschillen tussen dieren in ruwvoeropname, mobilisatie of aanzet van lichaamsreserves en/of benutting van de opgenomen voedingsstoffen.

Op dit moment worden in selectieprogramma's beslissingen genomen over de eigenschappen welke de melkkoe over 10 à 12 jaar moet bezitten. De huidige selectie heeft plaats bij een hoog krachtvoerniveau. De voedingsomstandigheden, zoals ruwvoer/krachtvoerverhouding, kunnen zich gaan wijzigen en het reguleringsmechanisme van de voeropname is mogelijk afhankelijk van de verteerbaarheid van het rantsoen. Daarnaast neemt het gebruik van sperma van Holstein-Friesian stieren in Nederland toe. De Nederlandse zwartbonten en de Holstein Friesians vertonen een genetisch verschil voor melkproduktie en deze twee subpopulaties zijn onder verschillende milieu-omstandigheden geselecteerd. Onderzoek naar een mogelijk genotype-rantsoen-interactie met verschillende melkveerassen in gematigde streken zijn in de literatuur echter niet gevonden.

Deze studie beschrijft de variatie in voeropname (energie en ruwvoer), produktiekenmerken (melk en melksamenstelling) en gewichtsverandering in twee subpopulaties afhankelijk van het rantsoen. Daarnaast werd het belang van de genotype-rantsoen-interactie voor deze kenmerken onderzocht. Deze doelstellingen werden bestudeerd in een experiment met melkkoeien gedurende twee opeenvolgende lactaties (experiment I en II) en de droogstand tussen deze twee experimenten.

De Nederlandse zwartbonten (FH) en de kruisingen tussen Holstein-Friesians en Nederlandse zwartbonten (HF) werden als subpopulaties gebruik. In het eerste experiment werden tweedekalfs en oudere dieren gebruikt. De analyse van de melkproduktie in de lactatie voor het eerste experiment en de lactatie als vaars (krachtvoer naar produktie) resulteerde in een contrast tussen de subpopulaties (FH-HF) van respectievelijk -974 (15,2%) en -813 kg (14,0%).

De rantsoenen bevatten ad libitum ruwvoer (experiment I - hooi; droogstand en experiment II - ingekuild gras) en een hoeveelheid krachtvoer onafhankelijk van de melkproduktie maar afhankelijk van de behandeling. In de twee experimenten werden een laag (ruwvoergroep) en een hoog krachtvoerniveau (krachtvoergroep) gehanteerd. De totale krachtvoergift per lactatie voor de ruwvoer- en krachtvoergroep was gemiddeld respectievelijk 570 en 2310 kg. Deze gift werd over de lactatie verdeeld in drie vaste stappen (figuur 3.1). Het rantsoen in de droogstand bevatte ad libitum ruwvoer en de laatste 6 weken voor het afkalven 1 kg krachtvoer per dag. De nawerkingseffecten van het eerste experiment op het tweede experiment zijn bestudeerd bij een rantsoenwisseling voor alle individuen.

In het eerste experiment zijn volledige lactatiegegevens geanalyseerd van 91 koeien. De genotype-rantsoen groepen bevatten de volgende aantallen: FH-Ruwvoer 23, FH-Krachtvoer 22, HF-Ruwvoer 23 en HF-Krachtvoer 23. In het tweede experiment en de droogstand zijn de aantallen per groep respectievelijk 16, 18, 17 en 13.

Energie- en ruwvoeropname. Met een frequentie van 3 of 4 weken gedurende de lactatie en elke 2 weken tijdens de droogstand werd de individuele ruwvoeropname gedurende 4 opeenvolgende dagen gemeten. De samenstelling en de in-vitro verteerbaarheid van het aangeboden ruwvoer werden elke week bepaald. De krachtvoeropname werd dagelijks vastgesteld.

De ruwvoer- en krachtvoergroepen hadden gemiddeld een maximale energie-opname van respectievelijk 14631 en 18988 VEM d^{-1}. De energie-opname van de ruwvoergroepen was in het eerste en tweede experiment duidelijk lager dan van de krachtvoergroepen namelijk een contrast van 3372 (21%) en 4269 VEM d^{-1} (27%). Een nawerkingseffect van het rantsoen in de eerste lactatie was aanwezig aan het begin van het tweede experiment. De ruwvoergroepen hadden een langere periode en een grotere negatieve energiebalans tijdens het eerste experiment in vergelijking met de krachtvoergroepen. Een voerregime met hetzelfde krachtvoerniveau voor alle koeien tijdens de droogstand heeft echter niet tot gevolg dat verschillen als gevolg van de voorgaande lactatie gedurende de droogstand worden gecompenseerd door middel van een hogere ruwvoeropname. Het contrast tussen de rantsoenen (ruwvoer-krachtvoer) voor de drogestofopname uit ruwvoer in de twee experimenten was respectievelijk 2,9 (22%) (gemiddeld: 11,7) en 2,1 kg d^{-1} (17%) (gemiddeld: 11,5). De resultaten geven aan dat de rantsoenen duidelijke verschillende voedingsomstandigheden tot gevolg hadden.

De verschillen tussen de subpopulaties voor de voeropnamekenmerken waren slechts significant ($P \leq 0,05$) aan het einde van de lactatie. Het contrast tussen de FH- en HF-groepen in de totale lactatie was voor de energie-opname in de twee experimenten respectievelijk -408 (3%) en -516 VEM d^{-1} (3%) en voor de drogestofopname uit ruwvoer -0,5 (4%) en -0,6 kg d^{-1} (5%).

De interactie tussen subpopulatie en rantsoen voor de energie- en ruwvoeropname was niet significant ($P > 0,05$) gedurenden de twee experimenten en de droogstand. De drogestofopname uit ruwvoer (gecorrigeerd voor lactatienummer, seizoen en tussenkalftijd) gedurende de twee experimenten had gemiddel een variatiecoëfficiënt van 7% met de laagste waarden in het midden van de lactatie (week 13-28). Deze periode van de lactatie had ook de hoogste herhaalbaarheden tussen de twee experimenten (+0,49 - +0,74 voor de 4 genotype-rantsoen groepen).

Melkproduktie en componenten. Eenmaal per week werd per koe de melkproduktie gemeten en de samenstelling bepaald. Het eerste experiment (vaste krachtvoerhoeveelheden) resulteerde in een variatiecoëfficiënt van ca. 10% voor de gecorrigeerde melkproduktie. In de voorafgaande lactatie werd krachtvoer verstrekt naar produktie en de variatiecoëfficiënt (gecorrigeerd) was ca. 14%. De contrasten tussen de subpopulaties vertoonden hetzelfde effect. De voorafgaande lactatie vertoonde een contrast (FH-HF) van -974 kg (15,2%). In de twee experimenten was het contrast respectievelijk -594 kg (10,1%) (gemiddeld: 5596) en -407 kg (7,2%) (gemiddeld: 5416). Deze verschillen tussen de twee subpopulaties zijn mede tot stand gekomen door een hogere persistentie van de HF-groep. Dit verschil in persistentie tussen de subpopulaties was echter niet voldoende om het relatief kleine contrast in topproduktie te compenseren en de te verwachten verschillen tussen de subpopulaties werden dan ook niet gerealiseerd. De verdeling van het krachtvoer over de koeien (afhankelijk of onafhankelijk van de melkproduktie) in een voerregime met ad libitum ruwvoer heeft een duidelijke invloed op de variatiecoëfficiënt van de totale melkproduktie. De grootte van de verschillen tussen subpopulaties en de fenotypische variatie zijn kleiner in een systeem met een vaste hoeveelheid krachtvoer onafhankelijk van de melkproduktie.

De FH-groep had hogere gehalten in de melk dan de HF-groep. Over de totale lactatie was het verschil in de twee experimenten voor vet (10 g $kg^{-1}d^{-1}$) respectievelijk +0,21 en +0,32 en voor eiwit (10 g $kg^{-1}d^{-1}$) +0,08 en +0,05. Deze verschillen tussen de subpopulaties hadden tot gevolg dat het contrast voor de hoeveelheid meetmelk (7,7% en 3,7%) kleiner was dan voor de melkhoeveelheid. De hoeveelheid meetmelk werd berekend op grond van de formule: FPCM = (0,349 + 0,107 Vetpercentage + 0,107 Eiwitpercentage) x Melkhoeveelheid.

De rantsoenen veroorzaakten een duidelijke invloed op de melk- en FPCM-produktie in de twee experimenten (ca. 20% - 1250 kg). De verhouding tussen vet- en eiwitpercentage veranderde tijdens de lactatie afhankelijk van het rantsoen. Daardoor waren aan het begin van de lactatie de contrasten voor de FPCM-produktie kleiner dan voor de melkproduktie, maar het tweede deel van de lactatie vertoonde het tegengestelde. De invloed van het voerregime in de voorgaande lactatie was duidelijk afhankelijk van het moment van de lactatie (tabel 5.2).

Een subpopulatie-rantsoen-interactie voor de melkproduktiekenmerken in de totale lactatie werd niet gevonden ($P > 0,05$) en in het algemeen ook niet voor de onderscheiden perioden (week, weken).

Gewichtsverandering. De individuele gewichtsverandering tijdens de lactatie in het eerste experiment werd nauwkeurig beschreven met een model met de volgende parameters: niveau, het moment tijdens de lactatie met laagste gewicht, de maximale gewichtsafname en een drachtigheidsparameter. De maximale gewichtsafname (inclusief de variatie tussen dieren per groep) was duidelijk afhankelijk van het rantsoen (FH-Ruwvoer -71 kg, FH-Krachtvoer -41 kg, HF-Ruwvoer -64 kg, HF-Krachtvoer -50 kg). De koeien op het lage krachtvoerrantsoen hadden aan het begin van de lactatie en gedurende een langere tijd van de lactatie een grotere afname van het lichaamsgewicht dan de dieren op het hoge krachtvoerrantsoen. Tevens was het niveau van het gewicht aan het begin van de lactatie voor de ruwvoergroepen van grotere invloed op de maximale afname.

Een nawerkingseffect werd in deze studie aangetoond. De gewichtsverandering in week 1-12 in de twee experimenten was voor de ruwvoergroepen respectievelijk -66 en -71 kg en voor de krachtvoergroepen -37 en -16 kg. Verschillen tussen rantsoenen aan het einde van het eerste experiment werden niet verkleind tijdens de droogstand.

Een subpopulatie-rantsoen-interactie en een effect van de subpopulatie op het gewichtsniveau en de verandering waren klein en niet significant ($P > 0,05$).

Verschil tussen energie-opname en behoefte. Dit kenmerk werd berekend op grond van de energie-opname en de behoefte aan energie voor melkproduktie en onderhoud. In het begin van de lactatie bestond een negatief verschil. In het eerste experiment werd een evenwicht bereikt voor de krachtvoergroepen tussen week 6 en 9 van de lactatie en voor de ruwvoergroepen tussen week 9 en 12. Een nawerkingseffect in het tweede experiment was aanwezig (tabel 5.2).

Het tekort aan energie-opname aan het begin van de lactatie resulteerde in een hoge verhouding tussen FPCM en energie-opname in deze periode. Dit tekort zal in het algemeen gecompenseerd moeten worden door een grotere mobilisatie van lichaamsreserves. Een nauwe relatie tussen gewichtsverandering en het verschil (energie-opname minus de behoefte voor melkproduktie en onderhoud) werd echter niet gevonden. Dit was vergelijkbaar met de literatuur.

Relaties tussen produktiekenmerken. De analyse van de relaties tussen kenmerken werd beperkt tot energievragende en -leverende processen. De volgende kenmerken werden gebruikt: FPCM, lichaamsgewicht, gewichtsverandering en energie-opname. De correlatiecoëfficiënten en een meervoudige regressie-analyse, met FPCM als afhankelijke variabele, werden berekend binnen een subpopulatie-rantsoen-groep.

De algemene relaties tussen de kenmerken FPCM, energie-opname en lichaamsgewicht gedurende de lactatie in het eerste experiment per subpopulatie-rantsoen-groep werden aangegeven in figuur 4.19. Deze curven zijn gebaseerd op het model waarvan de parameters zijn aangegeven bij de gewichtsverandering.

De ruwvoergroepen hadden een nauwere relatie tussen FPCM-produktie en energie-opname dan de krachtvoergroepen (correlatiecoëfficiënten totale lactatie: +0,78 en +0,58). De relatie tussen gewichtsverandering en FPCM vertoonde ook een verschil tussen rantsoenen. De krachtvoergroepen hadden een grotere negatieve correlatiecoëfficiënt. In het algemeen waren de relaties meer afhankelijk van het rantsoen dan van de subpopulatie. Het krachtvoerniveau en de verdeling van het krachtvoer over de koeien (afhankelijk of onafhankelijk van de melkproduktie) heeft een invloed op de relaties. Genetische parameters zijn slechts bekend voor voerregimes met krachtvoer naar produktie. Parameter-schattingen bij de verschillende voerregimes en de relaties tussen kenmerken van de eigenprestatietoets van stieren en de melkgevende dochters zijn noodzakelijk om een voorspelling te doen van de selectierespons bij verschillende milieu-omstandigheden.

Aanvullend op deze relaties werd in de discussie de verhouding FPCM tot energie-opname (efficiëntie) aangegeven. Deze efficiëntie had een hoge correlatie met FPCM (een tendens voor rantsoenverschillen), maar de correlatie tussen efficiëntie en energie-opname was laag. Het economisch belang van een hogere energie-opname is echter de mogelijkheid tot uitwisseling van krachtvoer door ruwvoer. Het effect bij deze twee rantsoenen werd geïllustreerd in de discussie bij twee prijsverhoudingen per eenheid energie afkomstig van ruwvoer of krachtvoer. Een gelijke verhouding resulteerde in een verschil tussen opbrengsten uit melk en voerkosten per koe in het voordeel van het hoge krachtvoerrantsoen. Een prijsverhouding 1 : 2 (ruwvoer : krachtvoer) gaf het grootste verschil voor het rantsoen met het lage krachtvoerniveau.

Appendix 1. Means and standard deviations (s.d.) of the percentage dry matter per kg roughage per week, experiment (I, II) and genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
week	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I (hay)								
3	81.9	2.3	81.6	2.5	82.3	2.4	81.8	1.8
6	82.3	2.2	82.3	2.3	82.4	1.5	82.2	1.9
9	83.2	2.2	82.6	1.6	84.1	1.9	83.5	2.4
12	82.9	2.0	83.2	2.6	83.2	1.7	83.8	1.6
16	83.1	2.7	83.2	1.9	82.3	2.5	83.4	1.9
20	82.5	2.2	83.2	2.0	82.6	1.9	82.4	1.9
24	83.4	1.3	82.3	2.2	82.8	2.2	82.7	2.0
28	83.0	1.7	82.8	1.9	83.3	1.2	82.6	2.0
32	82.5	1.8	82.7	1.6	81.9	1.9	82.1	1.7
36	82.4	1.6	82.3	1.3	82.4	1.1	82.2	1.4
40	82.5	0.7	82.1	1.5	82.1	1.4	82.4	1.2
Dry period (silage)								
6	41.3	4.8	40.2	5.0	42.9	3.7	40.0	6.1
4	42.7	4.0	41.7	4.3	44.3	3.3	40.8	4.7
2	43.8	3.4	41.5	4.3	43.9	3.1	41.7	4.4
Experiment II (silage)								
3	43.4	2.4	43.8	2.6	43.7	2.7	43.7	1.2
4	43.3	2.8	43.5	2.2	43.1	2.7	44.2	4.0
6	44.3	5.0	43.9	4.5	43.5	1.7	42.6	5.5
9	43.7	4.9	42.3	2.9	42.4	6.5	41.7	2.0
12	42.3	2.6	43.0	4.6	42.5	1.6	40.6	4.0
13	43.2	6.9	42.5	4.8	42.2	1.2	43.1	6.7
16	41.8	5.8	43.0	6.6	43.4	5.7	44.1	7.6
20	41.4	5.7	42.1	6.7	40.8	5.8	47.0	9.2
24	41.3	7.3	44.2	8.7	43.2	7.5	42.3	8.1
28	40.7	6.3	41.8	8.4	41.6	8.3	38.0	3.5
32	41.0	8.0	38.0	3.6	38.4	4.2	37.1	6.2
36	39.7	4.9	37.7	4.5	36.8	3.2	39.0	5.5
40	39.6	5.0	39.1	6.0	40.6	5.7	40.7	6.0

Appendix 2. Means and standard deviations (s.d.) of the crude fiber (%) per kg roughage dry matter per week, experiment (I, II) and genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
week	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I (hay)								
3	29.9	2.6	30.6	2.0	29.3	2.0	29.2	2.4
6	29.4	2.4	28.8	2.5	28.9	1.8	29.4	1.6
9	28.3	2.6	28.6	2.9	27.7	2.4	28.8	1.8
12	28.1	2.3	27.8	2.5	26.2	3.1	26.8	2.4
16	25.8	3.3	26.5	2.5	26.1	3.9	25.1	3.1
20	25.5	3.0	25.8	3.1	25.1	2.4	26.5	2.7
24	25.0	2.6	26.1	2.6	26.0	3.1	25.3	3.0
28	26.2	2.4	26.1	3.1	26.6	2.4	26.9	2.7
32	26.9	2.6	27.4	2.3	28.6	2.2	27.6	2.7
36	28.1	2.7	27.9	2.7	29.5	2.5	28.7	2.9
40	30.0	2.3	29.5	2.7	30.5	2.2	30.0	2.1
Dry period (silage)								
6	26.6	3.8	26.8	3.3	28.0	3.4	27.0	3.3
4	27.7	3.4	26.8	3.1	28.7	0.8	27.1	2.8
2	28.6	2.1	26.4	3.6	28.5	1.8	26.9	3.5
Experiment II (silage)								
3	28.2	2.2	28.9	1.3	28.3	2.7	28.9	0.7
4	28.2	2.1	28.7	1.3	28.6	2.3	28.0	3.1
6	27.5	3.3	27.9	3.1	28.9	0.8	27.5	3.3
9	27.4	3.2	28.1	1.5	26.8	3.6	28.1	1.4
12	27.6	1.0	27.5	3.1	28.0	1.2	26.9	1.3
13	26.4	4.1	27.2	2.9	28.3	1.3	25.6	3.6
16	26.9	3.1	25.9	3.6	26.6	3.3	25.2	4.3
20	26.9	3.1	25.6	3.4	26.1	3.0	23.4	5.4
24	25.9	3.7	25.1	4.7	25.7	4.1	25.7	4.3
28	27.1	3.0	25.8	4.3	26.0	4.3	27.9	0.9
32	26.3	3.9	28.8	1.0	27.8	1.0	27.8	3.0
36	27.4	1.3	28.0	1.4	28.2	1.3	27.7	1.4
40	27.5	1.4	27.8	1.6	27.5	1.5	27.2	1.7

Appendix 3. Means and standard deviations (s.d.) of the crude protein (%) per kg roughage dry matter per week, experiment (I, II) and genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
week	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I (hay)								
3	16.2	2.3	15.6	2.2	16.3	1.9	16.0	2.1
6	16.1	2.3	16.3	2.2	15.8	2.1	15.2	1.9
9	16.2	2.1	16.1	2.4	16.7	2.1	16.4	1.8
12	16.6	2.0	16.8	1.9	17.7	1.6	17.5	1.6
16	17.6	1.8	17.2	1.8	17.8	1.7	18.1	1.9
20	17.8	1.5	17.8	1.7	17.4	1.8	17.6	1.4
24	17.5	2.0	17.8	1.7	16.8	1.7	16.6	1.6
28	17.0	2.1	16.3	2.5	17.3	3.5	17.4	1.8
32	16.5	3.1	16.8	3.4	15.8	3.8	18.2	3.4
36	15.5	4.5	16.2	4.4	13.3	4.4	14.1	5.0
40	13.5	4.0	13.3	4.6	12.1	3.6	12.7	3.7
Dry period (silage)								
6	19.3	4.0	19.6	3.9	17.6	3.2	19.2	3.4
4	18.1	3.6	19.0	3.7	16.7	1.4	18.9	3.8
2	17.0	2.2	19.4	3.6	17.3	2.2	18.7	4.0
Experiment II (silage)								
3	17.5	2.2	17.0	1.3	17.6	2.5	17.1	0.9
4	17.8	2.3	17.0	1.4	17.7	2.4	17.7	1.5
6	17.9	1.8	17.5	1.7	16.8	0.9	18.4	1.7
9	17.7	1.8	18.1	1.4	18.5	2.0	18.3	1.3
12	18.0	1.5	18.5	1.4	18.1	1.6	18.9	1.4
13	18.4	2.0	18.6	1.5	17.8	1.0	19.6	1.5
16	18.2	1.7	19.3	1.6	18.9	1.5	19.1	1.9
20	18.6	1.6	19.0	1.9	18.4	2.0	19.4	2.2
24	18.7	2.2	18.8	2.1	18.8	1.9	18.1	2.3
28	18.8	1.8	18.2	2.2	18.2	2.1	17.8	1.8
32	18.7	2.2	18.0	1.7	18.6	2.0	18.8	2.1
36	18.6	1.8	18.6	1.8	18.5	2.0	19.5	1.2
40	18.8	1.7	19.7	1.1	19.1	1.5	19.6	1.1

Appendix 4. Means and standard deviations (s.d.) of the inorganic matter (%) per kg roughage dry matter per week, experiment (I, II), and genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
week	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I (hay)								
3	10.2	1.1	10.0	1.1	10.1	0.9	10.1	0.9
6	10.0	1.1	10.2	0.9	9.7	0.8	9.6	0.8
9	9.8	0.8	9.9	1.0	9.9	0.7	9.8	0.6
12	10.0	0.6	10.0	0.7	10.2	0.6	10.1	0.6
16	10.2	0.5	10.0	0.6	10.2	0.5	10.3	0.6
20	10.3	0.4	10.2	0.6	10.2	0.6	10.3	0.5
24	10.4	0.5	10.3	0.6	10.3	1.2	10.1	0.6
28	10.3	1.2	10.1	0.6	10.0	0.9	9.9	0.5
32	11.2	2.4	10.6	1.7	12.1	2.4	11.7	2.2
36	10.8	2.5	11.9	2.3	10.9	2.7	10.3	2.2
40	10.6	2.1	10.8	2.5	11.6	2.5	11.3	2.1
Dry period (silage)								
6	11.0	0.8	11.2	1.1	10.7	0.8	11.8	1.1
4	11.0	1.1	10.9	0.7	11.0	1.0	11.0	0.9
2	10.9	0.9	11.2	1.1	11.0	1.1	10.8	1.0
Experiment II (silage)								
3	10.4	0.7	10.7	1.2	10.7	1.0	10.1	0.6
4	10.5	0.7	10.5	1.1	10.4	1.0	10.1	0.4
6	10.9	1.2	10.2	0.8	10.5	1.3	10.3	0.8
9	10.4	0.9	10.2	0.6	10.5	0.7	10.1	0.6
12	10.2	0.4	10.1	0.6	10.1	0.5	10.5	0.7
13	10.2	0.7	10.1	0.7	10.0	0.3	10.6	0.9
16	10.1	0.5	10.4	0.8	10.2	0.7	10.2	0.7
20	10.0	0.5	10.2	0.7	10.1	0.7	9.8	0.4
24	10.2	0.7	9.9	0.5	9.9	0.4	9.8	0.5
28	10.0	0.4	9.9	0.4	10.0	0.4	10.0	0.5
32	10.2	0.7	10.2	0.7	10.2	0.4	10.3	0.8
36	10.6	0.9	10.7	0.9	10.4	0.7	10.9	0.7
40	10.8	1.0	10.9	0.8	10.7	0.7	11.0	0.9

Appendix 5. Means and standard deviations (s.d.) of the in-vitro digestibility (%) of the organic matter per kg roughage dry matter per week, experiment (I, II) and genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
week	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I (hay)								
3	63.9	3.5	62.6	2.4	64.8	3.1	64.8	3.3
6	64.6	3.3	64.9	3.2	65.1	2.3	64.4	2.1
9	65.5	2.4	65.1	2.9	66.0	2.5	65.3	2.5
12	65.6	2.4	66.0	2.6	67.3	2.5	67.1	2.2
16	67.1	3.3	67.0	2.2	66.1	4.7	68.0	3.2
20	66.9	3.7	66.9	3.4	67.1	2.6	66.0	3.4
24	65.2	4.1	65.6	3.6	63.0	4.4	64.1	3.8
28	64.4	4.2	63.6	4.1	63.3	3.1	64.8	2.9
32	60.3	6.5	62.5	4.5	57.2	6.4	59.2	5.7
36	58.6	5.6	58.7	6.1	56.5	4.8	58.4	4.9
40	57.3	4.0	57.3	5.2	55.2	4.9	57.0	4.6
Dry period (silage)								
6	62.9	4.6	63.8	3.3	62.0	3.9	62.8	3.6
4	62.2	4.0	63.5	4.1	61.2	3.3	63.1	3.7
2	61.5	3.7	64.4	4.1	62.0	3.5	63.8	3.6
Experiment II (silage)								
3	63.0	2.9	62.7	3.3	62.4	3.5	63.8	1.6
4	63.3	3.4	63.2	2.7	63.2	3.0	64.7	2.7
6	63.6	4.4	64.7	3.0	63.1	2.8	65.4	3.5
9	64.5	3.8	65.3	1.7	65.8	4.0	65.3	1.4
12	65.4	1.7	65.8	2.1	64.9	1.1	66.3	1.7
13	66.4	3.1	65.9	2.2	65.0	1.0	67.0	2.5
16	66.1	2.3	66.9	2.5	66.3	2.5	67.0	3.1
20	66.1	2.4	66.8	2.6	67.0	2.2	68.2	3.8
24	66.4	3.0	67.0	3.5	66.7	2.9	67.1	2.9
28	65.4	2.5	66.4	3.3	66.3	3.2	64.6	1.6
32	65.2	3.4	64.5	1.7	64.4	1.8	63.8	2.8
36	63.7	1.8	63.2	1.6	63.7	1.9	62.7	1.1
40	63.4	1.6	62.7	0.8	63.5	1.2	63.2	1.0

Appendix 6. Means standard deviations (s.d.) of the net energy content(VEM) per kg roughage dry matter per week, experiment (I, II) and genotype-ration group.

	DF-Roughage		DF-Concentrate		HF-Roughage		HF-Concentrate	
week	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiment I (hay)								
3	810	56	787	37	822	49	821	54
6	819	53	824	53	825	41	812	36
9	834	44	827	51	842	46	830	43
12	837	44	843	45	866	44	862	38
16	862	57	859	41	850	76	879	54
20	855	64	855	64	859	49	846	54
24	833	67	836	60	792	67	812	62
28	820	63	800	67	800	50	819	51
32	753	90	786	70	711	93	748	83
36	725	82	734	92	694	74	728	82
40	707	58	706	82	676	77	703	76
Dry period (silage)								
6	811	84	826	66	789	69	808	67
4	795	74	817	76	773	53	812	70
2	779	61	833	77	787	58	822	69
Experiment II (silage)								
3	803	50	795	51	798	58	811	26
4	809	58	803	43	807	52	828	47
6	814	72	826	51	799	43	842	59
9	826	61	838	31	848	67	840	26
12	839	31	848	37	832	22	857	30
13	856	55	851	40	832	18	872	44
16	851	40	869	44	857	43	870	53
20	850	40	866	44	864	41	886	65
24	859	49	867	58	862	49	865	53
28	843	37	856	55	853	53	827	16
32	840	54	825	17	828	18	820	43
36	818	19	811	15	817	19	809	14
40	814	17	809	11	817	15	816	12

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