THE INFLUENCE OF FEEDING VARIOUS ROUGHAGE:CONCENTRATE RATIOS ON MILK PRODUCTION OF FRIESLAND COWS

by

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INTRODUCTION

Labour problems, automation and changing dairy technology has led to a gradual modification of the traditional feed=ing systems of dairy cattle.

Furthermore, the present price of feed and milk has created a new approach to the feeding of these animals. To reduce labour costs and to inaugurate automation, more dairy farmers are mixing roughage and concentrates to form a dairy ration mixture termed a complete ration, all-in-one ration or total ration. Although it may take time before the majority of dairy farmers feed complete rations, the individual farmer applying this system today, is attaining effective results (Crowley, 1971).

Limited research has indicated that labour requirements can be reduced by 10 per cent when eliminating concentrate feed=ing in the parlour (MacLachlan, cited by Hoglund, 1969). Since group feeding and feeding of complete rations are adaptable to automation, Rakes (1969) has suggested that management difficulties can be overcome by adoption of this system.

It is, however, important to achieve automation without sacrificing milk production.

Complete rations are 'a very sound concept' from a nutritional standpoint (Yoder, 1972). This worker noted that satisfactory individual cow production can be achieved by feeding a complete ration ad lib., either by grouping or not grouping.

By feeding complete rations the dairy farmer can control the roughage : concentrate ratio more precisely without the management problems associated with traditional feeding methods viz.; when roughage and concentrates are fed separately.

Considerable attention has been focused on research asso= ciated with milk production responses to different quanti= ties fed, roughage:concentrate ratios, physical form and milk:feed and roughage:concentrate price relationships.

If the response of the individual cow and first-calf heifer to variable levels of concentrates in complete rations is known, the most profitable feeding program can be adopted. Input-output data could be of great use to project the most profitable adjustment in concentrate feeding under different feed:milk price relationships.

Cows of a high production potential usually respond favour= ably to an increase in the concentrate portion of complete rations. This is due to an increased nutrient concentration in the form of a higher portion of concentrates which should increase digestibility. Montgomery & Baumgardt (1965) have shown a positive relationship between feed intake and digestibility of rations up to a certain level of diges=tibility. Above this level feed intake was inversely related to the digestibility of rations and digestible energy intake remained static.

However, due to the influence of the physical form of rations and body capacity differences between cows and first-calf heifers on dry matter intake, the minimum digestibility at which energy intake is regulated is not well defined. This indicates that a profitable complete ration for cows is not necessarily the most profitable ration for first-calf heifers.

When the cost of concentrates is high, and the milk price and milk production ability low, then the feeding of more roughage and less concentrate may be a more favourable economic proposition. The lowest levels of roughage feed=ing are usually associated with high levels of milk produc=tion, high prices for milk and low prices for concentrates (Hoglund, 1969).

Due to the smaller body capacity of first-calf heifers compared to that of cows, it is doubtful whether they are capable of producing at a level commensurate with their inherited ability when fed high roughage and low concentrates in complete rations.

For these reasons a study to investigate the roughage:concen=trate relationship and resulting milk production response by lactating cows and first-calf heifers, was conducted. The animals were fed a range of lucern:concentrate ratios. These experimental rations were pelleted and fed *ad lib*. in combination with a restricted amount of maize silage for a 240-day period during lactation. The most profitable level of roughage:concentrate for cows and first-calf heifers was measured by returns above cost of feed.

The effect of the experimental rations on composition of milk, efficiency of utilization of metabolizable energy for milk production, reproduction and the health condition of cows and first-calf heifers, was investigated simultaneously. Furthermore, the possibility of obtaining similar results with non-pelleted but otherwise identical rations, was investigated.

CHAPTER 1

PROCEDURE AND METHODS

1.1 The experimental design

The experimental design as described by Lucas (1960), for single-lactation continuous trials, was followed in this study. Continuous trials are those in which an animal, once placed on an experimental treatment remains on that treatment for the duration of the trial.

In the present single-lactation continuous trial there were two periods of observation termed the standardization- and comparison period.

The experimental units were 28 lactating dairy cows and 36 first-calf heifers. The experimental treatments consisted of feeding restricted maize silage in addition to ad lib. feeding of four different ratios of lucern:concentrate rations, in pellet form.

During the standardization period all the animals were handled and fed in a standard manner. At the end of the standardiza= tion period 16 animals were allotted to each experimental treatment. The milk production during the standardization period was utilized in allotting the animals to treatment groups by the procedure of balancing. The animals were assigned to groups in such a way that the average milk pro= duction during the standardization period of the four groups varied as little as possible. Studies made by Lucas (1960) led to the view that balancing is acceptable in dairy experiments, and if done judiciously, is preferable in small experiments to random allotment, because it guarantees a maximum possible efficiency factor for the experimental treatment. The data were analysed as in a completely random design using Tukey's procedure for judging the significance of differences between treatments (Steel & Torrie, 1960).

1.2 The experimental cows

Thirty-six first-calf heifers and 28 lactating cows from the Glen Friesland herd were assigned to this experiment.
Pre-partum treatment was standard for experimental animals, all receiving lucern hay and maize silage ad lib.during the dry-period of 60 days. Immediately after calving the animals were brought into the experimental feeding parlour. Data relating to the animals used in this trial are summarised in Table 1.
There were non-significant differences ($P>0,05$) between treatment groups at the beginning of the trial.
The animals were placed on a standard ration for a 60-day standardization period. At the end of this period nine first-calf heifers and seven cows were allotted as previously described, to each of the four experimental treatments, for a 240-day comparison period.
Further procedures were identical to those used during the standardization period.

Table 1 Data concerning experimental animals at outset of pelleted-ration study

Variable description	Units	A 80L:20C[11]	B 60L:40C[11]	C 40L:60C[11]	D 20L:80L[11]	Diff[1]
			maize silage +			
Age (i) first-calf heifers	months	28,6	25,2	25,3	26,3	NS
(ii) cows	months	49,6	46,2	54,1	54,4	NS
Lactation No.						
(i) first-calf heifers		1,0	1,0	1,0	1,0	NS
(ii) cows		2,4	2,3	2,9	3,1	NS
Body mass after calving						
(i) first-calf heifers	kg	514	498	491	498	NS
(ii) cows	kg	652	617	640	661	NS
Daily milk yield during preceding lactation; cows	kg	17,14	16,03	16,41	17,32	NS
Fat % of milk during preceding lactation; cows	%	3,9	3,8	3,8	3,8	NS

1 Differences: NS; non-significant (P>0,05)

11 Ratios refer to lucern:concentrate composition of the rations (see 1.4.2)

1.3 Housing and care

During the standardization- and comparison periods the experimental animals were housed in a feeding parlour as shown in Fig.1.

Wood shavings were used for bedding. The animals were individually fed at 08h00 and 13h30, during both the stan=dardization- and comparison periods. Maize silage residue was collected and the mass determined before the morning feed. The pelleted ration residue was collected and its mass determined twice weekly. The animals were hand-milked at 05h30 - 06h00 and 15h00 - 15h30.

All experimental animals were regularly inspected during the day and at night. Water was available ad lib. from automatic drinking troughs.

The mass of the animals was determined immediately after calving, at 30-day intervals and also at the end of the comparison period.

1.4 Standardization- and experimental rations

1.4.1 Standardization ration

In the standardization period all the animals received 4,5 kg maize silage (Zea mays variety Oakleigh II) twice daily, lucern hay (Medicago sativa chaffed through a 2,5 cm sieve) ad lib., and 4 kg dairy meal (15% protein) per 10 kg milk produced.

The composition of the dairy meal is presented in Table 2.

The maize was ensiled in a trench when the grain was in the

Fig.1 Experimental feeding parlour

Table 2 Composition of dairy meal fed in the standardization period

Composition	Percentage
Yellow maize meal	50,0
Maize germ meal	14,0
Wheat bran	5,0
Lucern	10,0
Cottonseed cake meal	7,5
Prosup 230[1]	1,5
Monocalcium phosphate	1,0
Limestone	2,5
Salt (NaCl)	1,0
E C Feed[2]	5,0
Molasses (cane)	2,5

1 Prosup which contains approxiamtely 37% nitrogen mainly in the form of biuret, is produced by controlled heating of urea.

2 E C Feed is produced from microbial fermentation of molasses and corn steep liquor. The dried concentrate is rich in some vitamins of the B complex. In addition it contains calcium, potassium, magnesium, phosphorus, sulphur, iron, trace elements and 11 to 12% protein.

hard doughy stage. The lucern was cut in the bud stage.

1.4.2 Experimental rations

The composition of the pelleted rations (lucern:concentrate) used in the comparison period were 80:20 (ration A), 60:40 (ration B), 40:60 (ration C) and 20:80 (ration D), respec= tively.

During the comparison period the pelleted rations were fed ad lib. In addition 4,5 kg maize silage per feeding was supplied in a separate trough. The maize silage was taken from the same trench as the silage fed during the standardi= zation period.

The four pelleted rations were manufactured by Fedvoed Balanced Feed Manufacturers (Epol), Kroonstad. First grade lucern hay was finely ground through a 3,175 mm screen and compressed (steam process) together with the various ratios of concen= trates into pellets, one cm in diameter and three to four cm in length.

The composition of the different pelleted rations is presen= ted in Table 3. The concentrate was formulated to contain 15 per cent crude protein which was almost identical to the crude protein content of the lucern hay used in the pellets. This procedure avoided fluctuations in protein content when the ratio of hay to concentrate was changed. The estimated crude chemical composition of the pelleted rations is shown in Table 4.

The mass of the pellets and maize silage fed to each animal

Table 3 Composition of pelleted lucern:concentrate rations fed to cows and first-calf heifers

Composition	Pelleted rations			
	80L:20C	60L:40C	40L:60C	20L:80C
	%	%	%	%
Lucern meal	80,3	60,5	40,7	20,9
Yellow maize meal	10,0	20,0	30,0	40,0
Maize germ meal	2,5	7,5	12,5	17,5
Wheat bran	1,0	2,0	3,0	4,0
Cottonseed cake meal	1,5	3,0	4,5	6,0
Prosup 230	0,3	0,6	0,9	1,2
Monocalcium phos= phate	0,2	0,5	0,8	1,1
Limestone	0,5	1,0	1,5	2,0
Salt (NaCl)	0,2	0,4	0,6	0,8
E C Feed	1,0	2,0	3,0	4,0
Molasses (cane)	2,5	2,5	2,5	2,5

Table 4 Estimated crude chemical composition of pelleted lucern:concentrate rations fed to cows and first-calf heifers

Composition	Pelleted rations			
	80L:20C	60L:40C	40L:60C	20L:80C
	%	%	%	%
Crude protein	15,73	15,63	15,53	15,42
Fibre	24,87	20,00	15,04	10,10
Calcium	1,27	1,36	1,44	1,53
Phosphorus	0,27	0,35	0,44	0,54
Salt (NaCl)	0,20	0,40	0,60	0,80
TDN[1]	55,00	60,00	65,00	70,00

1 TDN; Total digestible nutrients

was determined at each feeding. During the standardization - and comparison period weekly samples of the maize silage were taken and analysed for dry matter content. Representa= tive samples of the pelleted rations were collected for digestibility trials and analyses. Bone meal was thoroughly mixed with the maize silage and fed at a level of 64 g per cow at feeding time.

1.5 Digestibility trial

The composition of the experimental rations in terms of digestible nutrients was estimated from the data collected in a digestibility trial using four lactating Friesland cows. In addition an evaluation of the nitrogen- and energy intake was made. Losses of nitrogen- and energy containing substances in the faeces, urine, combustible gasses and milk were taken into account.

1.5.1 The experimental design

A 4 x 4 Latin square design was set up with four lactating cows as the columns and four stages of lactation as the rows. The treatments were the four experimental pelleted rations fed *ad lib*. in addition to a restricted supply of maize silage.

The randomisation procedure of Fisher & Yates (1948) for a Latin square arrangement, was followed.

Analyses of variance for the Latin square (Steel & Torrie, 1960) were used to test for differences in food intake, food composition, milk production and -composition between treatments.

1.5.2 Experimental cows

Three potentially high producing Friesland cows and a first-calf heifer from the Glen herd were assigned to this experi= ment. None of the animals had been used in previous digestibility trials.
The animals were brought into the metabolism stalls for the first time after they had calved. Four 10-day collection trials were conducted during the second-, third-, fourth- and fifth month of lactation with each cow.
During the collection periods the urine was collected by means of urethral catheters equipped with inflatable balloons. Urine was conducted from the catheter via a flexible tube to a plastic container.
One cow had to be replaced after the first collection trial due to a bladder infection. The general health and condition of the remaining animals were satisfactory throughout the collection trials. The data of the replaced cow was not in= cluded in the statistical analyses. Missing data was esti= mated by the method of Steel & Torrie (1960).
Data concerning the cows used in this trial are summarized in Table 5. The cows were not bred until after completion of this trial so as to avoid complications in interpreting the data.

Table 5 Data concerning the animals used in digestibility trials

Variable description	Units	Experimental animals: Rissie 3	Rissie 4	Gilda 70	Echo 70
Age	month	67	54	25	39
Calving date	-	30/7/71	2/8/71	30/7/71	9/8/71
Lactation No.	-	4	2	1	2
Daily milk yield during preceding lactation	kg	20,14	15,13	-	13,96
Fat % of milk during preceding lactation	%	5,90	3,70	-	3,50
Body mass after calving	kg	620	638	464	573

1.5.3 Housing and care

During the preliminary- and collection periods the cows were housed in metabolism stalls shown in Fig.2 and were fed at 08h00 and at 14h00. Feed residues were collected each day before the cows were fed in the morning. The cows were hand-milked twice daily at 05h30 and 15h00. Milk yields were measured at all milkings.
Water containers for each cow were filled three times daily at 08h00, 14h00, and 21h00. Automatic water troughs pro= vided water ad lib.and intake was measured daily.
The mass of the cows was determined immediately after calving and at 08h00 at the beginning and end of each collection period.

1.5.4 Standardization- and experimental rations

1.5.4.1 Standardization ration

The feeding procedure as previously described (1.4.1) was followed during the standardization period.

1.5.4.2 Experimental rations

The experimental rations fed to the animals in this digesti= bility trial were identical to the rations described under 1.4.2. The pelleted experimental rations were fed ad lib. during the preliminary- and collection periods. In addition bone meal (64 g/cow) thoroughly mixed with the 4,5 kg of maize silage, was supplied at each feeding.

Fig.2 Metabolism stalls used for digestibility trials

During the collection trials random samples of the maize silage and pellets were taken daily and then pooled for each 10-day period. The pooled samples were prepared for analysis by freeze drying or drying (100^{o}C).
Nitrogen, organic matter, dry matter and crude fibre analyses were conducted by standard procedures (AOAC, 1965).
Cellulose determinations were made by the method of Crampton & Maynard (1938). Gross energy analyses were made using an automatic adiabatic bomb calorimeter.

1.5.5 Course of the digestibility trial

The chronological history of this trial is set out in Table 6.

1.5.6 Collection of faeces, urine and milk

During the periods of collection, samples of faeces, urine and milk were collected twice daily and pooled for 10-day periods. The catheter technique for the collection of urine was followed using the standard FG 26-150 ml Lapro-foley catheter. The design of the catheter is shown in Fig.3.
The vulva was opened with a speculum and the catheter inserted by guiding the point at an upward angle through the external urethral orifice. A long firm wire 460 mm in length which fitted in the catheter was used to guide it through the urethra into the bladder. The external urethral orifice is about 10 cm from the ventral point of the vulva opening and has the form of a longitudinal slit about 2,5 cm long.
Beneath this is a blind pouch, the suburethral diverticulum

Table 6 The chronological history of the digestibility trial

Date 1971	Period No.	Length of period	S[1], P[2] or C[3] period	Stage of lactation	Ration treatment[4] animals received			
-	-	days	-	month	Rissie 3	Rissie 4	Gilda 70	Echo 70
30/7 - 24/8	S	15-26	S	1	SR	SR	SR	SR
25/8 - 13/9	1(a)	20	P	1-2	C	B	D	A
14/9 - 23/9	1(b)	10	C	2	C	B	D	A
24/9 - 11/10	2(a)	18	P	2-3	A	C	B	D
12/10 - 21/10	2(b)	10	C	3	A	C	B	D
22/10 - 8/11	3(a)	18	P	3-4	D	A	C	B
9/11 - 18/11	3(b)	10	C	4	D	A	C	B
19/11 - 6/12	4(a)	18	P	4-5	B	D	A	C
7/12 - 16/12	4(b)	10	C	5	B	D	A	C

1 Standardization period

2 Preliminary period

3 Collection period

4 Ration treatments:-

SR = maize sialge, lucern hay & dairy meal

A = 80% lucern:20% concentrate pellets + maize silage

B = 60% lucern:40% concentrate pellets + maize silage

C = 40% lucern:60% concentrate pellets + maize silage

D = 20% lucern:80% concentrate pellets + maize silage

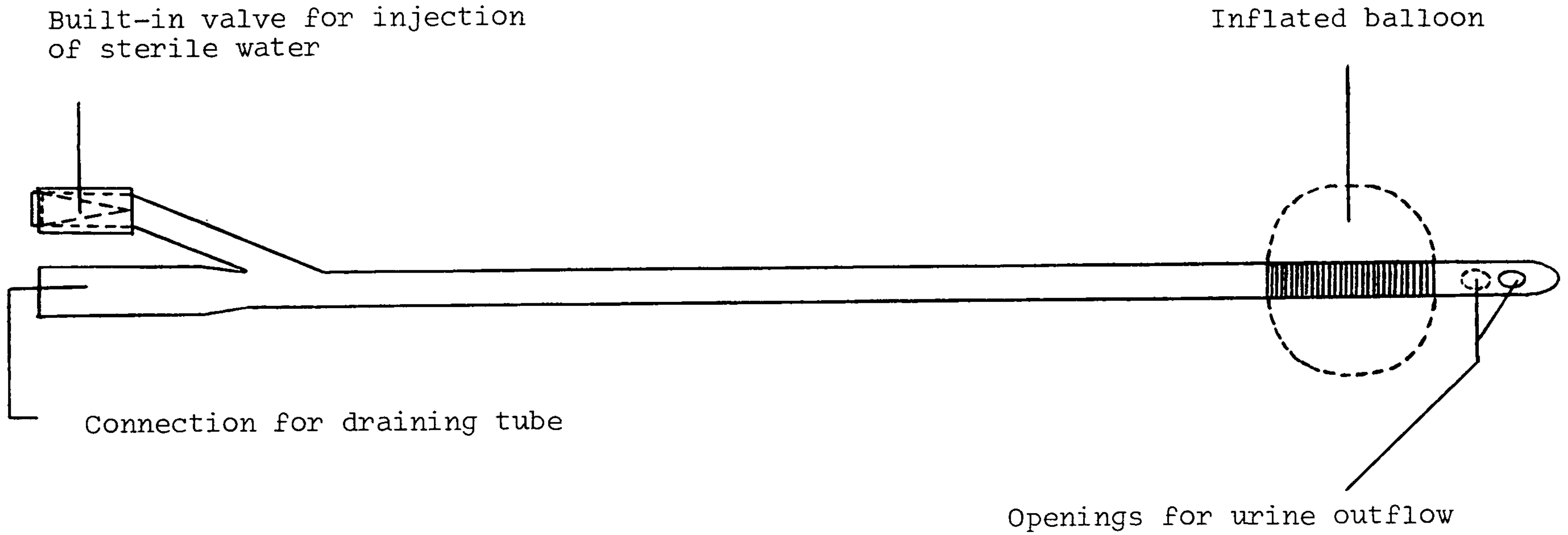

Fig.3 Diagrammatic sketch of catheter

which is about 3,5 cm long (Fig.4). If the catheter is guided in a downward position it enters the blind pouch. When guided into the correct orifice the catheter glides smoothly into the urethra.

A syringe without a needle was used to inject 70-80 ml of sterile water through the built-in valve in the catheter, causing inflation of the balloon. The guiding wire was then removed. The inflated balloon ensured that the front portion of the catheter remained inside the bladder. Cows provided with smaller types of catheters (30 ml) or large catheters which contained less than 70 ml of water were inclined to dislodge easily.

A latex medical tube, two metres in length, with an inner diameter of 5 mm and 3 mm wall thickness, served as a connecting tube between the catheter and plastic urine container of 22 litre capacity. The tube leading to the urine container formed a U-bend so that a small amount of urine remained in it to prevent air aspiration into the bladder. Continuous flow of urine from the bladder into the container occurred. Before removal of the catheters a bladder rinse of 20 ml antibiotic solution, was injected into the bladder via the catheter tube to prevent possible infection. The antibiotic solution contained 10 ml antibioticum [200 units procaine penicillin and dihydrostreptomycin sulphate, 0,25 g per ml] and 10 ml salt solution (5 g sodium chloride per 470 ml sterile water).

The balloon was deflated by inserting a syringe needle

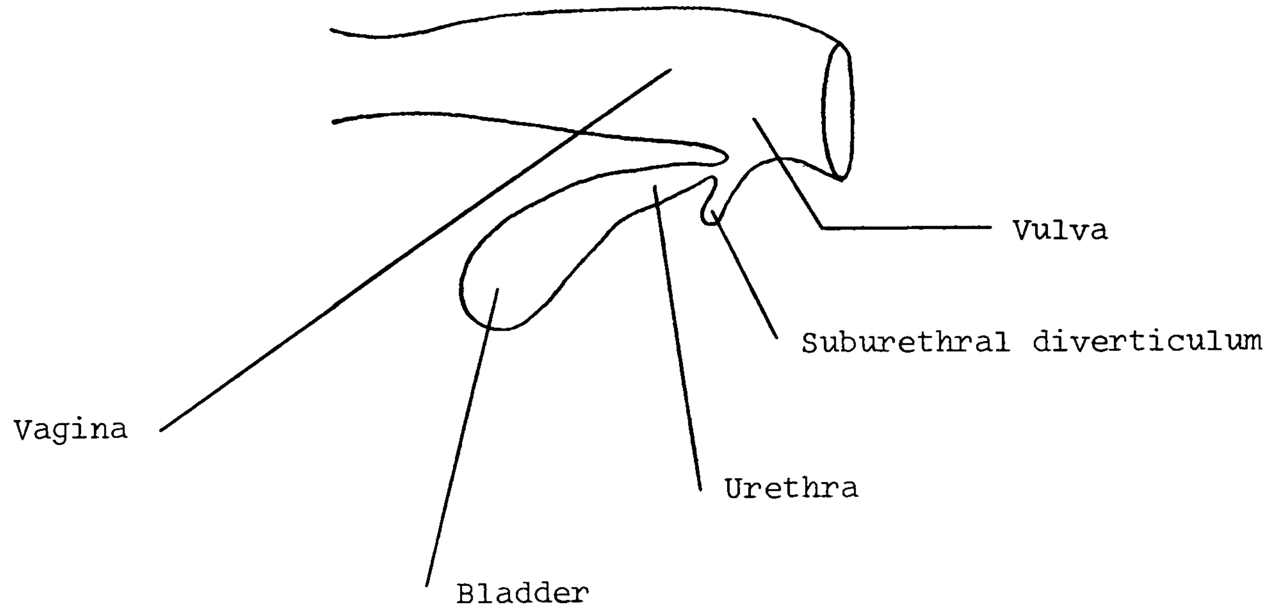

Fig.4 Diagrammatic sketch of part of urogenital tract of cow

through the built-in valve. This caused an outflow of water from the balloon.

The catheter was then removed. After the removal of the catheters, each cow received a daily intramuscular injection of 20 ml antibioticum over a period of four days as a pre=ventative measure against possible infection.

In all cases the total urine production was collected and there was no leakage between the catheter and the bladder of the cow. Catheters were left in the bladders for collection periods of 10-days. During this period the cows showed no appreciable signs of irritation or a decline in milk produc=tion or daily feed intake.

Up to 32 litres of urine were collected daily per cow. The urine was preserved by adding 20 ml of a solution consisting of 4N H_2SO_4 in which 9 per cent $CuSO_4$ was dissolved, per litre of urine. A urine sample (1%) was taken dialy from each cow.

Nitrogen analyses of the faeces, urine and milk were carried out according to the AOAC (1965) standard procedures. Gross energy content of the faeces, urine and milk were determined in an automatic adiabatic bomb calorimeter.

Dry matter, organic matter and crude fibre analyses of faeces were conducted according to the AOAC (1965) standard proce=dures. Cellulose analyses of faeces were carried out by means of the procedures developed by Crampton & Maynard (1938).

Digestible energy content of the diet was calculated by the deduction of faeces energy from the gross energy value of the ration.

Digestible energy less the energy lost in urine and in methane production was used as a basis to estimate the metabolizable energy content of the diet.

Methane production was estimated using the equation of Blaxter & Clapperton (1965);

$$C_m^1 = 3{,}03 + 0{,}074\ D^2$$

C_m^1 = Methane (CH_4) at maintenance (kcal/100 kcal)

D^2 = Apparent digestibility (kcal/100 kcal)

An evaluation of the nitrogen consumed in the feed was made by using the input-output nitrogen data from the digestibility trial. Nitrogen balance was measured as follows (McDonald, Edwards & Greenhalgh, 1973);

$$\text{Daily nitrogen balance} = \text{DMI} \times \frac{\%N^1}{100} \text{ in feed} - \left(\text{faeces DM} \times \frac{\%N^2}{100} + \text{ml urine} \times \frac{N^3}{100} + \text{ml milk} \times \frac{N^4}{100}\right)$$

DMI = daily dry matter intake in feed

N^1 = nitrogen % in feed

N^2 = nitrogen % in faeces

N^3 = nitrogen in urine g N/100 ml

N^4 = nitrogen in milk g N/100 ml

Feaces DM = daily dry matter excreted as faeces

ml urine = daily excretion of urine millilitre

ml milk = daily secretion of milk millilitre

1.6 Milk production and -composition

Milk yields were recorded at all milkings. The total solids of milk were determined by the AOAC methods (1965) and milk fat by the automatic Milko-tester, Mark III. The percentage of solids-not-fat of milk was estimated by deducting the milk fat percentage from the total solids percentage. Solids corrected milk (SCM) was calculated using the equation of Tyrrell & Reid (1965);

$$\text{Milk energy cal/g} = 2{,}205[41{,}84\ (\%\ \text{fat}) + 22{,}29\ (\%\ \text{SNF}) - 25{,}58]$$

1 kg SCM = Mcal solids corrected milk energy divided by 0,750. 4% Fat corrected milk (4% FCM) was calculated using the equation of Gaines & Overman (1938).

1.7 Duration of the experiment

The present study was conducted over a period of three years and seven months. Chronologically the experiment was carried out as set out in Table 7.

Table 7 Chronological history of the experiment

Date	Number of animals alloted to experimental rations A	B	C	D
	maize silage +			
	80L:20C	60L:40C	40L:60C	20L:80C
	n	n	n	n
27/4 - 30/6/69	2	1	-	1
1/7 - 30/9/69	-	2	1	2
1/10 - 31/12/69	3	1	2	3
1/1 - 31/3/70	2	3	1	2
1/4 - 30/6/70	1	1	1	-
1/7 - 30/9/70	1	1	1	2
1/10 - 31/12/70	-	-	1	-
1/1 - 31/3/71	1	1	1	1
1/4 - 30/6/71	4	5	4	3
1/7 - 30/9/71	-	1	4	1
1/10 - 31/12/71	1	-	-	1
1/1 - 31/3/72	1	-	-	-
Total number	16	16	16	16

1.8 Abbreviations

DE	-	digestible energy
DM	-	dry matter
c	-	cents
cm	-	centimetre
CP	-	comparison period
FCM	-	fat corrected milk
g	-	gram
GE	-	gross energy
kcal	-	kilocalories
kg	-	kilogram
l	-	litre
Mcal	-	megacalories
ME	-	metabolizable energy
ml	-	millilitre
mm	-	millimetre
OM	-	organic matter
P<0,05	-	significant at the 5% level
P<0,01	-	significant at the 1% level
NS	-	non-significant at the 5% level (P>0,05)
Ration A	-	maize silage + 80L:20C
Ration B	-	maize silage + 60L:40C
Ration C	-	maize silage + 40L:60C
Ration D	-	maize silage + 20L:80C
80L:20C	-	80% lucern:20% concentrate; pellets
60L:40C	-	60% lucern:40% concentrate; pellets
40L:60C	-	40% lucern:60% concentrate; pellets

20L:80C	-	20% lucern:80% concentrate; pellets
SCM	-	solids corrected milk
SNF	-	solids-not-fat
SP	-	standardization period
TS	-	total solids
VFA	-	volatile fatty acids
${W_{kg}}^{0,75}$	-	metabolic size

CHAPTER 2

RESULTS AND DISCUSSION

2.1 Changes in body mass of lactating dairy animals

2.1.1 Introduction

Changes in body mass of lactating cows result from a combina= tion of growth, pregnancy, and alternate deposition and subsequent catabolism of body tissue (Miller, Hooven & Creegan, 1969).

Age is, however, the primary factor influencing body mass variations of cows. The usual pattern in second and later lactations is a gradual depletion of fat reserves after calving followed by a period of relative balance and finally a period of fat deposition in late lactation (Miller, Hooven, Smith & Creegan, 1973). Mature cows decreased in mass from the first to the second month of lactation, while first-calf heifers gained slightly during this period (Miller et al., 1969). This difference was attributed to the greater utili= zation of fat reserves by the older cows. First-calf heifers gained in this period owing to lower level of milk yield and to continued growth. The highest mass gains occurred in first-calf heifers (84 kg) and the lowest in mature cows (34 kg) (Miller et al., 1969).

The mass of cows did not stabilize until about the sixth week after parturition (Bartlett, 1926). There appeared to be a slight tendency for older animals to gain faster near the end of lactation.

Reid (1961) noted that it is not unusual for cows to lose 45 to 90 kg of body mass during the first 75 days after calving, and some cows have been known to lose as much as 180 kg.

Although the body mass of cows increases until the age of seven years (Matthews & Fohrman, cited by Miller & Hooven, 1970), maximum skeletal growth is attained by the age of five years (Ragsdale, according to Miller & Hooven, 1970). Changes in body mass during lactation are closely associated with the feeding level and milk yield. The amount of tissue energy used during the early stage of lactation for milk production depends on the degree of fatness of the cow at time of parturition, the genetic potential of the cow to produce milk, feed intake and feed composition during early lactation (Moe, Tyrrell & Flatt, 1971).

A highly significant ($P<0,01$) effect of stage of lactation on body tissue utilized or stored was found by Flatt, Moe, Munson & Cooper,(1969b). According to these authors, the average body tissue loss during early lactation was 6,9 Mcal per day, compared with an average daily gain of body tissue energy of 1,2 Mcal in mid-lactation and 4,9 Mcal in late lactation. Flatt et al.(1969b) recorded no statistically significant ($P>0,05$) interaction between ration and stage of lactation. They stated that the cows receiving the high con= centrate ration tended to fatten in mid- and late lactation. The cows did not utilize as much body fat in early lactation as those cows which were fed rations with less concentrates

(40-60%). The cows receiving the 40 per cent concentrate ration deposited body fat in mid- and late lactation, but not to the same extent as when the 80 per cent concentrate ration was fed.

For various reasons body tissue changes may not be accurate=ly reflected by body mass changes (Flatt, 1966) but body mass change has the practical advantage of being easily measured (Miller et al., 1969).

2.1.2 Discussion of results

The mean body mass of the lactating cows and first-calf heifers before and after being fed on various rations are presented in Table 8.

Body masses of the cows in the four treatment groups were homogeneous ($P>0,05$) at the beginning of the comparison period and were non-significantly affected by the lucern to concentrate ratio fed in the comparison period. Similarly the body masses of the first-calf heifers were non-significant=ly ($P>0,05$) affected by ration treatment. This is in agree=ment with the findings of Flatt, Moe, Moore, Hooven, Lehmann, Ørskov & Hemken (1969a).

The effect of age on body mass changes was highly significant ($P<0,01$).

Body mass changes of cows and first-calf heifers during the standardization period and comparison period are presented in Figures 5 and 6.

At all stages of lactation the body mass of the cows fed a specific ration were always significantly greater than those

Table 8 Mean body mass changes of experimental animals fed various experimental rations

Variable description	Ration treatment A 80L:20C kg	B 60L:40C kg	C 40L:60C kg	D 20L:80C kg	Diff[1]
Body mass at beginning of comparison period:					
(i) cows	598	578	580	585	NS
(ii) first-calf heifers	499	495	481	491	NS
Body mass at end of comparison period					
(i) cows	657	637	654	655	NS
(ii) first-calf heifers	577	591	564	571	NS

1 Differences: NS; non-significant ($P>0,05$)

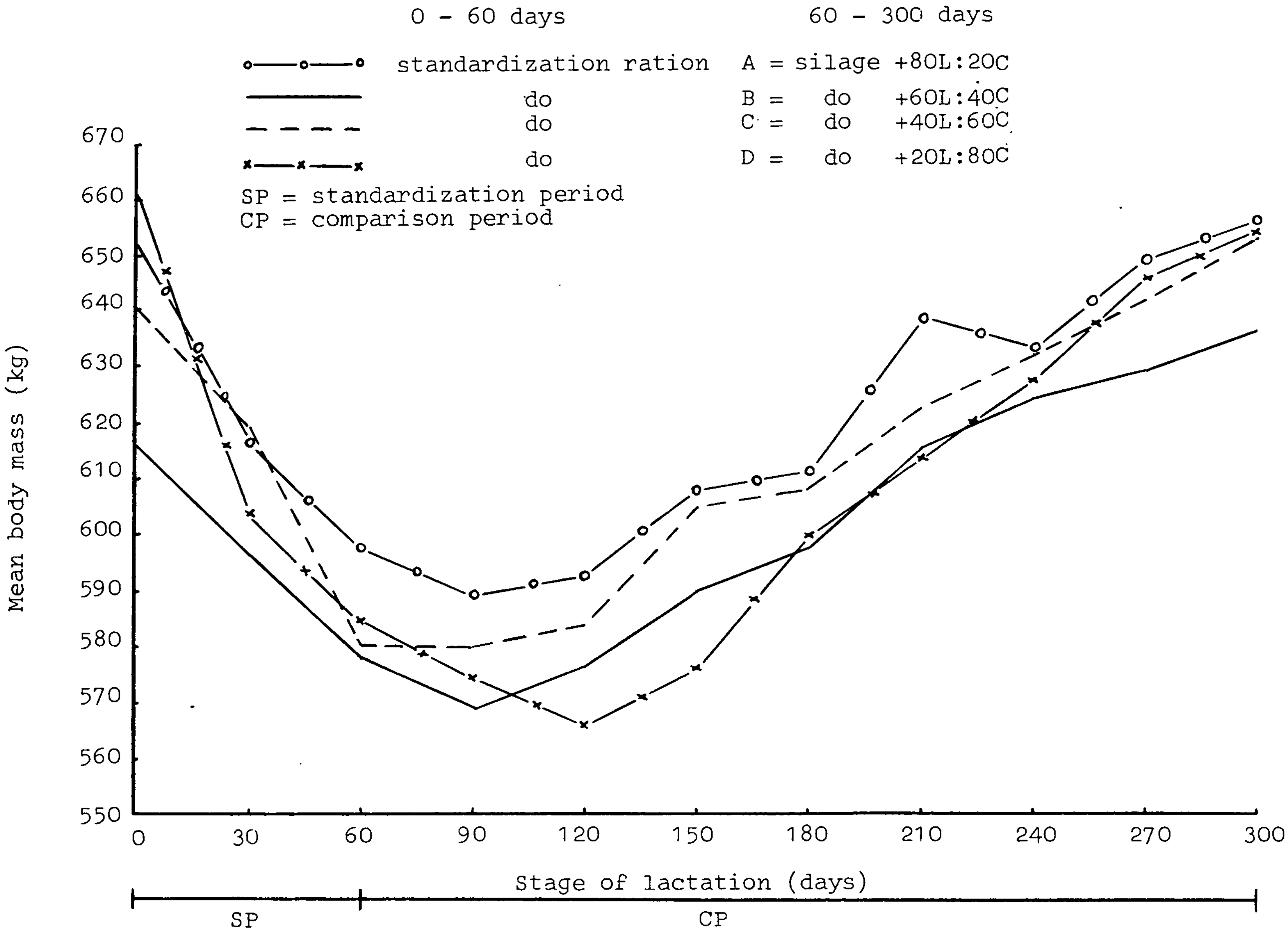

Fig.5 Changes in body mass of lactating cows due to the feeding of standardization- and experimental rations(A,B,C & D)

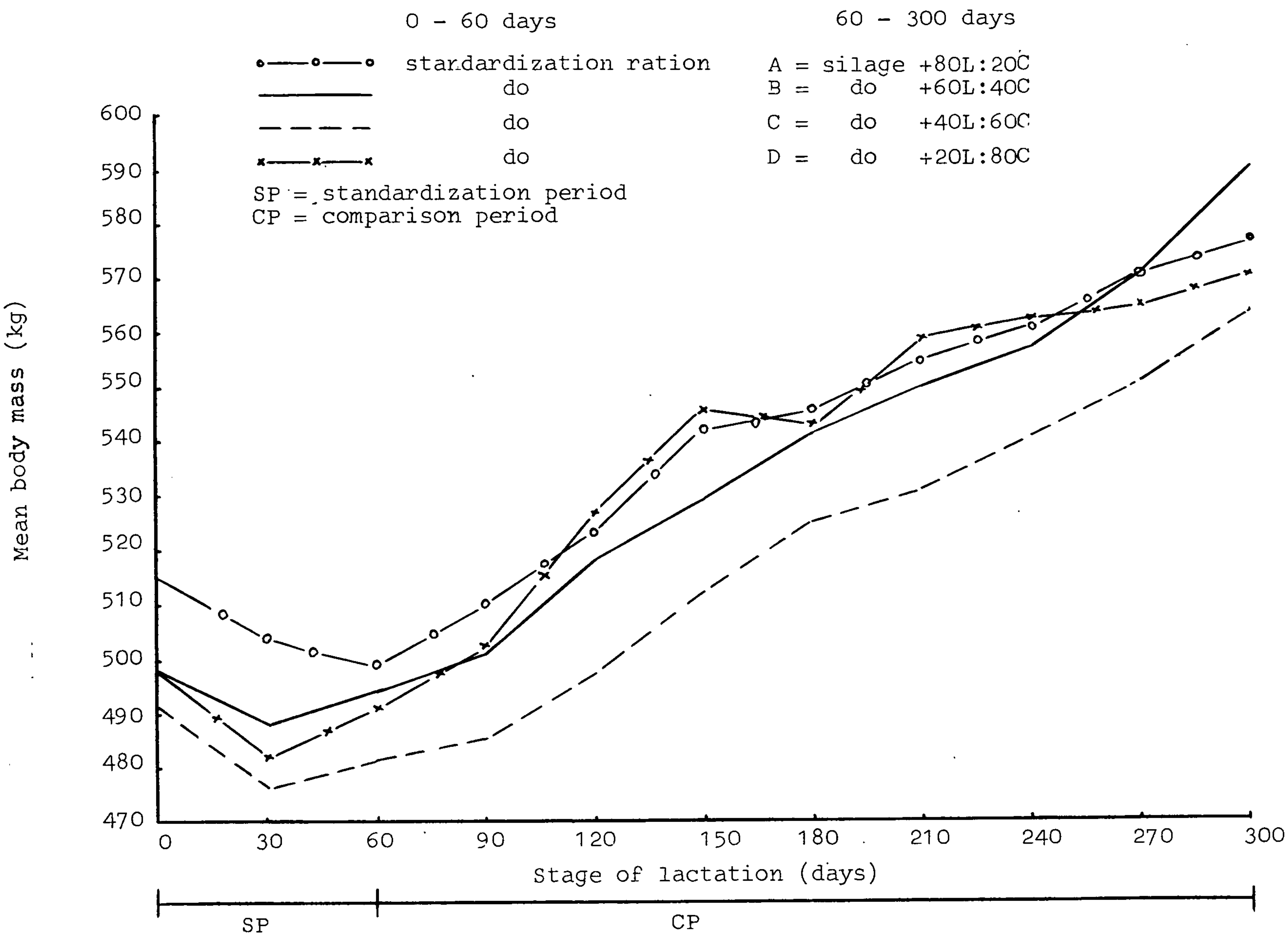

Fig.6 Changes in body mass of lactating first-calf heifers due to the feeding of standardization- and experimental rations (A,B,C & D)

of first-calf heifers on the same ration.

The body mass differences between cows and first-calf heifers were most evident during the first 120 days after parturition. The first-calf heifers tended to lose mass during the first 30 days after calving, in the case of the B, C and D treatment groups. The mean individual mass losses during this period were 9,8; 15,0 and 15,4 kg respectively for the B, C and D treatments. The first-calf heifers in the A treatment group lost body mass during the first 60-days after calving, the mean individual mass loss being 14,5 kg. The mean mass loss for all treatments was 13,7 kg per heifer. Within 120 days post calving the body mass of the heifers had increased by 9,0; 20,5; 6,0 and 29,7 kg, respectively for the A, B, C and D treatment groups. The individual mean body mass gain of the heifers during this period, irrespective of treatments, was 16,3 kg.

First-calf heifers gained 68,9; 98,1; 79,4 and 75,0 kg body mass during their first lactation when fed ration A, B, C and D, respectively. Mean individual gain of heifers for all treatments was 80,4 kg. This agrees with the findings of Miller et al.(1969), previously mentioned, indicating that heifers maintained normal growth throughout their first lactation, irrespective of the experimental ration consumed. On the other hand, the mass of the experimental cows in this study did not stabilize until 90 to 120 days after calving. The mean mass loss per cow during this period was 62,6; 48,0; 59,5 and 94,3 kg, respectively for the A, B, C and D treat= ment groups. Irrespective of treatments, the mean mass loss was 66,1 kg per cow during the first 90 to 120 days of lactation.

The increase in body mass of the cows was considerably lower during the 300-day lactation period than the mass gains of the first-calf heifers. The mean mass gains of the cows were 6,0; 23,1; 18,1 and -7,4 kg when consuming rations A, B, C and D respectively. Irrespective of ration treatment the mean mass gain was 9,9 kg per cow.

The differences between body mass changes of cows and first-calf heifers were attributed to the utilization of body tissue reserves of older cows. Furthermore, first-calf heifers gained more during their first lactation due to continued growth and the lower milk yield (Miller et al., 1969).

Changes in body tissue reserves due to ration treatment probably took place without being accurately reflected by the body mass changes of the cows or heifers. The small differences (P>0,05) in body mass between treatment groups cannot be attributed to ration effect only but may be influenced to a large extent by the amount of fill in the rumen due to individual differences in voluntary intake.

The effect of stage of lactation on body mass changes in the comparison period was highly significant (P<0,01). The body mass of the first-calf heifers and cows were considerably higher (P<0,01) in the seventh-, eighth-,ninth- and tenth month of lactation than the mass in the third and fourth month of lactation, irrespective of treatment. This is in agreement with the general body mass variation during lactation. The pattern is usually characterized by a gradual depletion of body tissue after calving, followed by a stage of balance and, eventually a period of fat deposition in late lactation (Flatt et al., 1969b). Ration effect x stage of lactation interactions for both age groups were non-significant ($P>0,05$).

2.2 Milk production and -composition

2.2.1 Introduction

Studies on varying energy content in complete rations have indicated an increase in milk production by increasing the concentrate portion of the complete feeds (Nelson, Ellzey & Morgan, 1968). Research has left little doubt that high-grain feeding resulted in an increase in milk production (Huffman, 1961). It was pointed out that high production potential cows would almost always respond positively to an increased grain content in the ration. Most of the in=creased production can be attributed to the greater energy content (Kesler & Spahr, 1964 and Escano & Rusoff, 1973). Unlimited grain feeding showed no advantage when the produc=tion potentials of the cows were low (Boyd & Mathew, 1962). Research has shown that certain feeding treatments will affect the concentration and composition of some milk constituents. Of all the constituents of milk, fat is the most dependent on the physical and chemical composition of the ration.
A frequent problem arising from feeding of rations which are

rich in concentrates is the depression of the fat percentage in the milk (Broster, Ridler & Foot, 1958; Bishop, Loosli, Trimberger & Turk, 1963 and Kesler & Spahr, 1964).
Ronning (1960) found that diets containing 30 and 40 per cent concentrates depressed fat content. Furthermore reduction in fat content is often accompanied by a change in chemical composition (Kesler & Spahr, 1964). Kunsman & Keeney (1963) observed a decrease in saturated and an increase in the un= saturated fatty acids when cows were fed a daily diet of 1,4 kg of hay plus grain in ad lib. quantities.
It has been established that the physical form, fineness of grinding,crude fibre level, crude fibre type and high-concen= trate restricted- roughage rations affects volatile fatty acid (VFA) production in the rumen. This results in a marked depression of the milk fat percentage (Powell, 1939; Van Soest & Allen, 1959 and Huber, Polan & Rosser,1967).
There is good evidence that diets which tend to cause a re= duction in milk fat percentage also tend to narrow the ratio of acetic to propionic acids found in rumen contents (Raun, Burroughs & Woods, 1962).
In addition, factors such as the heat development during pelleting and the hardness of the pellets, may affect the nutritive value of pelleted forage (Moore, 1964) and hence the fat percentage of milk.
Degree of grind fineness and frequency of feeding are impor= tant factors in the occurrence of milk fat depressions (Chalupa, O'Dell, Kutches & Lavker, 1970).

Critical grind size in relation to milk fat depression was approximately 0,64 cm (O'Dell, King & Cook, 1968).
The metabolic and health problems associated with high-concentrate feeding or with feeding finely ground and pelleted feeds can be reduced by increasing the frequency of feeding (Satter & Baumgardt, 1962).
With increased feeding frequency, variations in rumen vola= tile fatty acid concentrations, ammonia levels and pH values are reduced (Satter & Baumgardt, 1962).
When feeding complete rations containing 20 per cent roughage one can predict that the milk produced will contain a rela= tively low percentage of fat (Emery, Brown & Thomas, 1964 and Leighton & Rüpel, 1964).
Rakes (1969) indicated that although some exceptions have been noted even with complete feeds containing 40 per cent roughage (Welch & Maddux, 1965), 30 per cent roughage seems to be the level below which a definite drop in fat content can be expected.
Cows on diets containing less than 4 kg of hay daily, or an equivalent amount of some other roughage, or when the feed was finely ground, may produce milk with 40 per cent less fat than normal (Rook, 1959).
Protein is slightly affected while lactose and mineral con= tent are difficult to alter by feeding. The correlation existing between protein and fat content of milk seems to indicate that protein content may be influenced by changes in the ration (Johansson & Claesson, 1957). Almost every feeding treatment that is known to lower the fat content

will at least increase the protein percentage slightly. A change in solids-not-fat is due largely to a change in milk protein content (Murdock, Hodgson & Waldo, 1962). An increase in the solids-not-fat content of milk brought about by increasing the energy nutrition of the cow, can be primarily ascribed to an increased milk protein production (Rook & Line, 1961). An increase of 0,2 - 0,3 percentage units in solids-not fat, in cows producing normal milk (8,0 - 9,0 per cent solids-not-fat), has been reported when cows were fed 25-50 per cent more energy than provided for in Woodman's standards (Rook, 1959). Rook (1959) attributed the response to an increase in the protein fraction of milk. The increase in protein content is due to increase in both whey protein and casein content (Haenlein, Schultz & Hansen, 1968).

Although a large number of studies have indicated that the per cent solids-not-fat is increased when the plane of energy intake is increased (Castle & Watson, 1961), not all reports have indicated such an effect (Bernett & Olson, 1963). In several instances there was a significant increase in the percentage protein but not in total solids-not-fat (Boyd & Mathew, 1962.)

2.2.2 Discussion of results

The mean daily milk yield of cows fed the experimental rations in this study varied between 19,32 and 21,04 kg and in the case of first-calf heifers between 13,31 and 16,91 kg. These production records are highly satisfactory compared to the mean daily production of registered Frieslands in the Republic of South Africa of 14,76 to 15,23 kg for cows (4-4,5 years age group) and 12,04 to 12,17 kg for first-calf heifers (2-2,5 years age group) (Animal and Dairy Science Research Institute, 1973).

At the onset of the comparison period there were non-signi= ficant differences (P>0,05) in milk yields of the cows in the four treatment groups. The same applied to the milk yield of the first-calf heifers.

The effects of the experimental rations on the average amounts- and composition of daily milk produced by cows and heifers during the comparison period, are summarised in Tables 9 and 10. During the entire comparison period, there were non-significant (P>0,05) differences due to ration, in the daily amount of actual milk, 4% fat corrected milk and solids corrected milk produced by cows. Increasing the con= centrate portion of the experimental rations fed in this study did not lead to an increase in milk production. This was probably because cows voluntarily maintained a very similar metabolizable energy intake on each of the four rations in relation to physiological demand for energy; milk production playing a dominant role.

Ronning (1960) reported that when pellets containing finely ground alfalfa hay and grain type concentrates in various ratios were used, the milk production increased significantly when the concentrate intake was increased up to 30 per cent of the ration, but decreased at the 45 per cent level.

In contrast, the first-calf heifers on ration D (maize

Table 9 Mean composition of milk and mean daily milk production of cows during 240-day comparison period

Variable description	Units	A	B	C	D	Diff[1]
			maize silage +			
		80L:20C	60L:40C	40L:60C	20L:80C	
Daily production of:						
Milk	kg	19,32	19,79	19,67	21,04	NS
Fat	kg	0,65	0,60	0,58	0,64	NS
4% fat corrected milk	kg	17,55	16,90	16,57	18,08	NS
Solids corrected milk	kg	17,68	17,29	16,84	18,76	NS
Chemical composition of milk:						
Energy	kcal/100ml	68,94	65,82	64,51	67,28	NS
Milk fat	%	3,40	3,05	2,97	3,10	NS
Solids-not-fat	%	8,79	8,81	8,69	9,02	NS
Total solids	%	12,19	11,86	11,66	12,12	NS

1 Differences: NS; non-significant (P>0,05)

Table 10 Mean composition of milk and mean daily milk production of first-calf heifers during 240-day comparison period

Variable description	Units	Ration treatment A	B	C	D	Diff[1]
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
Daily production of:						
Milk	kg	14,18	13,31	13,80	16,91	NS
Fat	kg	0,48	0,44	0,45	0,53	NS
4% fat corrected milk	kg	12,86	11,92	12,23	14,66	NS
Solids corrected milk	kg	13,09	12,39	12,66	15,23	NS
Chemical composition of milk:						
Energy	kcal/100ml	69,40	70,84	69,10	67,49	NS
Milk fat	%	3,40	3,41	3,26	3,11	NS
Solids-not-fat	%	8,90	9,16	9,09	9,04	NS
Total solids	%	12,30	12,57	12,35	12,15	NS

1 Differences: NS; non-significant ($P>0,05$)

silage + 20L:80C) produced 19,3 to 27,0 per cent more actual milk, 14,0 to 23,0 per cent more 4% fat corrected milk and 16,3 to 22,9 per cent more solids corrected milk during the comparison period than the heifers consuming either the A, B or C rations, differences, however, were non-significant (P>0,05).

Cows on ration A, B and C produced significantly (P<0,05) more actual milk, 4% fat corrected milk and solids corrected milk during each stage of lactation in the comparison period, than the first-calf heifers. This is in agreement with the general findings of other workers (Drakeley & White, 1928 and Glen & M'Candlish, 1930). Cows fed ration D showed a significantly (P<0,05) higher production than first-calf heifers, during the third to fifth month of lactation and a non-significant difference during the sixth to tenth month.

The influence of the standardization and experimental rations on actual milk and solids corrected milk production through= out the lactation of cows and heifers, are presented in Figures 7, 8, 9 and 10.

With the exception of the first-calf heifers fed on ration D the daily production of milk tended to increase for 60 days following parturition after which it declined gradually.

Group D animals did not reach their maximum production until 120 to 150 days after parturition, after which production decreased gradually.

First-calf heifers had a lower peak milk production level than cows but maintained a more persistent production through=

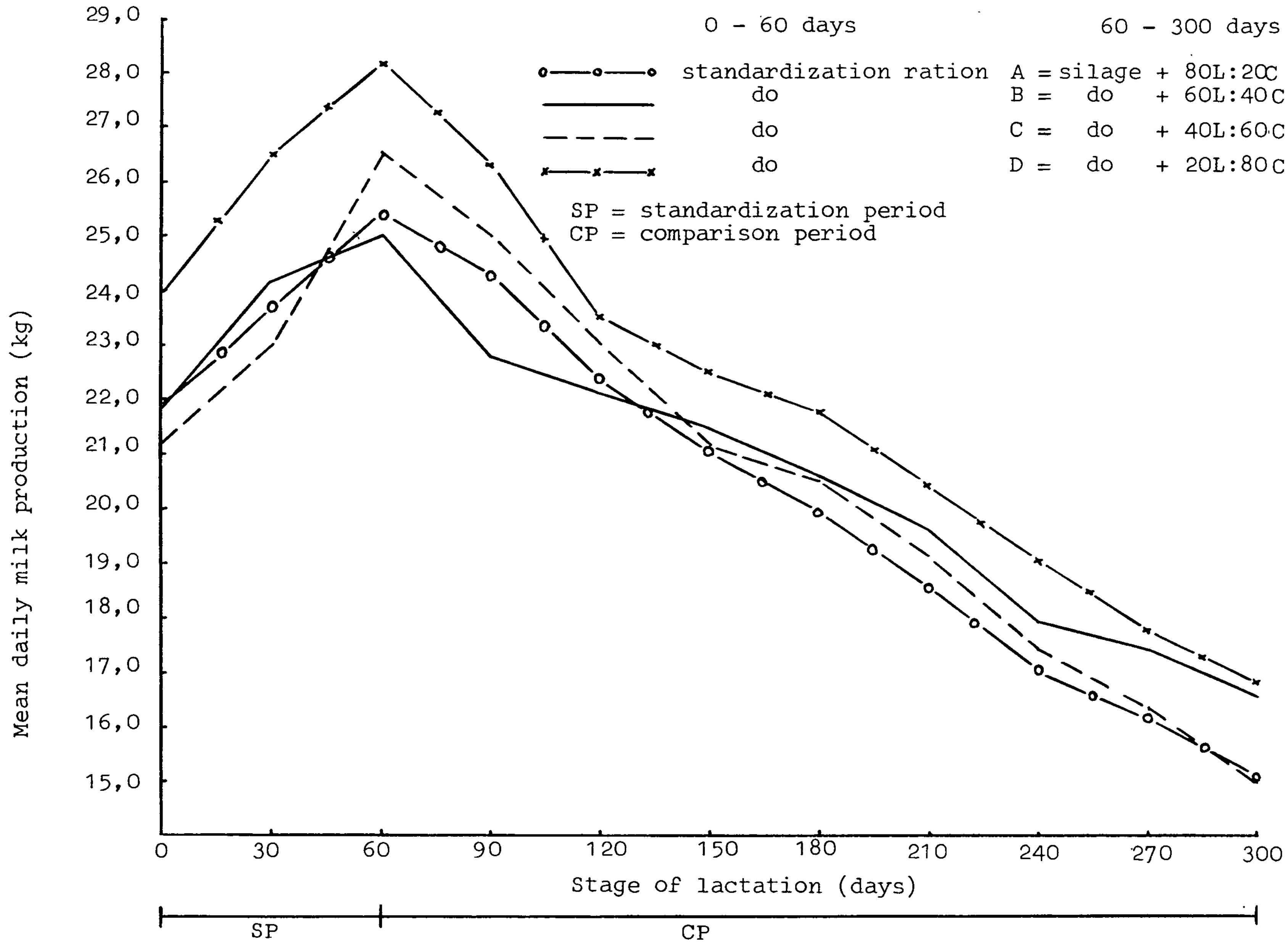

Fig.7 The effect of the feeding of standardization- and experimental rations (A, B, C.& D) on milk production of cows

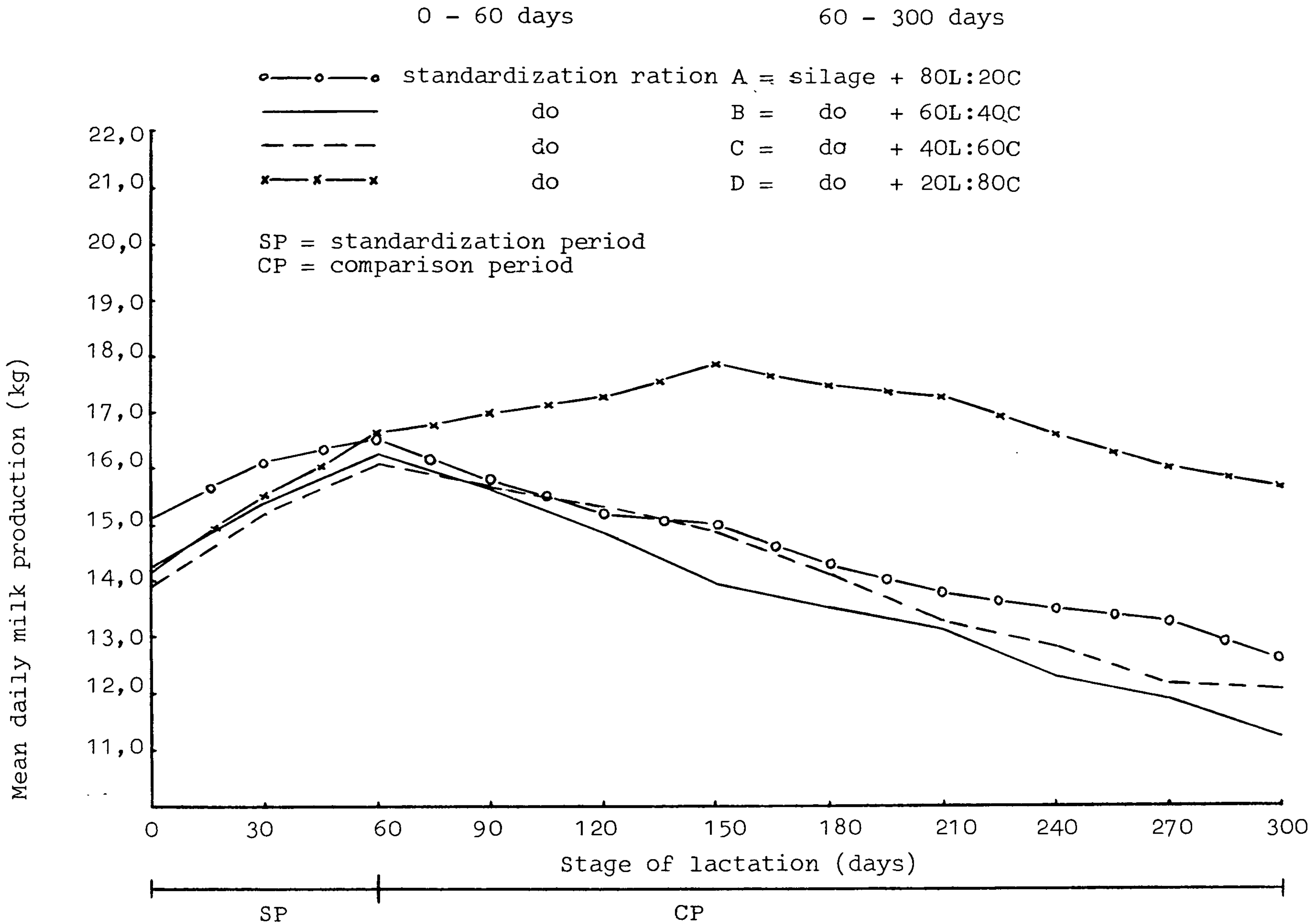

Fig.8 The effect of feeding of standardization- and experimental rations (A, B, C & D) on milk production of first-calf heifers

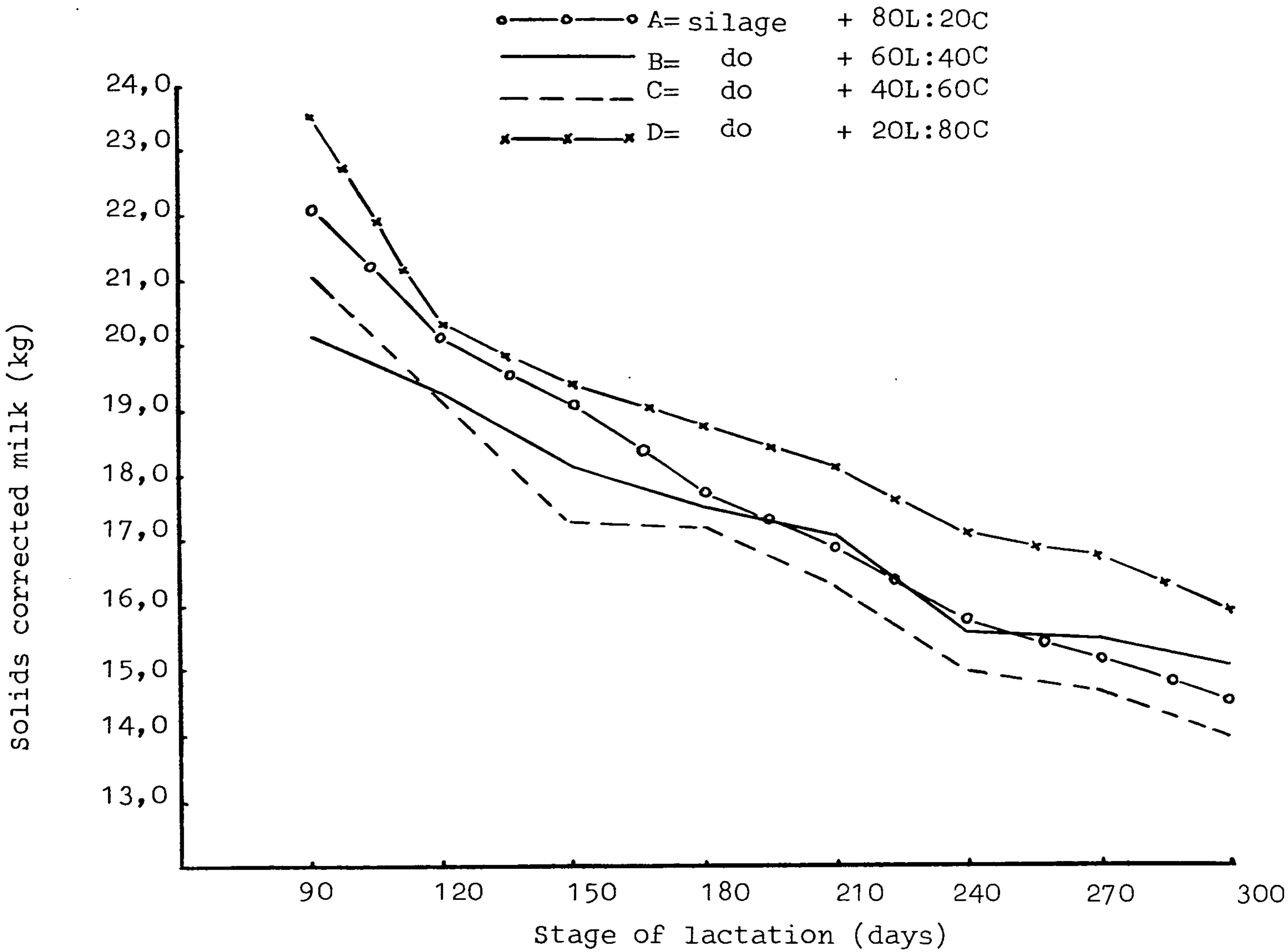

Fig.9 The effect of the feeding of experimental rations on solids corrected milk, produced by cows in comparison period

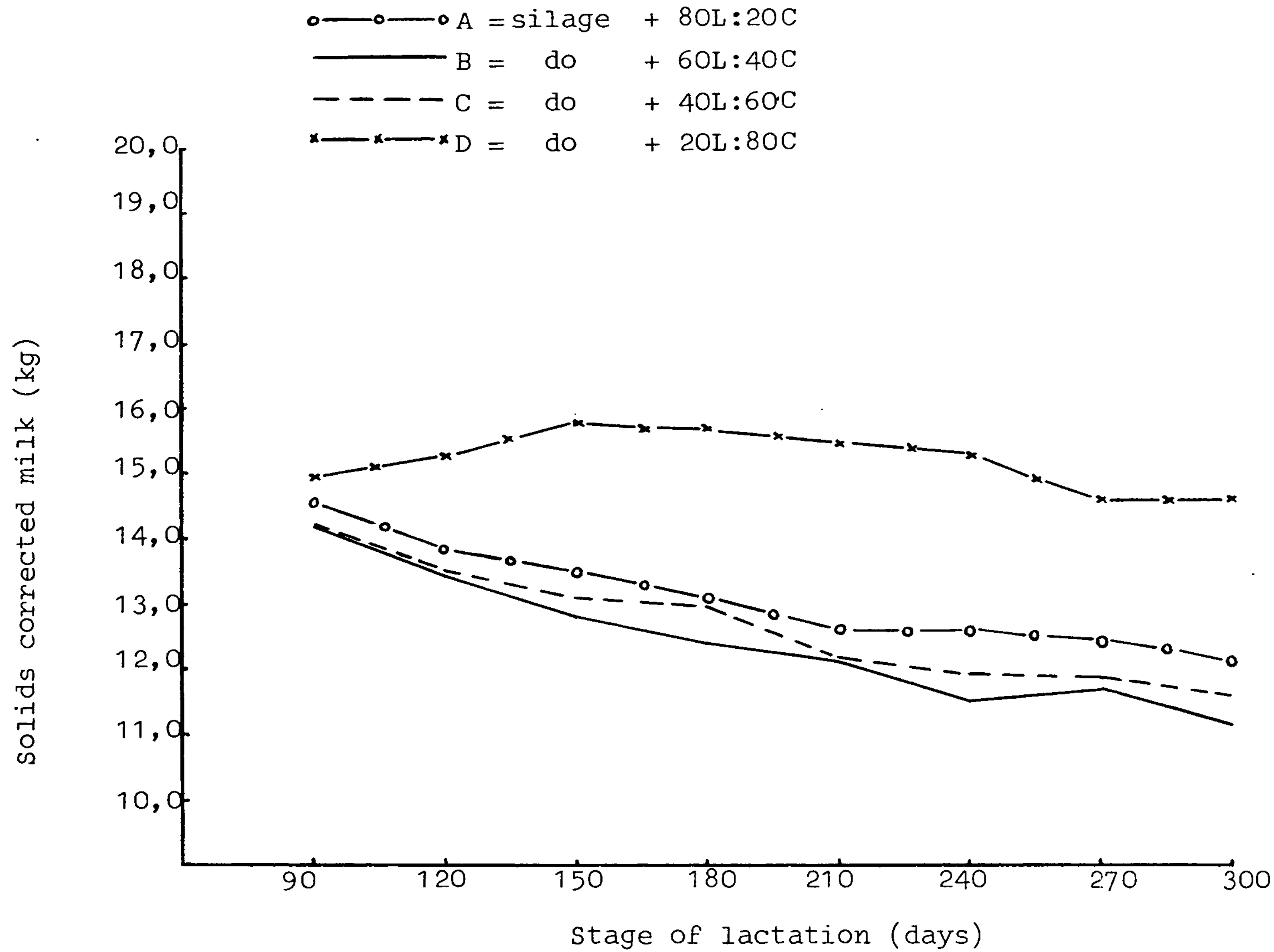

Fig.10 The effect of the feeding of experimental rations on solids corrected milk, produced by first-calf heifers in comparison period

out lactation. This agrees with the findings of Miller & Hooven (1969).

During the comparison period small non-significant ($P>0,05$) differences occurred in the mean composition of milk (Tables 9 and 10).

Solids-not-fat content of milk produced by cows ranged from 8,69 to 9,02 per cent and from 8,90 to 9,16 per cent in the case of first-calf heifers. The solids-not-fat content of milk produced by experimental animals on all four rations did not differ much from the solids-not-fat content (8,70%) of milk produced by cows in the Glen herd which were fed in the conventional manner.

The expected pattern of an increased solids-not-fat and protein content of milk due to an increase in the energy content in the ration (Hoogendoorn & Grieve, 1970) was not found in the present study. This is probably due to the fact that cows to a large extent maintained the same metabo= lizable energy intake on each of the four rations.

Reports from Bernett & Olson (1963) indicated no increase in the percentage solids-not-fat when the plane of energy in the ration was increased. Similar results were obtained in this study.

The milk produced by first-calf heifers had a significantly ($P<0,01$) higher solids-not-fat content during all stages of lactation, irrespective of ration treatment, than that produced by the cows. This agrees with the findings of Waite, White & Robertson (1956) who stated that the percentage of all major constituents of milk probably decreases slightly with advancing age.

During the lactation period of the cows and heifers the percentage of solids-not-fat in milk varied inversely with the amount of milk secreted although not in direct propor= tion.

The minimum percentage of solids-not-fat in the milk occurred 60 - 90 days after parturition in both age groups.

The general trend in percentage of solids-not-fat in milk of the four treatment groups and the two age groups, is shown in Figures 11, 12 and 13.

Cows and first-calf heifers consuming ration A (maize silage + 80L:20C) and first-calf heifers consuming ration B (maize silage + 60L:40C) tended to produce milk with a higher fat percentage than animals on the other experimental rations (Tables 9 and 10). These differences were, however, non-significant (P>0,05).

The fat percentage of milk produced from all four diets, irrespective of age, was lower than that produced by cows fed conventional rations in the Glen herd; percentages being 2,97 to 3,41 per cent for experimental animals compared to 3,82 per cent for non-experimental animals. This decrease in fat percentage must be attributed mainly to the finely ground roughage in the pellets.

Similarly, butter fat production was below normal when pelleted rations were fed to dairy cows, the effect being more marked when the rations contained 30 and 45 per cent concentrates than when no concentrates or when only 15 per

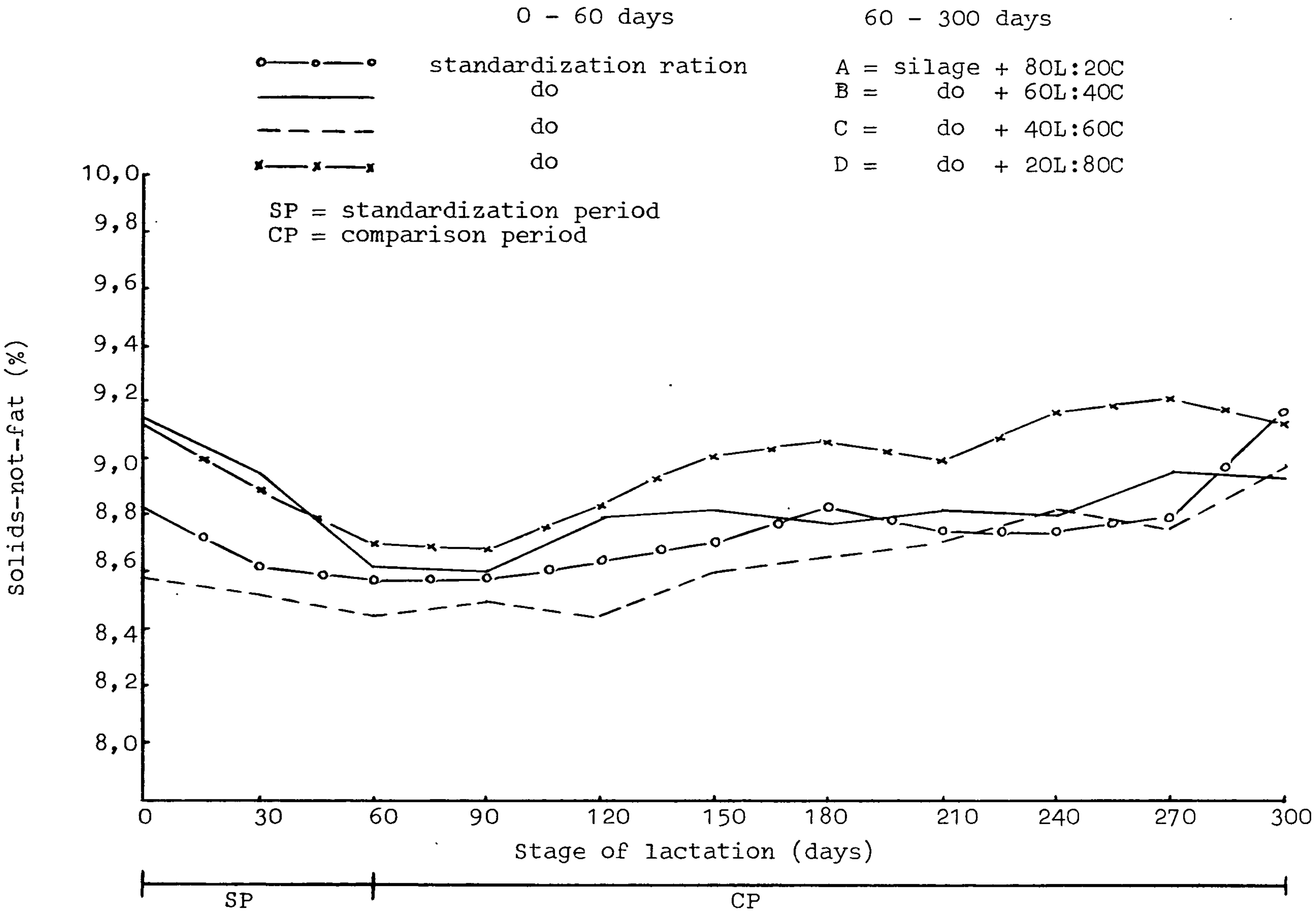

Fig.11 The effect of the feeding of standardization- and experimental rations (A, B, C & D) on percentage solids-not-fat of milk, produced by cows

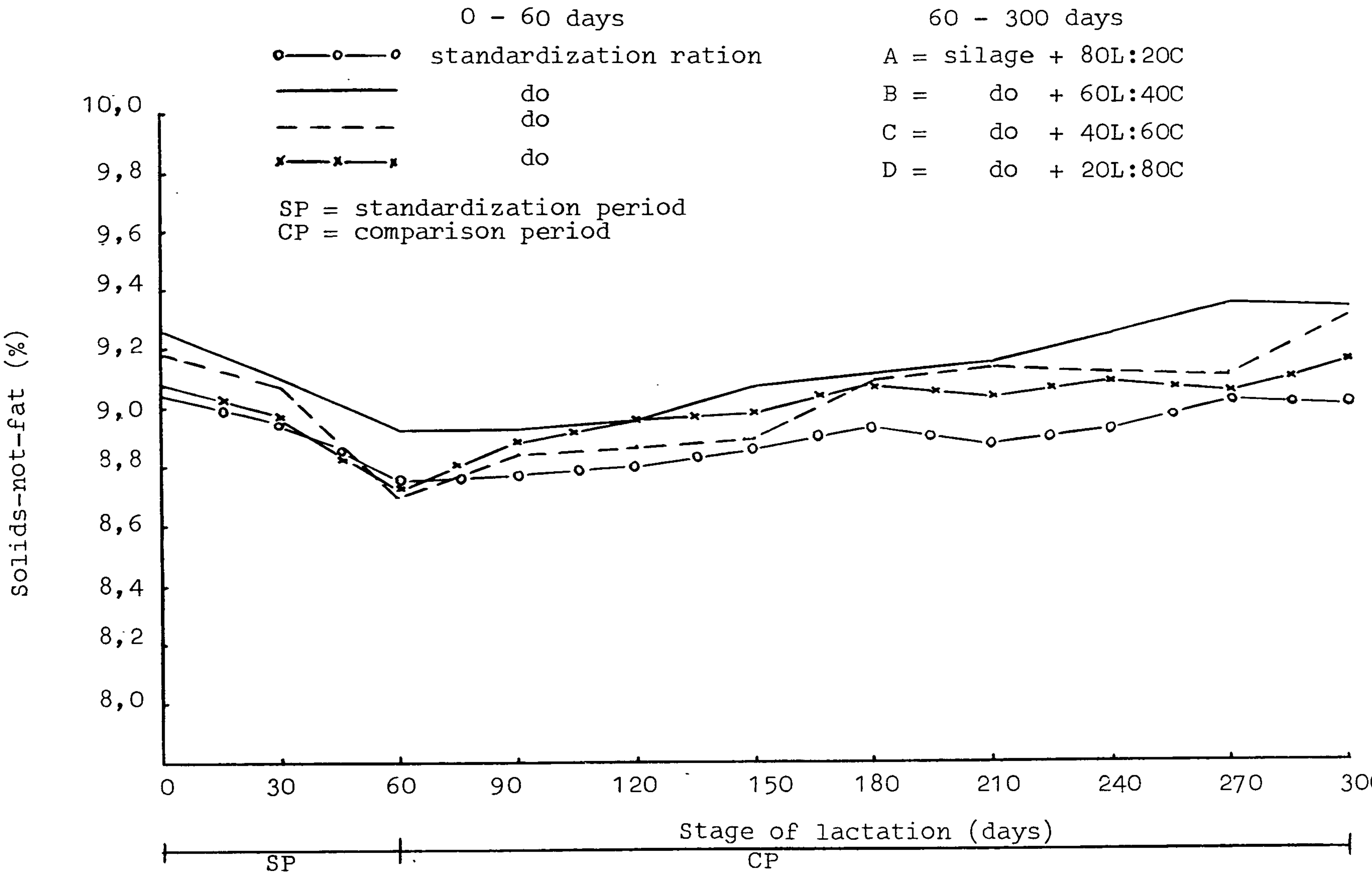

Fig.12 The effect of the feeding of standardization- and experimental rations (A, B, C & D) on percentage solids-not-fat of milk, produced by first-calf heifers

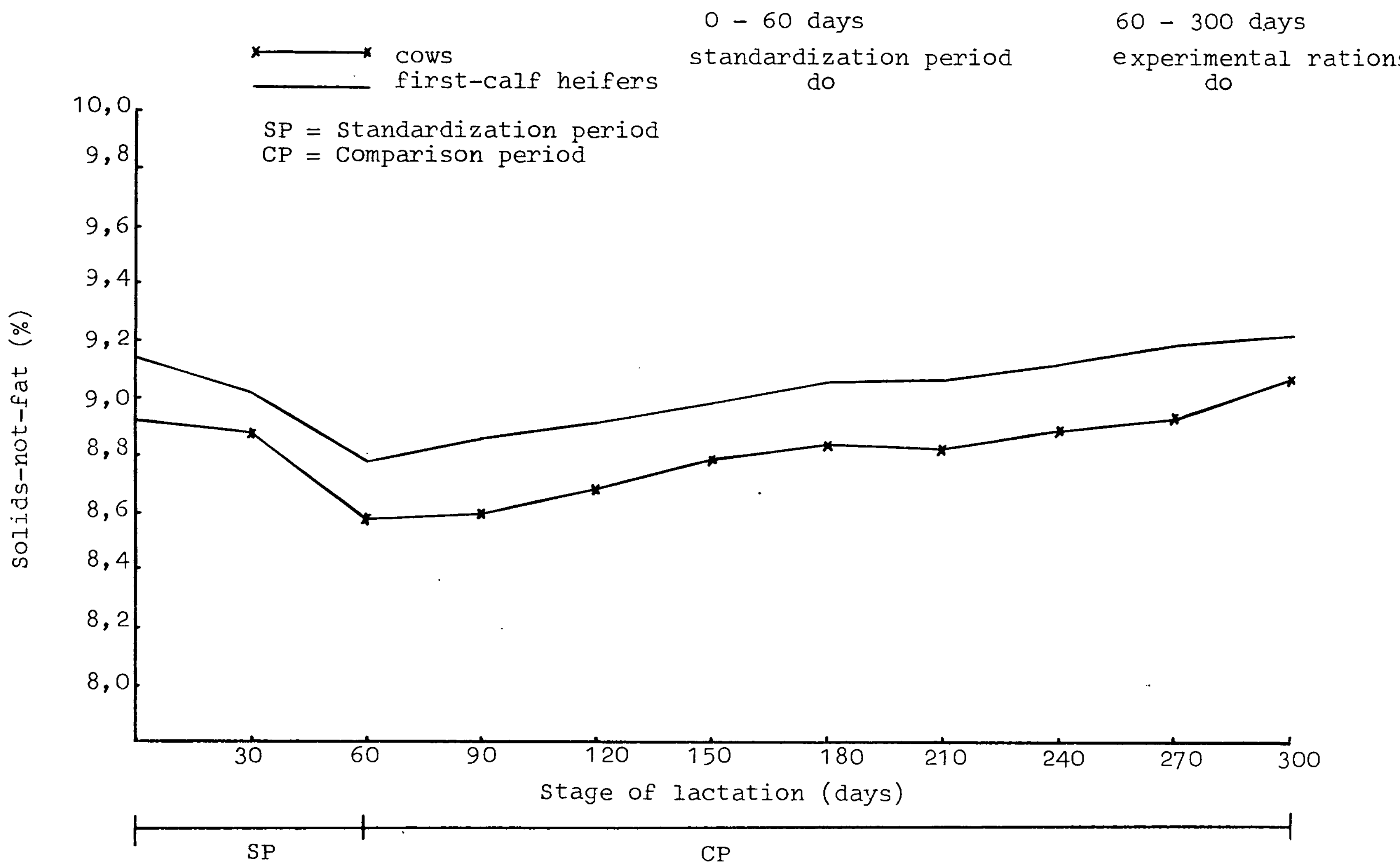

Fig. 13 The effect of age on percentage solids-not-fat of milk, irrespective of ration treatment cent was used (Ronning, 1960).

In contrast to these findings Putnam & Davis (1961) using relatively low producing cows, recorded no depression of milk fat content when pelleted complete feeds containing 25 per cent grass hay, were fed.

In the present study the lucern hay was ground through a 3,175 mm screen in preparation for pelleting. In combination with the various ratios of concentrates it was pelleted by compression through 9,525 mm diameter holes. Smaller sized pellets were used by Ronning (1960). In the study of Putnam & Davis (1961) hay was ground through a 9,525 mm screen and extruded from a 15,88 mm die resulting in a coarser grind and larger pellets. These workers did not observe any ration effect. The general depression of milk fat content observed in this study may be the result of the higher milk production level of the experimental animals and the differences in forage quality, hardness-, size- and coarseness of the pellets fed. Grind size of 0,64 cm and less is known to depress milk fat content (O'Dell et al., 1968). The grind size of 3,175 mm used in this study was considerably smaller than this critical size.

The effect of hardness of the pellets on fat production, is difficult to separate from other influences. A harder pellet, giving the pelleted ration a better physical form, could be an advantage. In this study increasing the proportion of lucern in the pellets caused an increase in hardness. A corresponding rise in fat percentage occurred. Differences,

however, were non-significant (P>0,05).
The fibre composition of the dry matter of the total ration consumed (maize silage plus pelleted ration) was 22,99; 19,73; 16,97 and 13,21 per cent for rations A, B, C and D, respectively. Ration D had a crude fibre content below the recommended minimum of 15,6 per cent crude fibre (Lofgren & Warner, 1970), resulting in a depression of the fat content of milk. Hawkins (according to Larkin & Fosgate, 1970) suggested that at least 14 to 16 per cent crude fibre is necessary for most cows on a complete ration. A fat percentage decline using a complete feed with a fibre content of 12 per cent was reported by Villavicencio, Rusoff, Girouard & Waters (1968).
In the present experiment the daily intake of between 2,30 and 2,51 kg maize silage (dry matter) in addition to the pellets, appeared to be insufficient to prevent a depression of the fat content. In contrast to this finding, Chalupa _et al_. (1970) found that the feeding of 1,4 or 2,8 kg corn silage (dry matter) in addition to concentrates and pelleted forage, produced a significant increase in milk fat percentage.
Various biochemical parameters have been studied and numerous postulations put forward to explain the decline in fat content. These include;(i) low rumen acetate production on ground roughage or high concentrate diets (Tyznik, according to Jorgensen, Schultz & Barr, 1965); (ii) high propionate production having an antiketogenic effect (van Soest & Allen, 1959); (iii) high propionate production suppressing the level

of non-sterified fatty acids in the blood via the action of glucose and insulin (McClymont & Vallance, 1962); and (iv) altered buffer capacity within the rumen (Emery, Brown & Thomas, 1964).

Acetate is used and is probably essential for synthesis of short chain fatty acids in milk fat (Popják, 1952). The feeding of acetate salts or acetic acid to cows with low fat may cause recovery toward a more normal milk composition (Rook & Balch, 1961).

Some observations which have been made do not substantiate this theory of acetate production (van Soest, 1963). For example, (a) there is no conclusive evidence that an acetate deficiency really exists, since the decline in the molar proportion of the rumen acetate could be the result of an increased production of propionic acid, and blood studies show no important drop in blood acetic acid associated with low milk fat (van Soest & Allen, 1959); (b) the absolute concentrations of rumen acetate are not significantly less on restricted roughage or high concentrates (van Soest & Allen, 1959); (c) the feeding of sodium propionate tends to cause low milk fat (Hawkins, 1959); and (d) fasting and reduction of intake causes an increase in the milk fat concentration (Smith, Howat & Roy, 1938).

Cows eating low-roughage-high-grain rations produce less saliva and their rumen content is more acid than that of cows fed usual rations. Saliva contains bicarbonates which help to control the acidity in the rumen. This may account for normalization of low fat levels of milk after feeding of bicarbonate of soda (Reid, 1964).

A significant increase in the proportion of rumen acetate, together with a decrease in propionate and valerate, was recorded when bentonite was added to fat-depressing rations (Rindsig, Schultz & Shook, 1969).

The individual effects of the finely ground lucern, restricted roughage feeding (ration C and D), low fibre content (ration D) and the physical structure of the experimental pellets on depression of milk fat, are difficult to separate when inter= preting the results of this study. The presence of more than one of these factors in a ration treatment, probably has an exaggerated depressive effect on milk fat content.

Irrespective of treatment there were non-significant ($P>0,05$) differences between the fat percentage of milk produced by cows and first-calf heifers.

The trend in percentage of fat produced in milk by animals during the lactation in the four treatment groups is shown in Figures 14 and 15. Depending on the experimental rations fed and the age group the minimum percentage of fat in milk produced by cows and first-calf heifers occurred between 90 and 210 days after parturition.

The percentages of total solids in milk produced by cows and heifers in the four treatment groups are shown in Figures 16, 17 and 18. Total milk solids declined after calving until the 90th day of lactation. Thereafter the total solids stayed more or less constant until the 150th to 180th day of

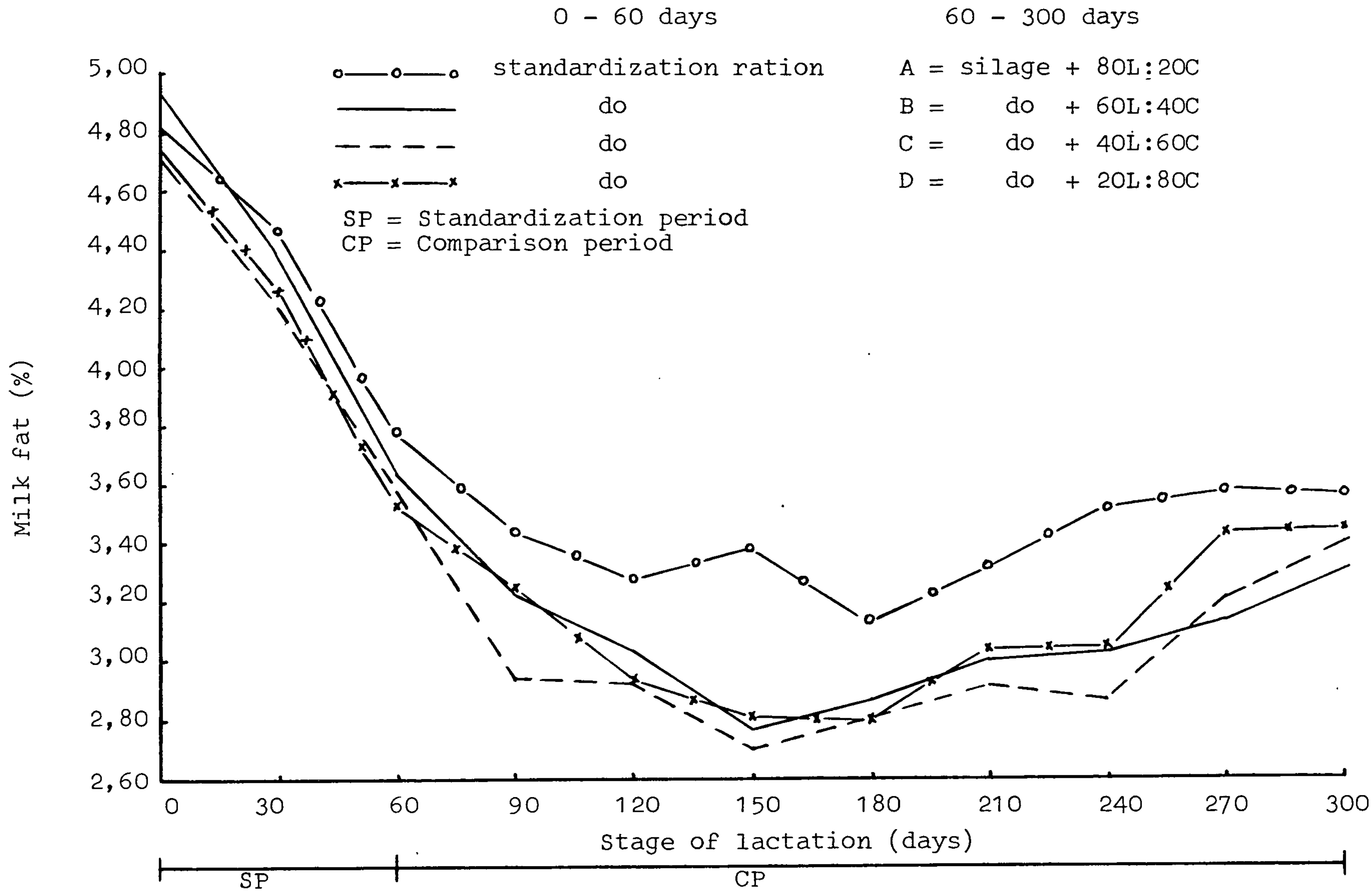

Fig.14 The effect of the feeding of standardization- and experimental rations (A, B, C & D) on fat percentage of milk, produced by cows

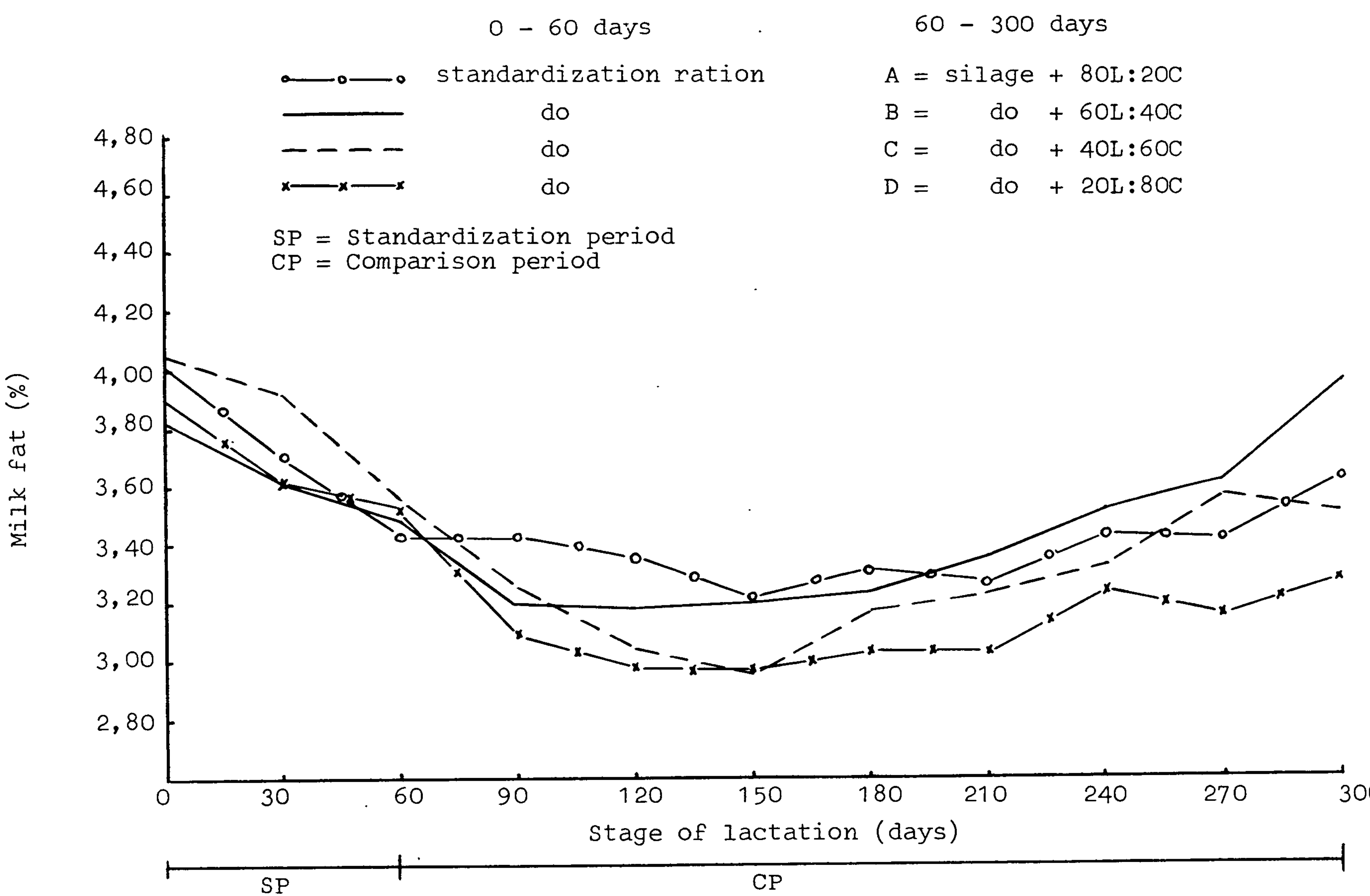

Fig.15 The effect of feeding of standardization- and experimental rations (A, B, C & D) on fat percentage of milk, produced by first-calf heifers

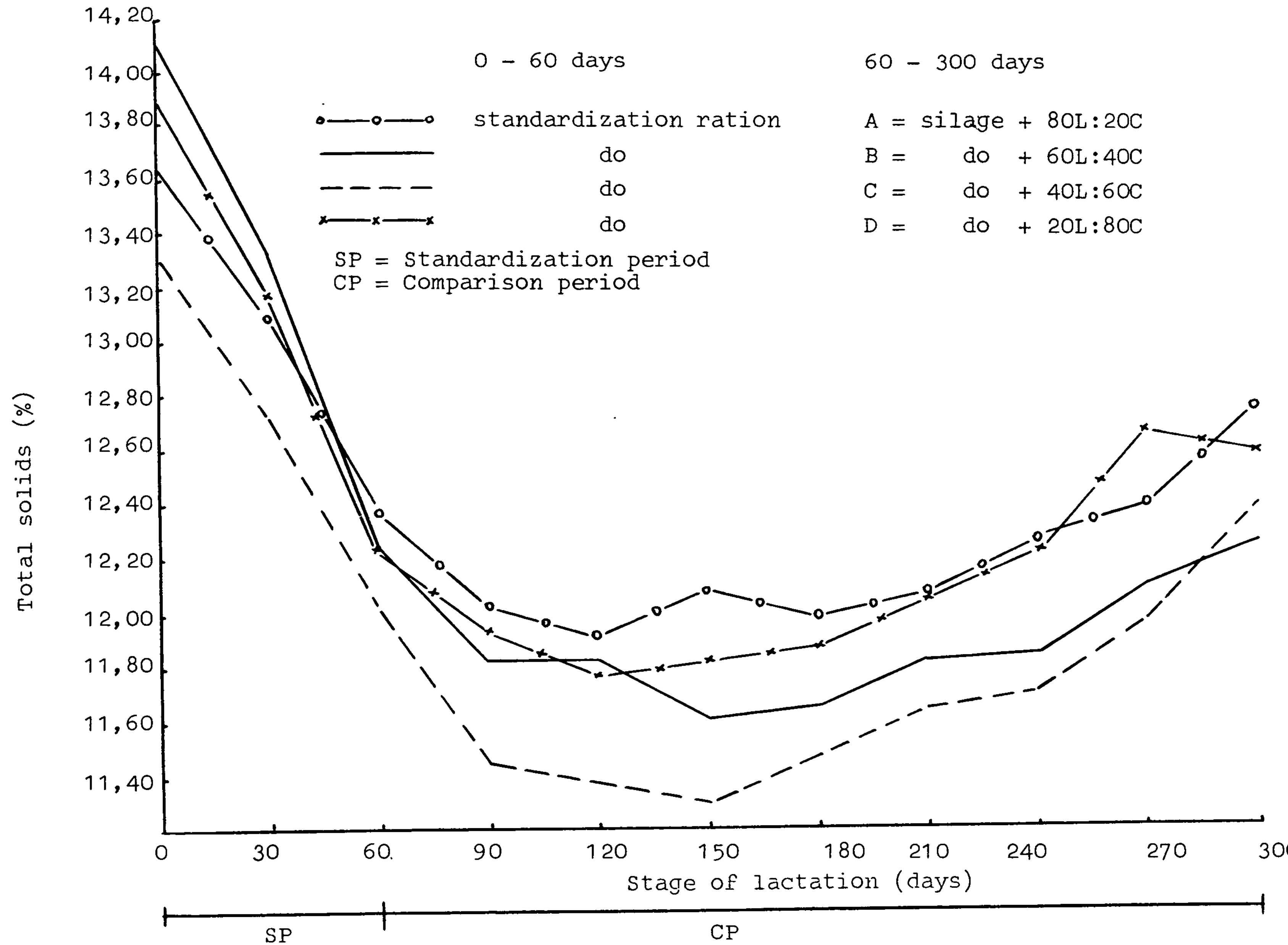

Fig.16 The influence of the feeding of standardization- and experimental rations (A, B, C & D) on percentage total solids of milk produced by cows

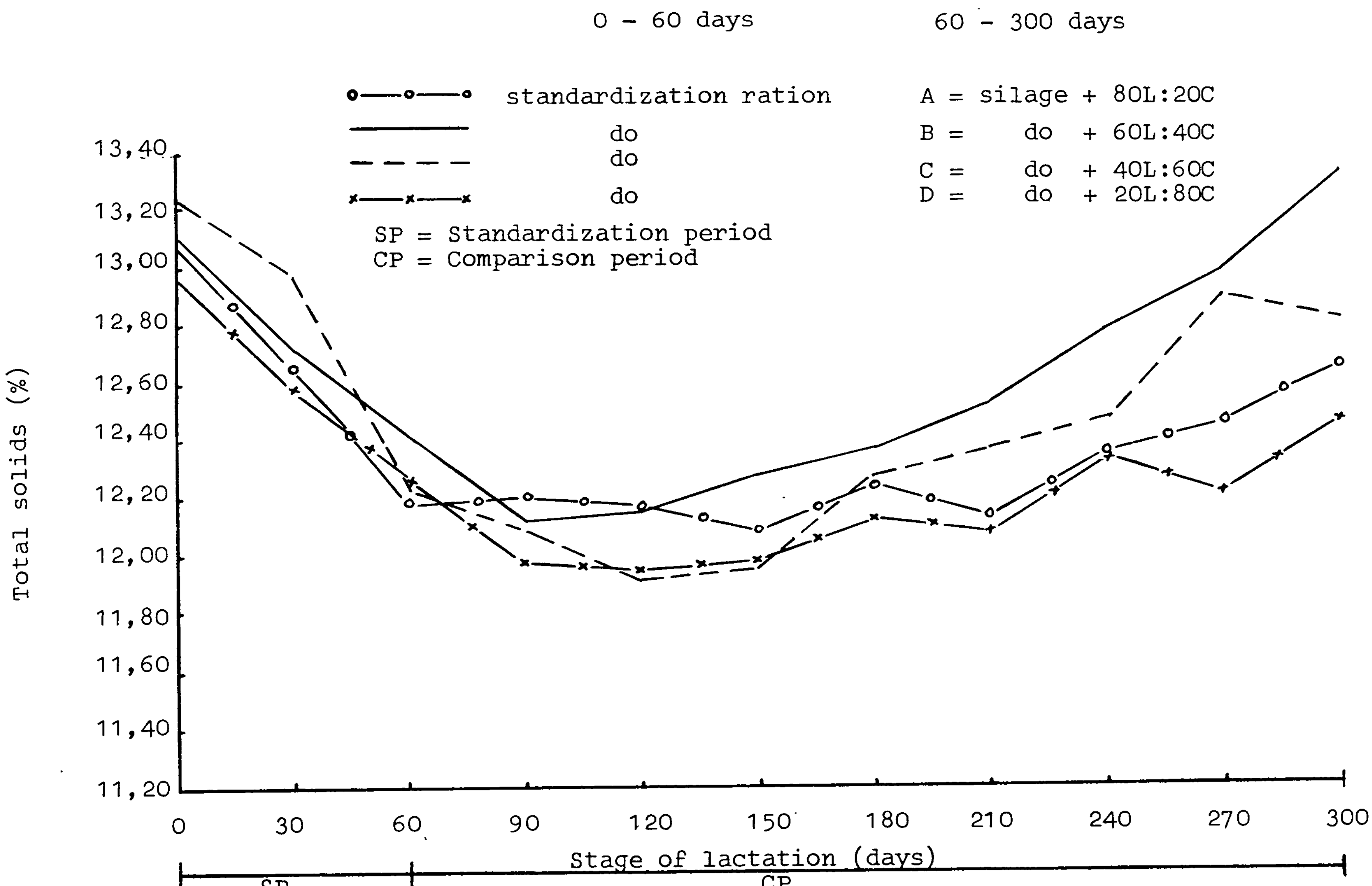

Fig.17 The influence of the feeding of standardization- and experimental rations (A, B, C & D) on percentage total solids of milk produced by first-calf heifers

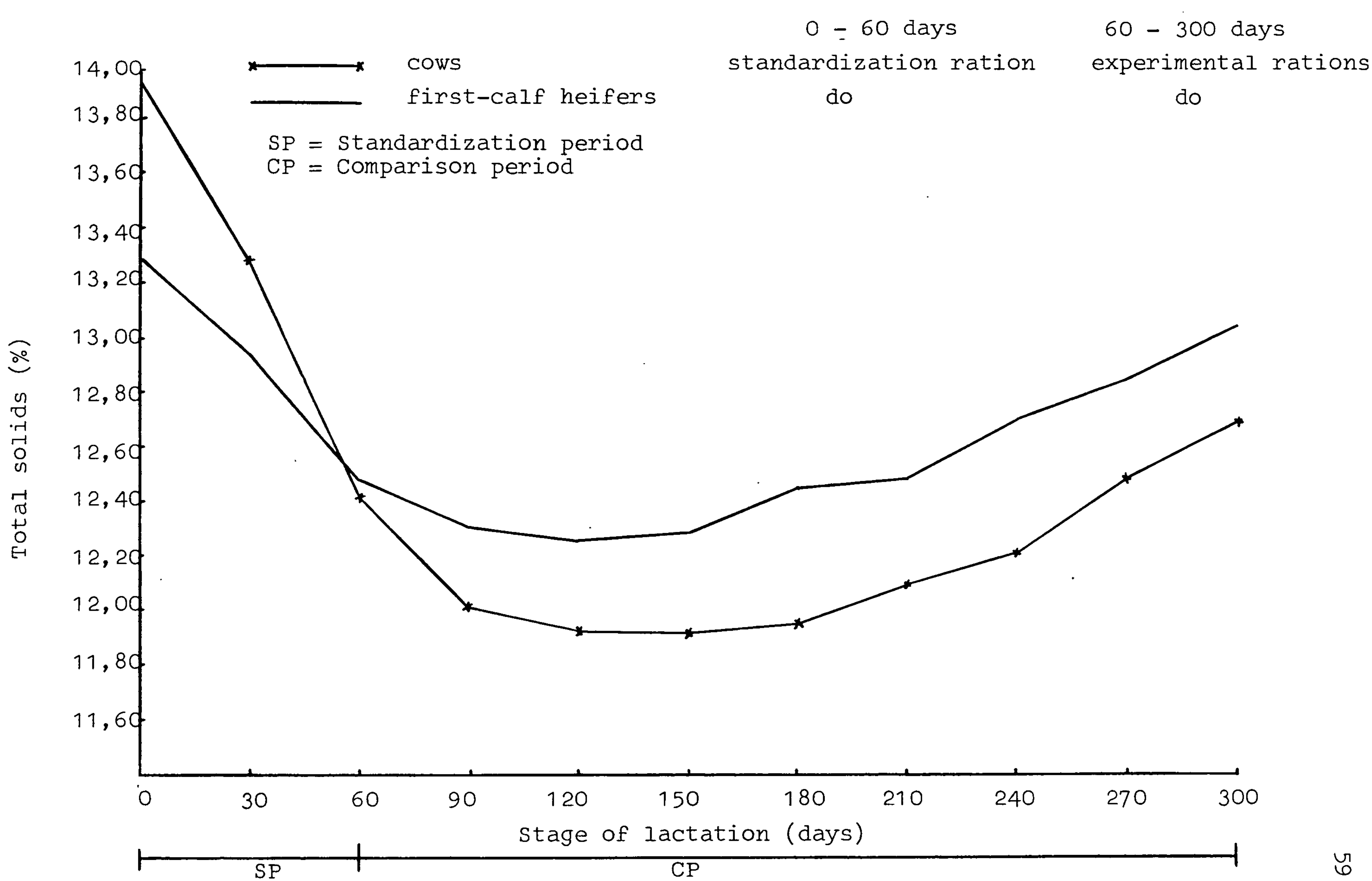

Fig.18 The effect of age on percentage total solids of milk, irrespective of ration treatment

lactation and then increased considerably during late lacta= tion.

During all stages of the comparison period, first-calf heifers produced milk with a significant ($P<0,01$) higher percentage of total solids than that produced by cows, irrespective of ration treatment. This is in agreement with the results from Waite et al. (1956).

The milk yield and composition of milk produced by cows during the digestibility trial is summarized in Table 11.

The results of the digestibility trial indicated that ration treatments had a non-significant effect on milk production and milk composition. The results are not directly comparable to those obtained with the 64 experimental animals because the digestibility trial was conducted only over the first five months of lactation. In the digestibility trial the percentage nitrogen and energy of milk were non-significantly ($P>0,05$) affected by ration although small differences existed.

2.3 Chemical composition of the dry matter of the experimen= tal rations consumed

The chemical composition of the dry matter of the maize silage, pellets and total experimental rations consumed, is presented in Tables 12, 13 and 14.

The gross energy contant (kcal/g) of the pelleted rations in= creased significantly ($P<0,05$) as the lucern portion in the ration increased (Table 13).

The percentage crude protein of the pelleted rations varied

Table 11 Mean composition of milk and mean daily milk production of animals during digestibility trial

Variable description	Units	A	B	C	D	Diff[1]
Daily production of;		maize silage + 80L:20C	60L:40C	40L:60C	20L:80C	
Milk	kg	19,81	21,89	19,34	22,58	NS
Fat	kg	0,70	0,74	0,63	0,59	NS
4% fat corrected milk	kg	18,38	19,82	17,22	17,88	NS
Solids corrected milk	kg	19,17	19,75	17,47	19,04	NS
Chemical composition of milk;						
Energy	kcal/100ml	71,73	67,60	67,52	63,25	NS
Nitrogen	%	0,5128	0,5175	0,5249	0,5255	NS
Protein	%	3,27	3,30	3,34	3,35	NS
Milk fat	%	3,49	3,33	3,25	2,63	NS
Solids-not-fat	%	8,66	8,78	8,73	8,88	NS
Total solids	%	12,15	12,11	11,98	11,51	NS

1 Differences: NS; non-significant (P>0,05)

Table 12 Mean chemical composition of the dry matter of maize silage

Variable description	Units	Composition
Dry matter	%	28,14
Gross energy	kcal/g	4,38
Nitrogen	%	1,41
Crude protein	%	8,78
Cellulose	%	25,06
Crude fibre	%	21,90
Organic matter	%	92,59

Table 13 Mean chemical composition of dry matter of varying lucern:concentrate ratios, in pellet form

Variable description	Units	A 80L:20C	B 60L:40C	C 40L:60C	D 20L:80C	Diff[1]
		Ration treatment				
Dry matter	%	90,71	91,17	91,31	90,86	NS
Gross energy[2]	kcal/g	4,34	4,31	4,27	4,27	*
Nitrogen	%	2,81	2,94	2,91	2,91	NS
Crude protein	%	17,56	18,37	18,20	18,19	NS
Cellulose[3]	%	26,54	22,53	19,29	15,31	**
Crude fibre[4]	%	23,16	19,34	16,11	12,01	**
Organic matter	%	90,53	90,55	90,18	90,49	NS

1 Differences: *$P<0,05$; ** $P<0,01$
NS; non-significant ($P>0,05$)

2 A $\overset{*}{>}$ C, D

3 A $\overset{**}{>}$ B, C & D
B $\overset{**}{>}$ C & D
C $\overset{**}{>}$ D

4 A $\overset{**}{>}$ B, C & D
B $\overset{**}{>}$ C & D
C $\overset{**}{>}$ D

Table 14 Mean chemical composition of the dry matter of the total ration consumed (maize silage and varying lucern:concentrate ratios, in pellet form)

Variable description	Units	Ration treatment A	B	C	D	Diff[1]
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
Gross energy[2]	kcal/g	4,34	4,32	4,29	4,30	**
Crude protein	%	16,30	17,00	16,82	17,03	NS
Cellulose[3]	%	26,31	22,88	20,12	16,44	**
Crude fibre[4]	%	22,99	19,73	16,97	13,21	**
Organic matter	&	90,82	90,87	90,55	90,90	NS

1 Differences: **P<0,01

NS; non-significant (P>0,05)

2 A $\overset{**}{>}$ C

A $\overset{*}{>}$ D

B $\overset{*}{>}$ C

3 A $\overset{**}{>}$ B, C & D

B $\overset{**}{>}$ D

B $\overset{*}{>}$ C

C $\overset{**}{>}$ D

4 A $\overset{**}{>}$ C & D

A $\overset{*}{>}$ B

B $\overset{**}{>}$ D

B $\overset{*}{>}$ C

C $\overset{*}{>}$ D

only very slightly, being 17,56; 18,37; 18,20 and 18,19 per cent respectively for pelleted rations 80L:20C; 60L:40C; 40L:60C and 20L:80C. The differences were non-significant. The chemical analyses showed that the crude protein contents (Table 13) were slightly higher than the estimated values presented in Table 4.

Differences in cellulose and crude fibre content of the pellets were highly significant ($P<0,01$). As expected, the percentages increased with an increase in the lucern portion in the pellets (Table 13). The organic matter contents of the four experimental pelleted rations did not differ signi= ficantly from each other. The actual chemical composition of the total ration consumed (Table 14) also differed slight= ly from the estimated composition (Table 4) and showed the same tendency as the pellet composition alone (Table 13).

2.4 Digestibility of the experimental rations

2.4.1 Introduction

The digestibility of a food can be defined as that portion which is not excreted in the faeces and which is, therefore, assumed to be absorbed by the animal. In general it is expressed in terms of dry matter and as a percentage viz. the digestibility coefficient (McDonald et al., 1973). Type and amount of concentrate or roughage or both, are important. Cows of a high production potential usually respond to a favourable change in ration composition (Bloom, Jacobson, McGilliard, Homeyer & Heady, 1957).

The digestibility of feeds is usually determined in non-producing animals consuming rather small amounts of feed. However, one cannot assume that coefficients of digestibility obtained in such investigations can also apply to high-producing cows consuming large amounts of feed. For this reason the digestibility of the four experimental rations consumed was determined by means of a digestibility trial using four lactating dairy animals as described under 1.5.

2.4.2 Discussion of results

The digestibility of the components of the experimental rations consumed by lactating dairy animals is summarised in Table 15.

With the exception of crude fibre and cellulose the digesti= bility of all the components increased with reduction in lucern content. In this study nutrient allowances were in= creased by adding greater proportions of concentrates which should increase digestibility.

This is in agreement with the conclusions of Bloom, Jacobson, Allen, McGilliard & Homeyer (1957); Putnam & Loosli (1959) and Flatt et al.(1969a). Others observed no such effect (Kane, Jacobson & Moore, 1961).

Most reports agree that fibre digestibility is decreased when the concentrate portion of the diet is increased, probably due to altered rumen fermentation (Putnam & Loosli, 1959; Lovell & Rusoff, 1963 and Kesler & Spahr, 1964).

In the present experiment the digestibility of the cellulose

Table 15 Mean digestibility coefficients of components of experimental rations consumed by lactating dairy animals

Variable description	Units	Ration treatment A	B	C	D	Diff[1]
			maize silage +			
		80L:20C	60L:40C	40L:60C	20L:80C	
Dry matter[2]	%	55,55	59,50	62,03	65,33	*
Energy[3]	%	54,34	58,61	61,59	65,34	*
Nitrogen	%	67,85	71,83	73,10	75,40	NS
Crude protein	%	67,85	71,83	73,10	75,40	NS
Cellulose	%	44,65	40,88	45,00	43,68	NS
Crude fibre	%	28,41	26,30	29,09	24,91	NS
Organic matter[4]	%	58,40	61,83	64,73	68,03	*

1 Differences: *P<0,05, NS; non-significant (P>0,05)

2 D $\overset{*}{>}$ A

3 D $\overset{*}{>}$ A

4 D $\overset{*}{>}$ A

varied slightly between ration treatments, differences, however, were non-significant ($P>0,05$).

With the exception of ration C (maize silage + 40L:60C) there was a tendency towards reduction in crude fibre digest= ibility with increase in the concentrate content. Differences were non-significant.

The percentage digestible nutrients of the experimental rations consumed, are presented in Table 16. With the excep= tion of digestible crude fibre and cellulose, increasing the proportion of concentrates in the ration resulted in an in= crease in percentage digestible nutrients. Digestible crude fibre and -cellulose decreased as the concentrate portion in the ration increased, differences being highly significant ($P<0,01$).

2.5 Daily consumption of nutrients

2.5.1 Introduction

Voluntary intake is an important factor determining total energy consumption and hence animal performance (Blaxter, 1967). The exact nature of the stimuli involved in determining the amount of feed a cow will voluntarily consume has not been established (Rakes, 1969). Limitations on the amount of feed a cow will consume arise from physiological functions, the physical characteristics of the ingredients in the ration, the amount of feed available, space available in the diges= tive tract, the amount of undigested residue contained in the digestive tract, rate of digestion, individuality,

Table 16 Mean digestible nutrients of experimental rations consumed by lactating dairy animals

Variable description	Units	A	B	C	D	Diff[1]
			maize silage +			
		80L:20C	60L:40C	40L:60C	20L:80C	
Digestible energy[2]	kcal/g	2,359	2,534	2,640	2,810	*
Metabolizable energy[3]	kcal/g	1,928	2,086	2,175	2,347	*
Digestible protein	%	11,09	12,26	12,29	12,83	NS
Digestible cellulose[4]	%	11,73	9,40	9,06	7,26	**
Digestible crude fibre[5]	%	6,51	5,21	4,94	3,15	**
Digestible organic matter[6]	%	53,02	56,18	58,61	61,85	*

1 Differences: *P<0,05, ** P<0,01, NS; non-significant (P>0,05)

2 D $\overset{*}{>}$ A

3 D $\overset{*}{>}$ A

4 A $\overset{**}{>}$ B, C & D

B $\overset{**}{>}$ D

C $\overset{*}{>}$ D

5 A $\overset{**}{>}$ D

B $\overset{*}{>}$ D

6 D $\overset{*}{>}$ A

frequency of feeding, milk production level and heat produc= tion per cow.

Physical- and physiological factors regulating feed intake varied in relation to the digestibility of the feed. At low digestibility (53 to 65 per cent) they are body mass (reflect= ing roughage capacity), indigestible residue (reflecting rate of passage of undigested residue), and dry matter digestibi= lity. At higher digestibility (66 to 80 per cent) intake was associated with capacity to metabolize nutrients (metabolic size), milk production and the percentage digestibility (Conrad, Pratt & Hibbs, 1962). It has been suggested that at digestibilities below 65 per cent, rumen fill is a pre= dominant controlling factor regulating feed intake while above this other mechanisms are involved (Conrad, 1966). Waldo (1967) suggested that this figure is not absolute and that it may change depending on the requirement of the animal. On balance, it is difficult to visualize a dramatic change in feed intake controlling factors as diet digestibility in= creases. It is probably a gradual change with one factor supplanting the other (Warner, 1974).

When the diet is high in nutritive value, food intake may be regulated to keep energy intake constant (Montgomery & Baum= gardt, 1965). The digestion coefficients at which physical limitations on eating capacity were no longer dominant and at which the influence of production became dominant varied with body size and milk production (Conrad, 1971).

The larger cows overcome the limitations of poor quality roughage (low in digestibility) at a lower digestibility level than the smaller cow. Secondly, high producing cows require rations of higher digestibility to attain their maximum inherited level of production. Conrad (1971) con= cluded that since the digestive tract is limited in size, it is apparent that small breeds need rations of the highest digestibility to produce at a level commensurate with their inherited capacity.

Because of the smaller size of the digestive tract of first-calf heifers compared to that of cows (Morrison, 1957), large portions of poor quality roughage do not seem desirable for these animals.

The amount of digestible energy which high-producing cows can or will consume from most forages is insufficient to meet their nutritional needs (Swanson, Hinton & Miles, 1967). This energy deficiency can be balanced by

(a) increased forage digestibility

(b) increased efficiency of utilizing digested nutrients

(c) increased supplementation with concentrates without a comparable decrease in intake of net energy from forage (Crampton, Donefer & Lloyd, 1960).

Maximum nutrient intake is reached when concentrates consti= tute 50 to 60 per cent of the total dry matter consumed. Maximum intake will vary due to individual preferences for certain feeds. Increasing the proportion of concentrates above 60 per cent may result in a slight reduction in intake

(Kesler & Spahr, 1964). Their data indicated that milk production, body mass and unaccounted-for individual cow variation were considerably more important in regulating feed intake than the proportion of concentrates in the ration, especially when concentrates constituted at least 45 per cent of the dry matter fed. Forages of distinctly different quality probably would change the range in which the greatest intake occurred.

Intakes of the high-concentrate rations appeared to be related to energy expenditures of the animal (Elam, 1968). McCullough (cited by Coppock, Noller, Crowl, McLellon & Rhykerd, 1972) suggested that blending forage and grain in a complete ration will induce most cows to eat to meet their energy requirements.

To investigate the possibility that ruminants possess the ability to "measure" calories, Montgomery & Baumgardt (1965) fed four pelleted alfalfa meal:corn rations (digestibility of dry matter varying between 55,9 and 68,9%) to Holstein heifers under completely ad lib. conditions. The digestible energy concentration increased with the addition of corn but the feed dry matter intake decreased as the digestibility of the ration increased. The net effect of these changes was that the animals voluntarily maintained the same digestible calorie intake on each of the four rations. Montgomery & Baumgardt, op cit. suggested that the digestible dry matter x density characteristics of the rations were such that fill did not limit intake; the animals energy-regulating mechanism becoming operative. They concluded that any further increase in calorie density will result in a decrease in food intake so that the calories of the digestible energy or metabolizable energy consumed remain constant, although there might be a change in the types of metabolites.

Using high-producing cows fed on rations with dry matter digestion coefficients varying between 71,6 and 78,2 per cent, Flatt et al.(1969a), came to the same conclusion.

Moe et al.(1971) reported that intense selection of dairy cattle for high milk yield resulted in a situation in which the genetic ability to produce milk during early lactation exceeded the ability of the animal to ingest sufficient feed to meet requirements for energy. High-producing lactating dairy cows have an immense capacity for mobilizing body fat at the peak of lactation and body composition changes can occur without being accurately reflected in body mass changes (Flatt, 1966).

The combined energy contribution from body fat and feed should therefore enable the cow to reach a higher peak of milk pro= duction during the early stages of lactation when nutrient requirements are at the highest (Hemken, 1971). Voluntary feed intake generally increases during the first 8 to 12 weeks of the lactation. The pattern in high producing cows is usually a gradual depletion of fat reserves after calving, followed by a period of relative balance and finally, a period of fat deposition in late lactation (Miller et al., 1973).

The extent of the role that fat and other control mechanisms play on voluntary feed intake during these first critical weeks of lactation is not clearly understood (Hemken, 1971). Feeding large proportions of roughage does not seem desirable in a complete ration for high producing animals. Feeding rations containing relatively low roughage proportions to cows with lower production potentials or those in the later stages of lactation tend to increase body fat deposition (Baumgardt, 1967 and Rakes, 1969). Best results have been reported with complete rations containing roughage:concen= trate proportions of 60:40 and 30:70. An all concentrate ration gave the highest milk production but milk fat content was seriously depressed and over conditioning was noted. Milk yield was depressed on the 90:10 roughage:concentrate diet and animals lost condition (Ronning & Laben, 1966).

2.5.2 Discussion of results

Daily consumption of dry matter, gross energy and metaboliz= able energy by cows and first-calf heifers, fed four experi= mental rations during the comparison period, are summarised in Tables 17 and 18.
Differences in dry matter and energy intake by the experi= mental animals on various rations were non-significant ($P>0,05$). The dry matter and gross energy intake of cows tended to decrease (Table 17) as the dry matter digestibility of the ration increased. Similarly, as the metabolizable energy concentration increased (increasing with the decreasing

Table 17 Mean daily consumption of maize silage and pelleted lucern:concentrate rations by cows during comparison period

Variable description	Units	Ration treatment A	B	C	D	Diff[1]
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
Daily consump= tion of:						
Dry matter						
silage	kg	2,38	2,29	2,17	2,07	NS
pellets	kg	16,40	15,45	14,78	15,11	NS
total	kg	18,78	17,74	16,95	17,18	NS
total	$g/W_{kg}^{0,75}$	150,88	145,73	137,61	142,04	NS
Dry matter intake as % of body mass	%	3,03	2,94	2,77	2,85	NS
Gross energy	kcal	81450	76640	72667	73747	NS
Metabolizable energy	kcal	36163	36986	36885	40362	NS

1 Differences: NS, non-significant (P>0,05)

Table 18 Mean daily consumption of maize silage and pelleted lucern:concentrate rations by first-calf heifers during comparison period

Variable description	Units	Ration treatment A	B	C	D	Diff[1]
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
Daily consump= tion of:						
Dry matter						
silage	kg	2,19	2,10	1,88	2,12	NS
pellets	kg	13,40	12,68	12,75	12,84	NS
total	kg	15,59	14,78	14,63	14,96	NS
total	$g/W_{kg}^{0,75}$	137,91	131,38	133,85	132,64	NS
Dry matter intake as a % of body mass	%	2,86	2,73	2,80	2,74	NS
Gross energy	kcal	67710	63877	62713	64307	NS
Metabolizable energy	kcal	30066	30827	31833	35202	NS

1 Differences: NS; non-significant (P>0,05)

proportion of lucern) the voluntary intake tended to decrease. As a result of this the kcal of metabolizable energy consumed remained more or less constant between rations.

The average daily milk yield of cows in each treatment group (Table 9) was related to the metabolizable energy intake of each group. This indicated that metabolizable energy intake by cows was associated with the metabolic size, milk produc= tion and the per cent dry matter digestibility (Conrad, 1971). A point at which fill no longer limited intake was probably reached in the case of the experimental cows. The influence of milk production and physiological factors apparently became dominant. The dry matter digestibility of the four experimental rations (varying between 55,55 to 65,33 per cent), the physical form of the pelleted rations, the larger body size and higher milk yield of the cows, enabled them to regulate the amount of food consumed in relation to daily energy needs; milk production requirements becoming dominant. By pelleting the total ration the cows were able to obtain sufficient metabolizable energy to meet their milk production requirements without being limited by rumen fill.

Montgomery & Baumgardt (1965) reported similar results with non-lactating Holstein heifers. However, the question arises whether lactating first-calf heifers can also regulate food intake to maintain equivalent energy intakes from pelleted rations of varying concentrate portions. The first-calf heifers in this study showed no appreciable decrease in dry matter intake as the dry matter digestibility of the ration increased (Table 18). The intake of dry matter per metabolic live mass was fairly constant being 137,91; 131,38; 133,85 and 132,64 $g/W_{kg}^{0,75}$ when ration A, B, C and D respectively, were consumed. Likewise the gross energy consumed remained more or less equal amongst rations. As the dry matter digest= ibility of the ration increased the metabolizable energy in= take tended to increase, differences being non-significant. This indicates that body mass (reflecting rumen size) proba= bly limited dry matter intake and the kcal of metabolizable energy consumed. Although metabolizable energy intake of first-calf heifers on ration D was greater than that on rations A, B and C, it was non-significant. The first-calf heifers probably could not overcome the limitation of the lower digestibility of rations A, B and C, compared to that of ration D, because of the limited size of the digestive tract and rate of passage of undigested residue. The rela= tively low digestibility of most high-roughage rations is such that intake may be limited by distention in some part of the tract (Baumgardt, 1967).

Conrad (1971) stressed the fact that larger cows overcome the limitations of poor quality roughage (low in digestibility) at a lower digestibility than smaller cows.

In this study the experimental cows overcame the problem of rations with a lower digestibility by consuming slightly more (although non-significant) of the specific ration due to their larger capacity whereas first-calf heifers could not overcome this problem. However, the non-lactating heifers fed all-pelleted rations in the study of Montgomery & Baumgardt (1965) voluntarily maintained the same digestible calorie intake on each ration. This may have been due to the lower daily energy requirements of non-lactating heifers in which case body capacity would not have been limiting. Because the daily energy requirements of the lactating first-calf heifers used in this study were considerably higher, body capacity was probably limiting.

Conrad (1971) stated that small breeds need rations of the highest digestibility to produce at a level commensurate with their inherited capacity. This statement may also be applic= able to first-calf heifers since those consuming ration D (maize silage + 20L:80C) showed a tendency (although non-significant) to produce more milk than those on the other rations. This could be due to the slightly higher metaboliz= able energy intake because of the higher digestibility of ration D.

Changes in daily dry matter intake (g per $W_{kg}^{0,75}$) by cows and first-calf heifers due to ration treatment and stage of lactation occurred and are presented in Figures 19 and 20. Differences in dry matter intake due to stage of lactation were significant ($P<0,01$), irrespective of ration treatment. Differences due to ration treatment were non-significant ($P>0,05$).

Irrespective of treatment, the cows increased their dry matter consumption until the fifth to sixth month following parturition before intake started to decline.

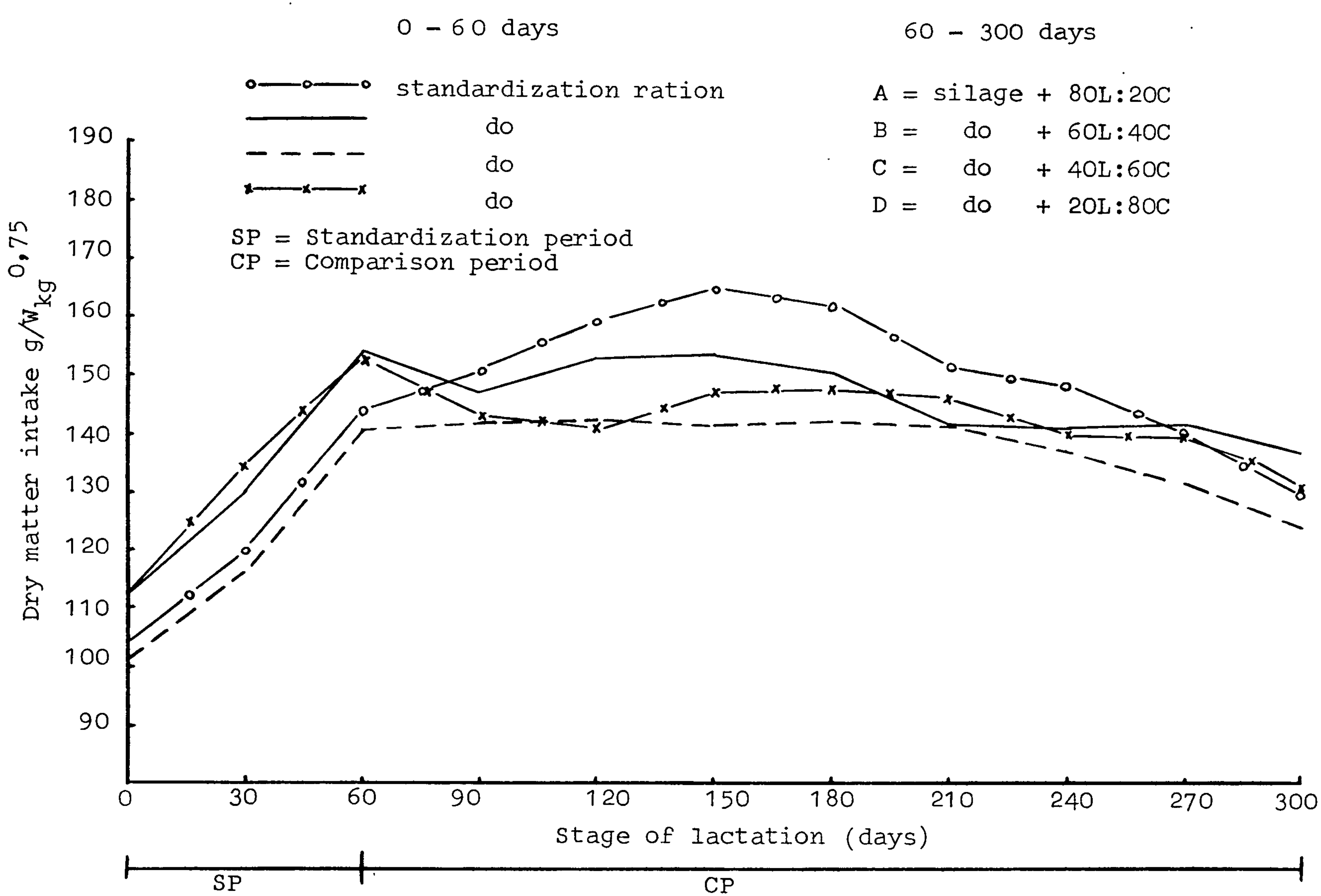

Fig.19 The influence of the feeding of standardization- and experimental rations (A, B, C & D) on dry matter intake by cows

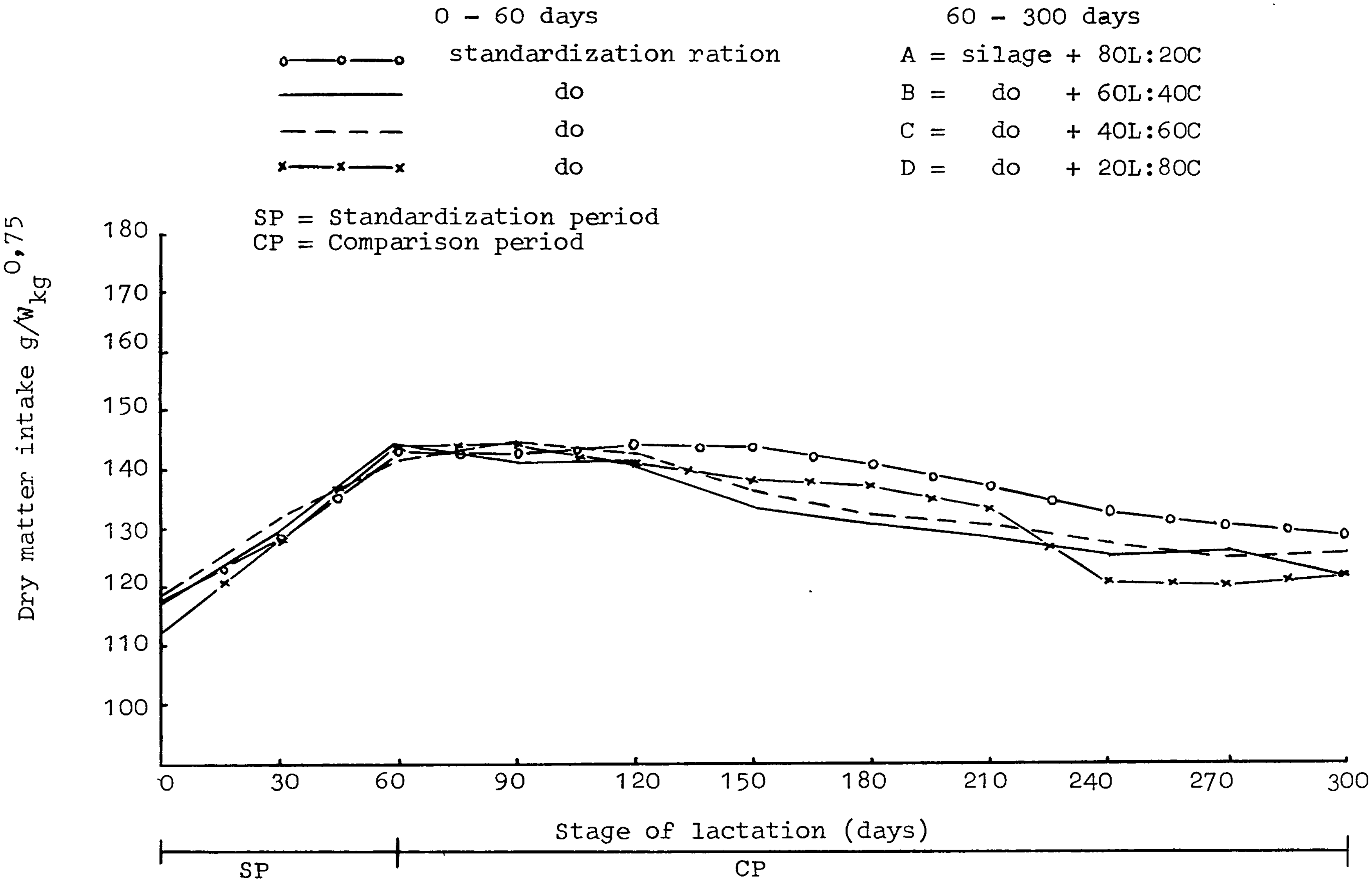

Fig.20 The influence of the feeding of standardization- and experimental rations(A, B, C & D) on dry matter intake by first-calf heifers

A gradual increase in intake of dry matter by first-calf heifers occurred until the 60th day after calving, irrespec=tive of ration treatment. From the 60th to 120th day, consumption stayed at a constant level after which dry matter intake gradually began to decline.

Cows on all the rations consumed significantly ($P<0,01$) more dry matter during the fifth to ninth month of lacta=tion than the first-calf heifers.

Irrespective of pellet ration composition, age of animal or lactation stage,maize silage intake was more or less con=stant.

The effect of ration and stage of lactation on gross energy intake by cows and first-calf heifers during the comparison period, is shown in Figures 21 and 22.

Cows fed ration A (maize silage + 80L:20C) showed a signi=ficantly ($P<0,01$) greater gross energy intake during the fourth to eighth month of lactation than during the 10th month. Non-significant differences in gross energy intake due to stage of lactation occurred when cows consumed ration B (maize silage + 60L:40C). Cows fed ration C consumed significantly ($P<0,05$) more gross energy during the sixth and seventh month of lactation than during the 10th month. Significantly ($P<0,05$) more gross energy was consumed during the sixth month and seventh month than during the fourth month of lactation when cows were on ration D.

Stage of lactation had a non-significant ($P>0,05$) effect on the consumption of gross energy when rations A, B and C were fed to first-calf heifers. First-calf heifers fed ration D

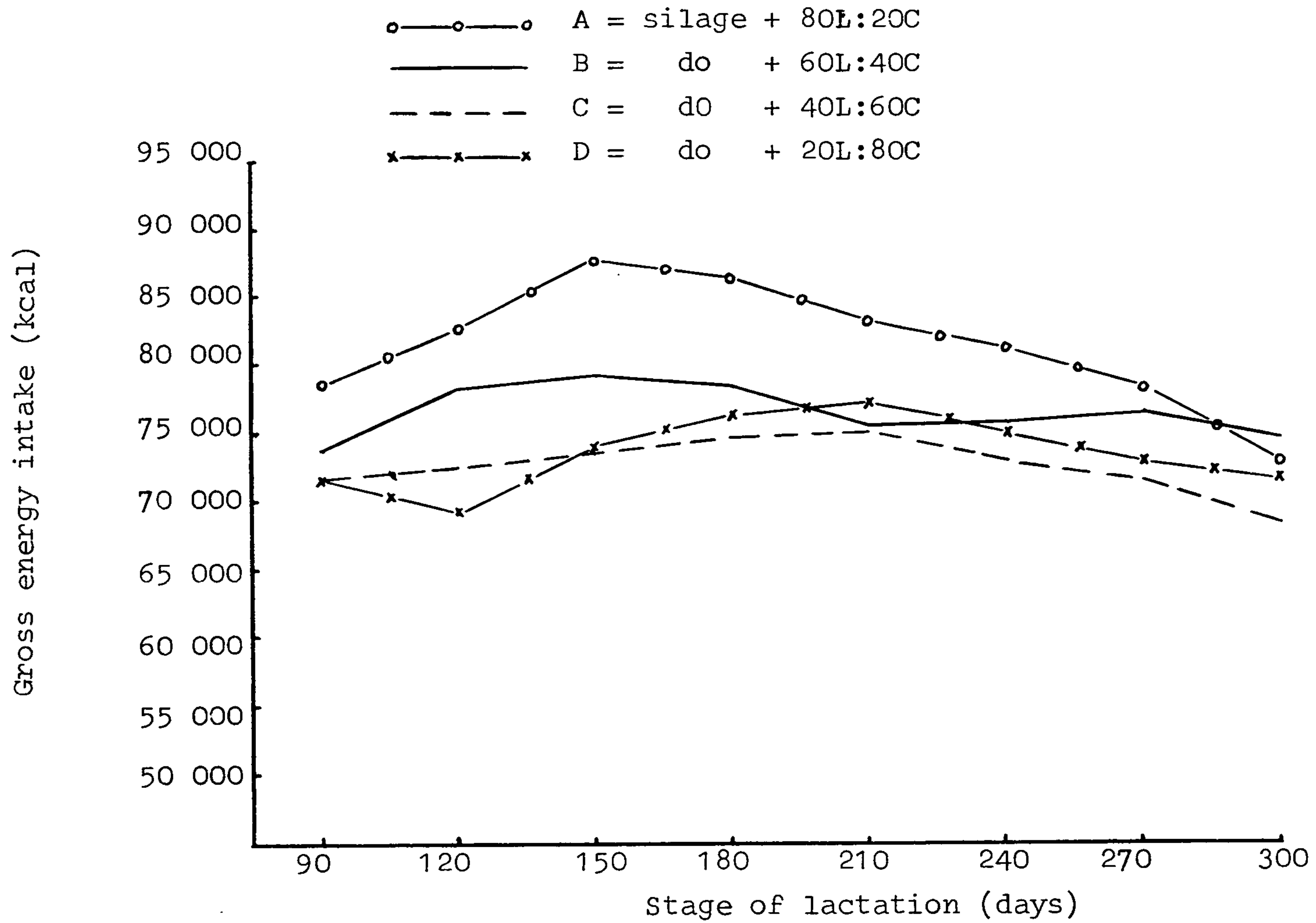

Fig.21 Influence of ration (A, B, C & D) effect on gross energy intake by cows during comparison period

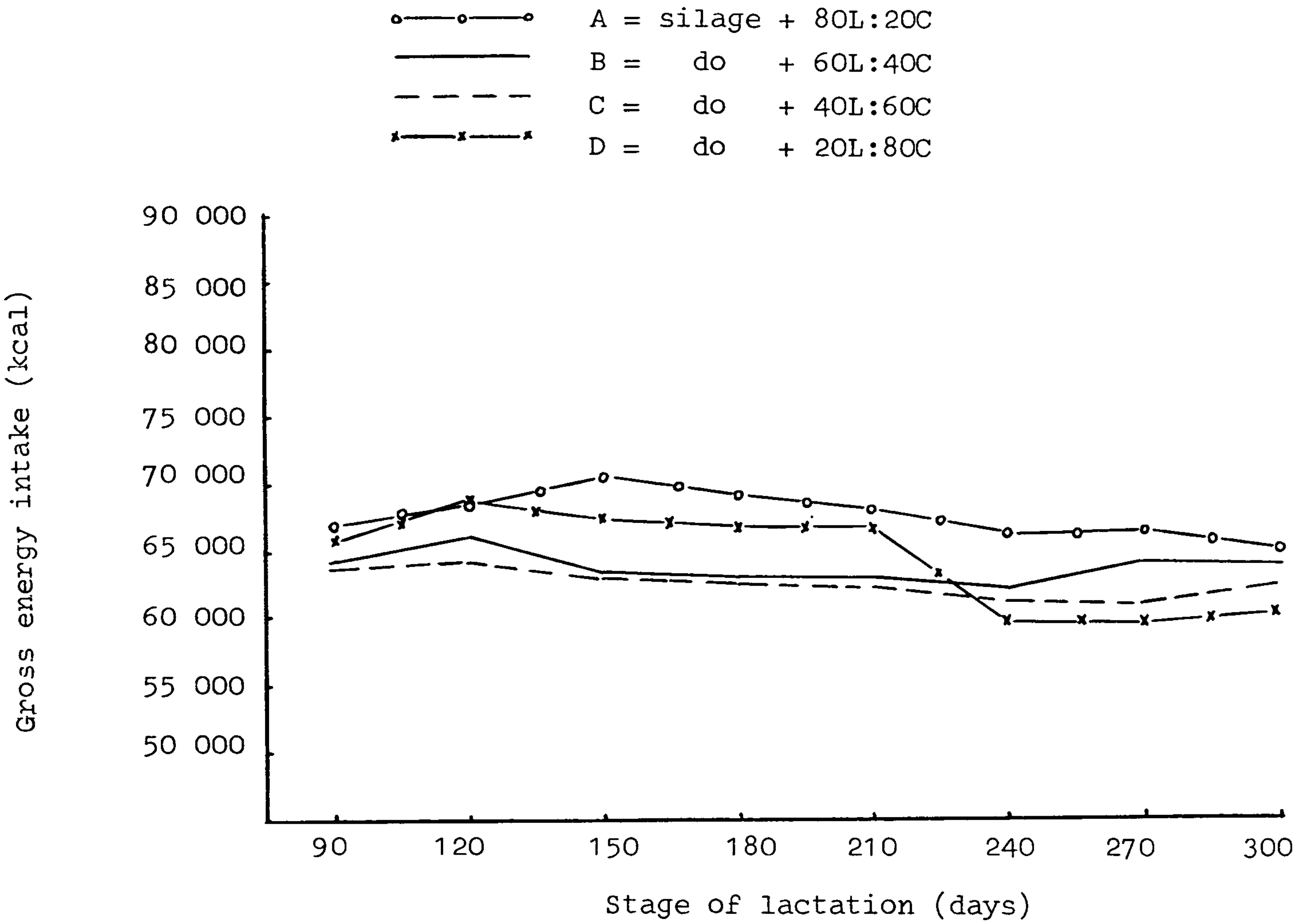

Fig.22 Influence of ration (A, B, C & D) effect on gross energy intake by first-calf heifers during comparison period

consumed significantly ($P<0,01$) more gross energy during the fourth to seventh month of lactation than during the eighth to tenth month.

Within each stage of lactation the gross energy intake of cows was significantly ($P<0,01$) higher than that of first-calf heifers when rations A and B were fed.

Gross energy intake by cows was significantly ($P<0,05$) higher during the fifth to ninth month of lactation than that of heifers when on ration C. Intake of gross energy by cows was significantly ($P<0,05$) higher from the sixth to tenth month of lactation than that of first-calf heifers, when fed ration D.

Changes during the comparison period in mean daily metaboliz= able energy intake by cows and first-calf heifers, on various rations and at various stages of lactation, are presented in Figures 23 and 24.

Irrespective of ration treatment cows consumed significantly ($P<0,05$) more metabolizable energy during the fifth, sixth and seventh month of lactation than during the tenth month. First-calf heifers consumed significantly ($P<0,05$) more metabolizable energy during the fourth month of lactation than during the eighth month, irrespective of treatment. During each stage of lactation in the comparison period, cows consumed significantly ($P<0,01$) more metabolizable energy than first-calf heifers, irrespective of ration treat= ment.

The dry matter and energy intake by cows in the digestibility

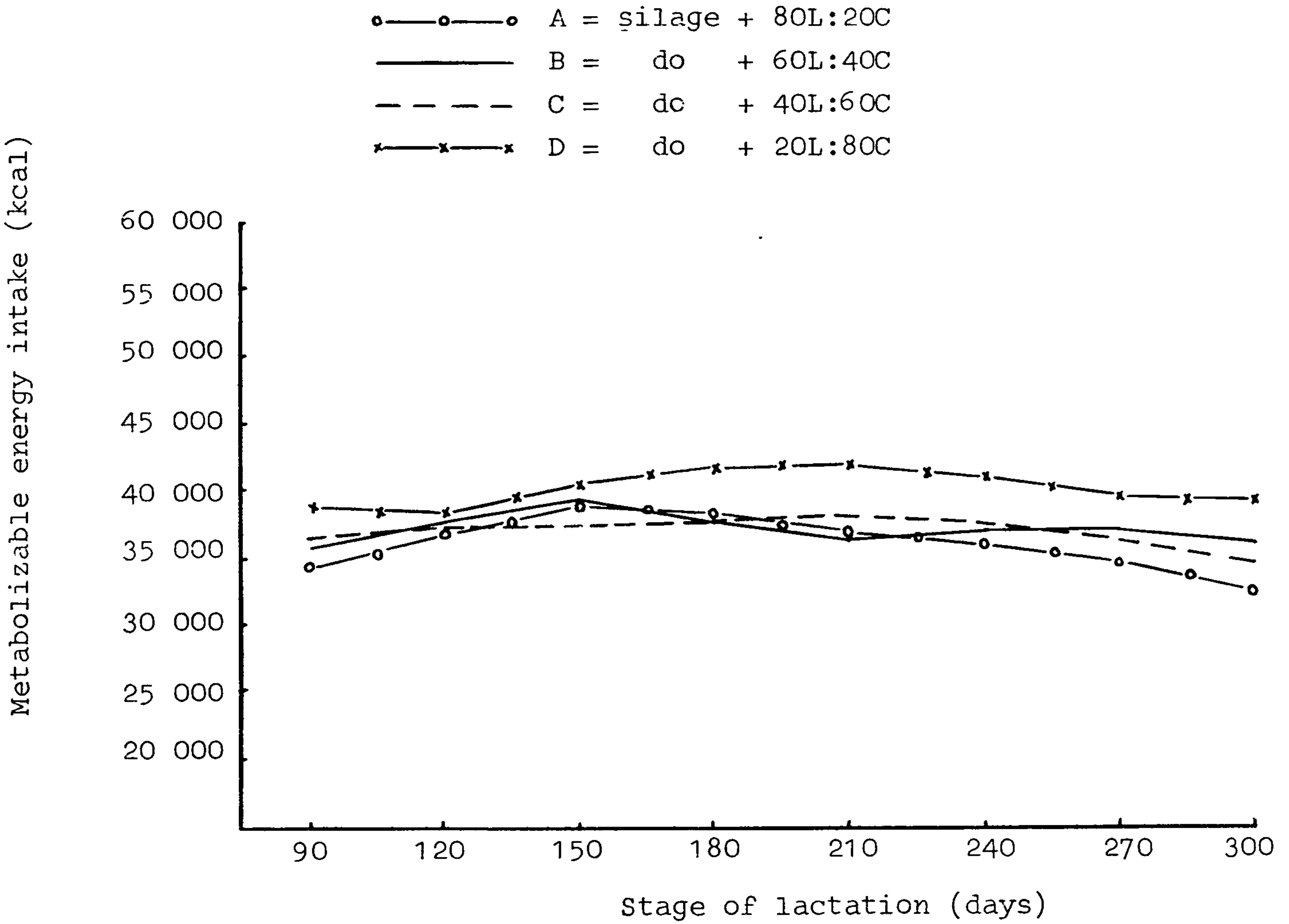

Fig.23 The influence of ration (A, B, C & D) effect on metabolizable energy intake by cows during comparison period

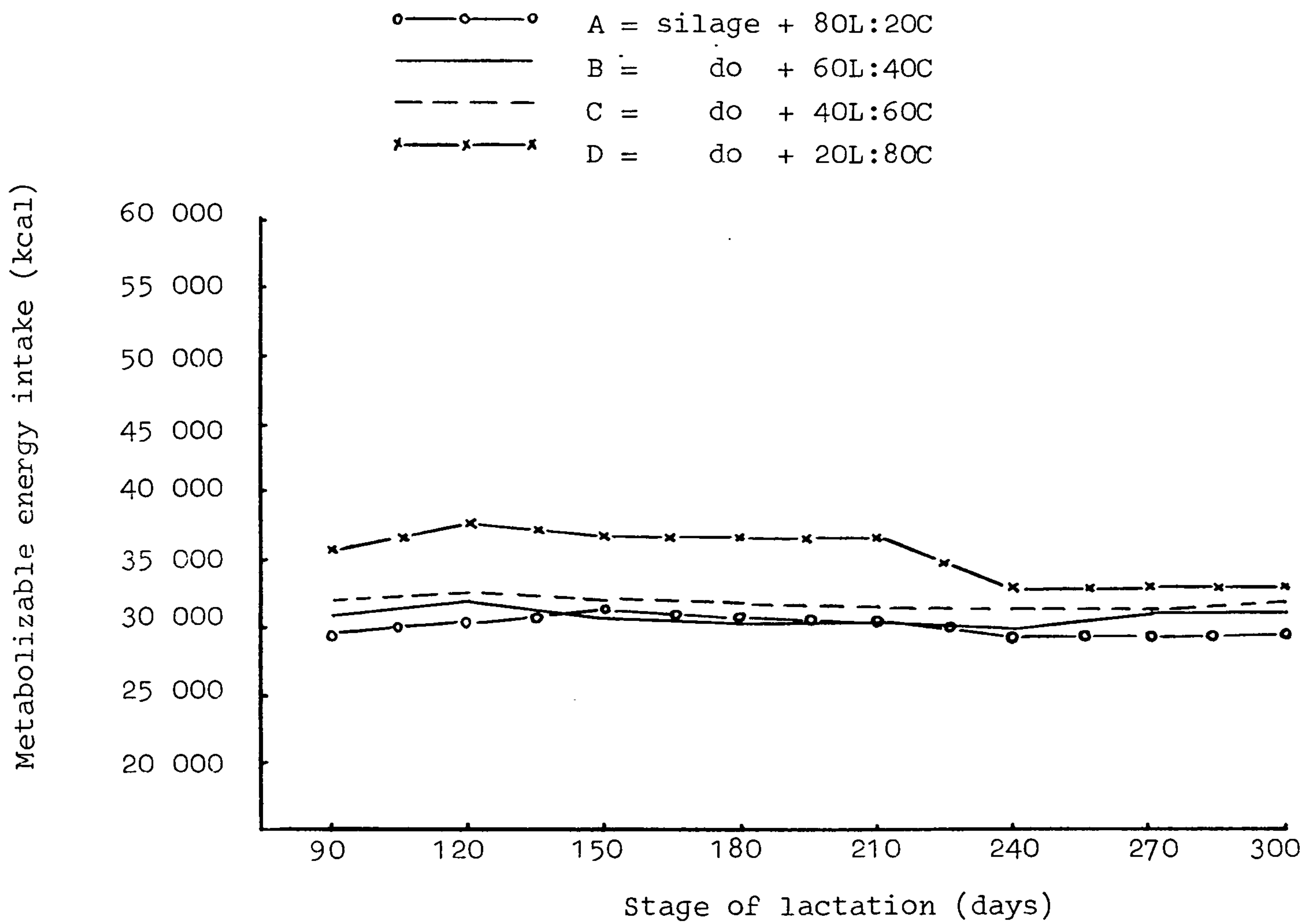

Fig.24 The influence of ration (A, B, C & D) effect on metabolizable energy intake by first-calf heifers during comparison period

trial (Table 19), fed the same experimental rations, followed a similar tendency.

Crude protein and organic matter intake was not affected by ration treatment. As expected the cellulose and crude fibre intake increased as the lucern portion of the ration increased. The daily nitrogen intake by lactating animals and the amounts of nitrogen in faeces, urine and milk during the digestibility trial are summarised in Table 20.

The cows were in a positive nitrogen balance storing 21,85; 35,22; 15,84 and 41,81 g nitrogen daily, when consuming rations A, B, C and D respectively; differences being non-significant (P>0,05).

According to Crampton & Harris (1969) the daily digestible protein requirements for maintenance of cows with a body mass of 600 kg are 340 g. Furthermore, the daily digestible pro= tein requirements per kg milk (4,0% fat content), for cows producing less than 20 kg of milk daily, are 46 g. After making provision for digestible protein requirements for maintenance, the cows in the present digestibility trial received 86,28; 91,12; 94,65 and 104,53 g digestible protein per kg of 4% fat corrected milk, when consuming ration A, B, C and D respectively. This indicated that the experimental animals received more than sufficient digestible protein for maintenance and milk production.

Water intake was non-significantly (P>0,05) influenced by ration treatment, being 86,05; 82,90; 84,63 and 86,30 litres daily per cow, when fed ration A, B, C and D respectively.

Table 19 Mean daily intake of nutrients by lactating cows during digestibility trial

Variable description	Units	A	B	C	D	Diff[1]
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
Dry matter						
silage	kg	2,44	2,41	2,30	2,51	NS
pellets	kg	14,97	15,08	13,67	14,60	NS
total	kg	17,41	17,49	15,97	17,11	NS
total	$g/W_{kg}^{0,75}$	149	150	139	146	NS
Gross energy						
silage	kcal	10702	10576	10077	10976	NS
pellets	kcal	64888	64943	58284	62543	NS
total	kcal	75590	75519	68361	73519	NS
Digestible energy total	kcal	41178	44059	42008	48534	NS
Metabolizable energy total	kcal	33711	36254	34678	40613	NS
Crude protein						
silage	kg	0,21	0,21	0,20	0,21	NS
pellets	kg	2,62	2,77	2,51	2,71	NS
total	kg	2,83	2,98	2,71	2,92	NS
Digestible protein total	kg	1,94	2,15	1,98	2,22	NS
Organic matter						
silage	kg	2,26	2,24	2,13	2,22	NS
pellets	kg	13,54	13,66	12,31	13,23	NS
total	kg	15,80	15,90	14,44	15,45	NS
Digestible OM total	kg	9,25	9,80	9,32	10,68	NS
Cellulose						
silage	kg	0,61	0,61	0,57	0,62	NS
pellets[2]	kg	3,98	3,38	2,64	2,08	**
total[3]	kg	4,59	3,99	3,21	2,70	*
Digestible cellulose total[4]	kg	2,07	1,62	1,45	1,20	*

Column headings A–D: Ration treatment.

(Table continued on p.90)

Crude fibre						
silage	kg	0,54	0,53	0,50	0,54	NS
pellets[5]	kg	3,47	2,92	2,20	1,61	**
total[6]	kg	4,01	3,45	2,70	2,15	**
Digestible crude fibre						
total[7]	kg	1,15	0,90	0,78	0,50	*
Water	l	86,05	82,90	84,63	86,30	NS

1 Differences: *P<0,05, **P<0,01
NS; non-significant (P>0,05)

2 A $\overset{**}{>}$ D, A $\overset{*}{>}$ C, B $\overset{*}{>}$ D

3 A $\overset{*}{>}$ C & D

4 A $\overset{*}{>}$ D

5 A $\overset{**}{>}$ D, A $\overset{*}{>}$ C, B $\overset{*}{>}$ D

6 A $\overset{**}{>}$ D, A $\overset{*}{>}$ C, B $\overset{*}{>}$ D

7 A $\overset{*}{>}$ D

Table 20 Mean daily nitrogen intake and -loss by lactating cows during digestibility trial

Variable description	Units	A	B	C	D	Diff[1]
				Ration treatment		
				maize silage +		
		80L:20C	60L:40C	40L:60C	20L:80C	
Feed nitrogen (FN)	g	454,20	477,09	433,51	467,90	NS
Faeces nitrogen	g	143,98	133,38	116,98	113,67	NS
Urine nitrogen	g	188,81	194,72	199,26	194,67	NS
Milk nitrogen	g	99,56	113,77	101,43	117,75	NS
Total nitrogen balance	g	+21,85	+35,22	+15,84	+41,81	NS
Percentage of nitrogen intake						
Faeces nitrogen	% of FN	32,10	28,12	26,90	24,66	NS
Urine nitro= gen	% of FN	42,48	41,05	47,02	41,77	NS
Milk nitro= gen	% of FN	21,77	23,93	22,98	24,89	NS
Total nitrogen balance	% of FN	3,65	6,90	3,10	8,68	NS

1 Differences: NS; non-significant ($P>0,05$)

This is contrary to the conclusions of Flatt et al.(1969a), who found that water consumed daily was significantly ($P<0,01$) affected by ration, increasing from 54,7 litres when lacta= ting cows received 20% alfalfa + 80% concentrates to 69,9 litres per day when they consumed 60% alfalfa + 40% concentrate ration.

2.6 Efficiency of utilization of metabolizable energy for milk production

2.6.1 Introduction

Biological efficiency and energy efficiency in particular have been expressed in various ways. Brody (1945) and Baum= gardt (1967) expressed energy efficiency as gross efficiency. This expression, however, does not eliminate the fixed main= tenance change or take into account any changes in body mass (Baumgardt, op cit.). High producing lactating dairy cows have an immense capacity for utilizing body fat and these body composition changes can occur without being accurately reflected in body mass changes. Flatt (1966) therefore stated that failure to take these tissue changes into account can lead to gross misinterpretation of feed input-milk output experiments.

For this reason energetic efficiency is expressed more accurately as metabolizable energy efficiency. To estimate the efficiency of utilization of metabolizable energy for milk production, assumptions concerning requirements for maintenance and tissue gains must be made (Flatt, op cit.). The efficiency of utilization of metabolizable energy for lactation depends upon the relative proportion of volatile fatty acids in the rumen (Blaxter, 1962).

The molar proportions of volatile fatty acids present in the rumen are influenced by the roughage:concentrate ratio, and the physical form of the roughage. The molar proportion of the rumen acetic acid is less on ground-roughage or high concentrate diets (Phillipson, 1951). The molar proportion of acetic acid in the rumen determines energy diversion to either milk production or body tissue formation (Armstrong & Blaxter, 1965).

There is a fundamental antagonism between metabolism geared to produce milk efficiently and that geared to produce high gains in body mass (van Soest, 1963). Flatt et al.(1969b) found that as the roughage content of diets fed to cows ad lib. decreased, the pattern of energy distribution amongst the productive functions changed with more energy diverted towards body tissue formation. Thus, when the roughage in= take was restricted to between 40 and 20 per cent of the ration, the cows utilized less body fat and secreted less milk.

In effect, the cows on the high concentrate rations had less energy available for milk secretion than those fed the 60 per cent roughage ration because they did not draw upon their body reserves to supplement the energy in the feed. The amount of tissue energy used during the early stage of lactation for milk production depends on the degree of fat= ness of the cow at time of parturition, the genetic potential of the cow to produce milk, feed intake and feed composition during early lactation (Moe et al.,1971). Data from these workers suggests that milk may be produced from body tissue reserves with an efficiency of 82 to 84 per cent and that the body tissue reserves may be replenished in late lactation by deposition of body tissue with an efficiency equal to or exceeding that of milk production.

Body mass change does not necessarily accurately reflect changes in body tissue reserves (Moe, Flatt & Tyrrell, 1972). To correlate tissue energy changes to live mass change with= out some consideration being given to the rumen fill seems unrealistic (Moe et al., 1971). These workers stated that undetected utilization of this energy reserve may significant= ly affect the amount of feed required per unit of milk produced. Direct measurement of conversion efficiency of body tissue energy to milk is impossible since one cannot distinguish between that portion of the milk produced as a consequence of tissue mobilization and that portion produced from dietary energy (Moe et al., 1971).

Factors used to calculate the metabolizable energy deposited as tissue or available from tissue for milk production,were 1,61 kcal metabolizable energy/kcal of tissue gained and 1,43 kcal metabolizable energy/kcal of tissue lost (Flatt, 1966). The metabolizable energy consumed, adjusted for tissue gain or loss, represented the amount of metabolizable energy available for milk production and maintenance (Coppock, Flatt, Moore & Stewart, 1964a).

Deduction of the metabolizable energy required for maintenance from the metabolizable energy available for milk plus main= tenance, yields the metabolizable energy available for milk production. The milk energy output divided by the metaboliz= able energy available for milk, expressed as a percentage, expresses lactation efficiency (Coppock et al., 1964a).
In the present study efficiency of metabolizable energy utilization for milk production was expressed similarly.
Coppock et al.(op cit.) used a maintenance requirement value of 131 kcal metabolizable energy per $W_{kg}^{0,75}$ given by Kleiber, Regan & Mead to calculate maintenance needs. They assumed a constant maintenance requirement during lactation. According to Wallace (1959), however, maintenance requirements may decline or increase throughout lactation. For this reason the maintenance requirements were not kept constant in this study but were adjusted to each stage of lactation. No additional adjustments were made for body tissue gain or loss.
It was assumed that the efficiency with which metabolizable energy was used for providing energy for maintenance was 74 per cent (Agricultural Research Council (ARC), 1965). Main= tenance requirements were calculated by multiplying the fasting metabolism value of the animal by 1,35. The fasting metabolism value for cattle expressed on the basis of 500 kg body mass was taken as 70 kcal/$W_{kg}^{0,75}$ for cows and 80 kcal/$W_{kg}^{0,75}$ for first-calf heifers (ARC, 1965).
According to Blaxter (1962) the efficiency with which metabo= lizable energy was converted to milk was maximal (about 70 per cent) when the proportion of acetic acid in the rumen

was between 50 and 60 per cent.

The hay-to-grain ratio has been shown to influence the molar proportion of volatile fatty acids present in the rumen,with forages effecting a higher molar proportion of acetic acid than mixed rations (Shaw, 1961). An increase in the propor= tions of propionic and butyric acids(resulting from high grain feeding), accompanied by a decrease in acetic acid and in yield of methane, may be related to the efficiency of conversion of metabolizable energy to milk and fat (Coppock, Flatt, Moore & Stewart, 1964b).

Burt (1957) reported a diminishing milk production for each added unit of feed input (energy intake) above a certain level. Putnam & Loosli (1959) and Harner & Spahr (1971) also obtained a decreasing trend in feed efficiency as energy in their complete rations was increased. As the level of feed intake was increased, the gross efficiency increased at a decreasing rate. This diminishing returns effect is proba= bly due to increasing proportions of dietary energy being diverted to the production of new body tissue (Baumgardt, 1967). Diversion of part of the absorbed energy into body mass gain or contribution to energy pools by body tissue loss, can have a marked effect on the efficiency value (Baumgardt, 1967).

An apparent decline or rise in efficiency may have been due to over or under estimation of energy available for milk production, since body mass measurements may not have accurately reflected changes in the energy contents of body

tissue (Cowan, Oliver & Elliott, 1971).
It appears that efficiency of feed conversion is dependent on whether increased energy intake is reflected in increased milk production and whether the milk fat percentage is de= pressed (Kesler & Spahr, 1964). A ration which contains a proportion of concentrates high enough to cause milk fat depression is not as effective for milk production as one containing less grain but still meeting nutrient requirements (van Soest, 1963). That proportion of hay:grain which is on the threshold of depressing milk fat content is probably the most efficient for milk production (van Soest, 1963).
Data from Flatt (1966) indicated that there was little difference in efficiency of utilization of metabolizable energy for rations containing 40 to 80 per cent concentrates. There was no indication that a depression in the efficiency of utilization of metabolizable energy occurred when cows were consuming four times above maintenance requirements.

2.6.2 Discussion of results

The efficiency of use of metabolizable energy for milk pro= duction by cows is summarised in Table 21. It was highest for cows fed ration A (maize silage + 80L:20C) followed by cows fed on the 60, 40 and 20 per cent lucern diet, percentages being 55,04; 51,80; 50,47 and 49,74 respectively. Differences were non-significant. These findings are in general agreement with data of Cowan et al.(1971) indicating that the efficien= cies were highest for cows fed on a 50 per cent roughage diet

Table 21 Mean efficiency of use of metabolizable energy for milk production by cows on experimental rations during comparison period

Ration treatment maize silage plus	ME[2] concentration in feed kcal/g	Intake DM $g/W_{kg}^{0,75}$	Intake ME kcal	Maintenance kcal	ME available for milk kcal	FCM kg	Milk Fat %	Milk Energy kcal	Efficiencies of use of ME for milk production: milk energy as % of ME - maintenance
80L:20C	1,928	150,88	36163	11772	24391	17,55	3,40	13264	55,04
60L:40C	2,086	145,73	36986	11527	25459	16,90	3,05	12967	51,80
40L:60C	2,175	137,61	36885	11683	25202	16,57	2,97	12632	50,47
20L:80C	2,347	142,04	40362	11548	28814	18,08	3,10	14074	49,74
Diff[1]	*	NS	NS	NS	NS	NS	NS	NS	NS

1 Differences: *$P<0,05$, NS; non-significant ($P>0,05$)

2 20L:80C $\overset{*}{>}$ 80L:20C

followed by cows fed 35, 20 and 5 per cent roughage diets. The efficiencies were 66,0; 56,6; 56,0 and 50,4 per cent respectively.

In the present study undetected utilization of energy reserves for milk production may have affected the calculated efficiencies of milk production.

Cowan et al.(1971) stated that diets which contain high proportions of roughage, increase the production of acetic acid in the rumen, encourage body tissue utilization and may, by increasing the availability of acetate for milk synthesis, produce high milk yields. On the other hand, cows fed with low-roughage diets gained considerably more body tissue energy than could be accounted for by live body mass measure= ments. Therefore, less energy may have been available for milk production and milk may have been produced more efficient= ly.

If these findings are applied to the present study one may expect, that the higher efficiency of use of metabolizable energy for milk production when cows consumed ration A (maize silage + 80L:20C) could be attributed to the utilization of more body tissue to supplement the dietary energy, even though body mass did not show this.

Likewise, body deposition and the suppressing of body tissue utilization, when cows consumed the higher concentrate rations (rations B, C and D), probably took place without being reflected in body mass changes between treatments. Due to the similar milk yields of cows on the various rations, metabolizable energy consumption was probably adjusted to the degree of body tissue utilization or deposition and the milk potential of the cows, indicating that milk production was a determinant of metabolizable energy intake.

A significant ($P<0,05$) effect of stage of lactation on efficiency of use of metabolizable energy for milk production by cows during the comparison period, was found (Fig.25). Irrespective of treatment in the comparison period, cows produced milk more efficiently ($P<0,05$) during the third and fourth month of lactation than during the later months. The efficiency of use of metabolizable energy for milk production was the lowest during the eighth, ninth and tenth month of lactation. This is confirmed by Flatt et al.(1969b) who found a highly significant ($P<0,01$) effect of stage of lactation on body tissue mobilization and storage. The lac=tating cow is able to mobilize extremely large amounts of body tissue in early lactation and conversely during later lactation is able to deposit very large amounts of body tissue (Flatt, Moore, Hooven & Plowman, 1965).

The decline in efficiency with advancing lactation may be a reflection of the catabolism of fat reserves during the early part of the lactation. As the reserves are depleted, the calculated efficiency ratio would be expected to drop marked=ly (Miller & Hooven, 1969).

The result is that input-output experiments may be greatly influenced by feeding in relation to the ability and stage of lactation of the experimental animals.

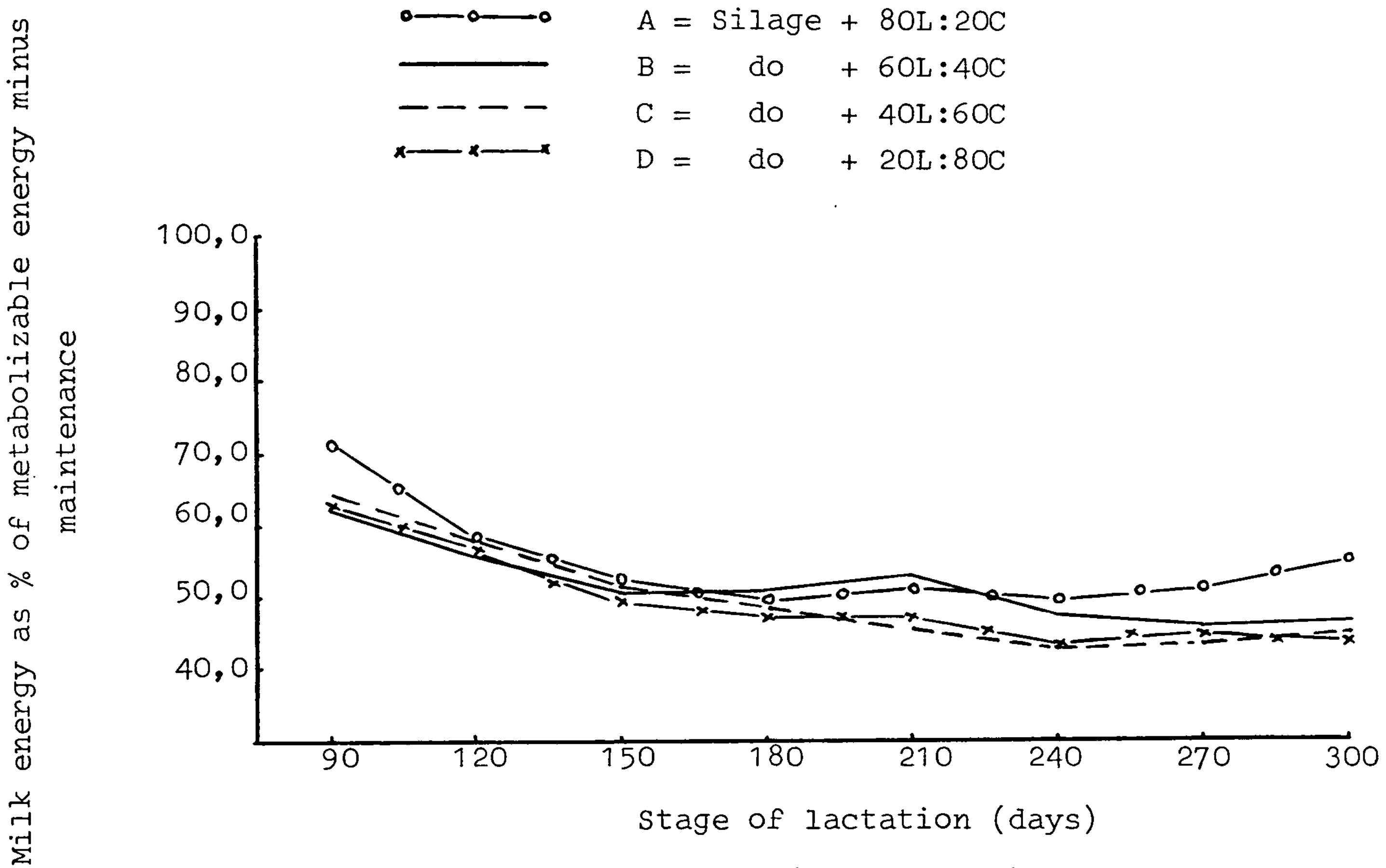

Fig.25 Influence of ration (A, B, C & D) effect on efficiency of use of metabolizable energy for milk production by cows during comparison period

The effect of stage of lactation on the efficiency of use of metabolizable energy for milk production by cows is seen clearly when the data of the digestibility trial (Tables 22 and 23) are compared to the results in the comparison period (Table 21). Although the efficiencies decreased in a similar way (decreasing with an increase in the concentrate portion of the ration) the efficiencies were slightly higher for rations A, B and C. This may be due to the fact that these means were calculated over the first five months of lacta=tion (length of digestibility trial) as against calculation of the means over the 240-day comparison period (Table 21). The lower efficiency observed in the digestibility trial on ration D, is not clearly understood.

The efficiency of use of metabolizable energy for milk produc=tion by first-calf heifers (Table 24) almost followed the same pattern as that of the cows; being the highest for heifers consuming ration A, followed by ration D, B and C. Differences were non-significant. The lower efficiency of heifers fed ration C is probably due to the slightly lower maintenance requirements of this group due to a lower mean body mass.

Ronning (1960) observed a similar tendency in that the efficiency of use of dietary energy was markedly lower on the high concentrate rations than on either the low concen=trate or concentrate free diet. Differences in efficiency may again be attributed to body tissue mobilisation or deposi=tion.

Table 22 Energy balance of cows during digestibility trial

Variable description	Ration treatment A	B	C	D	Diff[1]
	maize silage +				
Energy contents of feeds, excreta and products	80L:20C	60L:40C	40L:60C	20L:80C	
	kcal				
Gross energy (GE)	75590	75519	68361	73519	NS
Faeces energy	34412	31460	26353	24985	NS
Digestible energy (DE)	41178	44059	42008	48534	NS
Urine energy	2130	2256	2149	2103	NS
Methane energy	5537	5549	5181	5818	NS
Metabolizable energy (ME)	33711	36254	34678	40613	NS
Energy for main= tenance (EM)	10972	10990	10827	11027	NS
Milk energy	14376	14815	13101	14276	NS
Percentage of GE intake	%				
Faeces energy[2]	45,66	41,39	38,41	34,66	*
Digestible energy[3]	54,34	58,61	61,59	65,34	*
Urine energy	2,88	2,98	3,24	2,92	NS
Methane energy[4]	7,05	7,37	7,59	7,86	*
Metabolizable energy[5]	44,41	48,26	50,76	54,56	*
Milk energy	19,02	19,57	18,74	19,21	NS
Percentage of ME intake	%				
milk energy	42,07	40,68	36,82	35,26	NS
Percentage of ME-EM	%				
milk energy	62,83	58,51	53,83	48,94	NS

1 Differences: *P<0,05, NS; non-significant (P>0,05)

2 A $\overset{*}{>}$ D

3 D $\overset{*}{>}$ A

4 D $\overset{*}{>}$ A

5 D $\overset{*}{>}$ A

Table 23 The efficiency of use of metabolizable energy for milk production by cows during the digest= ibility trial

Ration treat= ment	Collec= tion period	ME intake kcal/ cow/ day	Main= tenance kcal/ cow/ day	ME avail= able for milk kcal/ cow/ day	Energy value of milk kcal	Efficiencies of use of ME for milk pro= duction: milk energy as; % of ME	% of ME-main= tenance
80L:20C + maize	1b	34260	10877	23383	21515	62,80	92,01
silage	2b	41071	12030	29041	15935	38,80	54,87
	3b	35407	11746	23661	12172	34,38	51,44
	4b	24105	9233	14872	7883	32,70	53,00
mean	-	33711	10972	22739	14376	42,07	62,83
60L:40C + maize	1b	38046	11888	26158	17249	45,34	65,94
silage	2b	33156	9459	23697	11522	34,75	48,62
	3b	37636	10584	27052	15256	40,54	56,40
	4b	36176	12030	24146	15232	42,10	63,08
mean	-	36254	10990	25263	14815	40,68	58,51
40L:60C + maize	1b	40954	11746	29208	17219	42,04	58,95
silage	2b	33752	11671	22081	14422	42,73	65,31
	3b	25699	9384	16315	6471	25,18	39,66
	4b	38308	10508	27800	14291	37,30	51,41
mean	-	34678	10827	23851	13101	36,82	53,83
20L:80C + maize	1b	34081	9532	24549	12914	37,89	52,60
silage	2b	39505	10735	28770	15847	40,11	55,08
	3b	41475	11888	29587	14066	33,91	47,54
	4b	47392	11954	35438	14277	30,12	40,29
mean	-	40613	11027	29587	14276	35,26	48,94

Table 24 Mean efficiency of use of metabolizable energy for milk production by first-calf heifers on experimental rations during comparison period

Ration treat= ment maize silage plus	ME[2] concen= tration in feed kcal/g	Intake DM $g/W_{kg}^{0,75}$	Intake ME kcal	Mainten= ance kcal	ME avail= able for milk kcal	Milk FCM kg	Milk Fat %	Milk Energy kcal	Efficiencies of use of ME for milk production: milk energy as % of ME - maintenance
80L:20C	1,928	137,91	30066	12218	17848	12,86	3,40	9821	55,57
60L:40C	2,086	131,38	30827	12170	18657	11,92	3,41	9271	50,00
40L:60C	2,175	133,85	31833	11813	20020	12,23	3,26	9497	47,75
20L:80C	2,347	132,64	35202	12205	22997	14,66	3,11	11421	50,97
Diff[1]	*	NS	NS	NS	NS	NS	NS	NS	NS

1 Differences: *P<0,05, NS; non-significant (P>0,05)

2 20L:80C $\overset{*}{>}$ 80L:20C

The effect of stage of lactation on the efficiency of use of metabolizable energy for milk production by first-calf heifers (Fig.26) was less pronounced as in the case of cows, differences being non-significant ($P>0,05$).
Irrespective of treatment, the cows produced milk signifi= cantly ($P<0,01$) more efficiently in the comparison period, during the third and fourth month of lactation than the first-calf heifers. Since the body reserves of cows were greater than those of first-calf heifers, they were able to utilize more body tissue during this stage of lactation. First-calf heifers were more dependant on dietary energy for milk production. Furthermore, they showed body mass gains within 60 days following parturition, indicating body tissue deposition.
During the fifth, sixth and seventh month of lactation, efficiency of milk production of cows and heifers was almost identical. In the eighth and ninth month of lactation heifers were significantly ($P<0,05$) more efficient than cows. This indicated greater body tissue deposition by cows than by heifers at this stage of lactation. There were no signifi= cant differences between cows and heifers in the tenth month. According to the ARC (1965) standards, the daily metabolizable energy required by lactating Friesian cows, with a body mass of 590 kg, when producing 14,0 to 18,8 kg 4% fat corrected milk daily, is 33 000 to 41 200 kcal. In the present study the mean body mass of the cows was 618 kg, producing 16,57 to 18,08 kg 4% fat corrected milk with a daily metabolizable energy intake of 36 163 to 40 362 kcal. The metabolizable

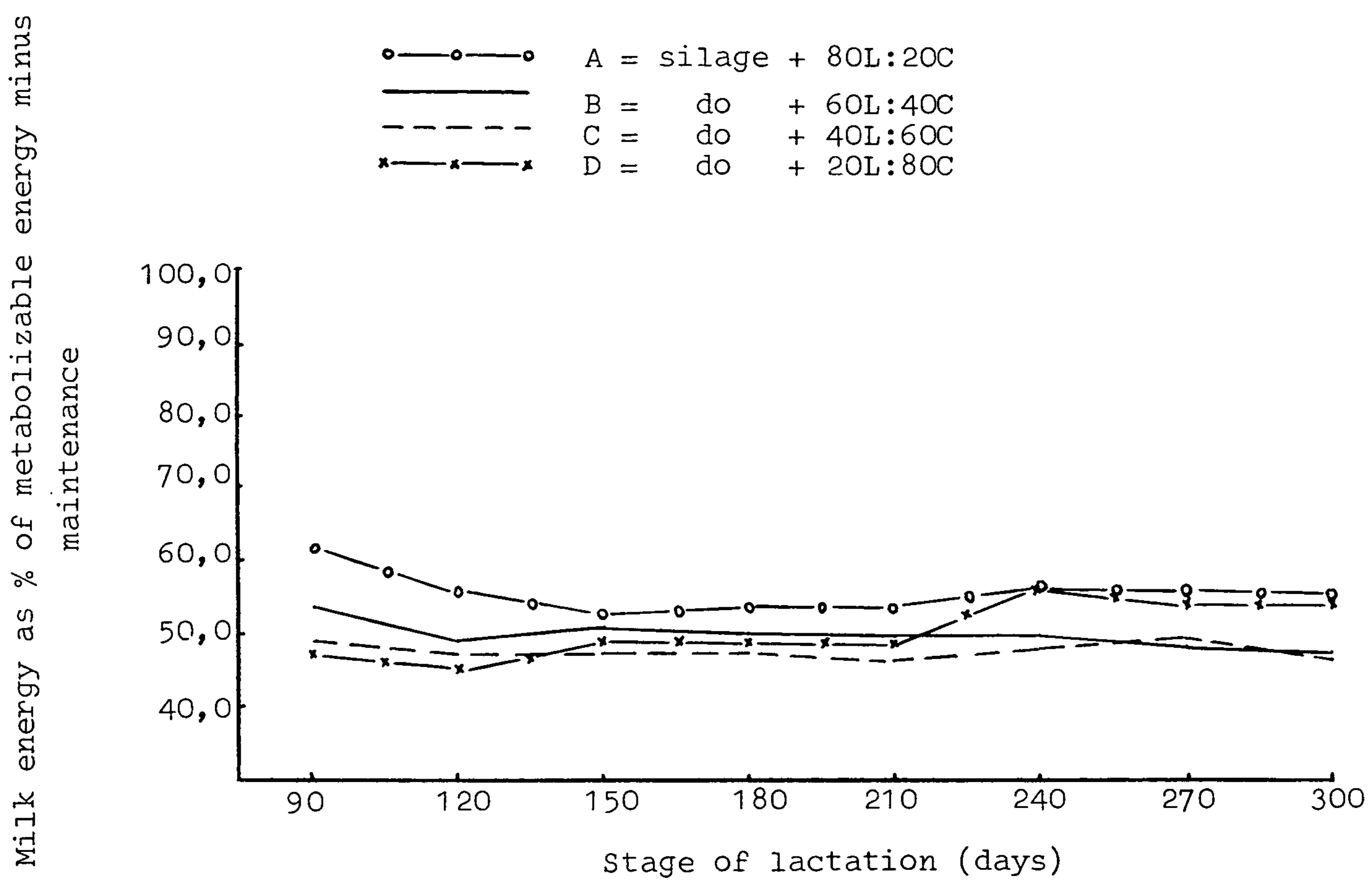

Fig.26 Influence of ration (A, B, C & D) on efficiency of use of metabolizable energy for milk production by first-calf heifers during comparison period

energy fell within the limits recommended by the ARC (1965) standards.

2.7 Daily returns over total production cost of milk

2.7.1 Introduction

The most economical level to feed concentrates to individual cows is associated with milk production response to variable quantities fed and milk:feed and grain:forage price relation= ships (Hoglund, 1964). Therefore dairymen should adjust their feeding programs to milk:feed and grain:forage price relation= ships (Hoglund, 1969).

High proportions of forage are usually fed when the forage quality is very high, the grain price high and the milk price low, or when production is at relatively low levels. The lowest levels of forage feeding are associated with high levels of milk production, high prices for milk, and low prices for grain (Hoglund, 1969).

Individual diary farmers are faced with problems of selecting the combination of feeds to minimize costs and maximize net returns (Hoglund, 1969). These problems may include the following:

(a) Milk: feed and grain:roughage price relationships. Cost-price relationships and the choice of economic forage crops vary considerably from region to region. This influences the optimum combination of forage and grain to feed (Hoglund, 1969).

(b) Feed intake associated with milk production responses.

(c) Complete ration feeding versus traditional feeding. To minimize labour requirements and maximize automation, concentrate and roughage portions of the ration are blended to form a product called a complete feed. This feed is then made available in self-feeders or mechanical feeding devices (Rakes, 1969). The relative amounts of different ration ingredients consumed by the dairy cow can be controlled without the management difficulties encountered when concen= trates and roughages are fed separately. Expenditures of energy by normal grazing cows resulted in maintenance requirements being 40 to 50 per cent higher than for cows fed and confined in a barn (McMeekan, 1952).

(d) Group feeding versus individual feeding. Group-fed cows consumed 7,1 per cent more than the same cows fed indi= vidually in stanchions(Coppock, Noller, Crowl, McLellon & Rhykerd, 1972). According to Hyppola and Hasunen (cited by Coppock et al.,1972) cows fed individually, ingested 5 per cent less dry matter than the same cows when group-fed. They suggested that competition within the group stimulated greater intake.

(e) Parlour feeding versus elimination of parlour feeding. Stoddard (1969) found that cows require approximately three minutes to consume one kilogram of concentrate and that the average milking time for a cow milked in a parlour was 4,5 minutes. Thus, cows producing levels of milk high enough to require more than 1,5 kg of concentrate per milking must remain in the parlour longer than 4,5 minutes to finish their grain. Stoddard (1969) suggested the elimination of grain feeding in the parlour as one method of milking the maximum number of cows per hour.

Limited research (MacLachlan, cited by Hoglund, 1969) indi= cates that labour requirements for dairy cows can be reduced by 10 per cent by eliminating concentrate feeding in the parlour.

(f) Consumption of feed and milk production responses of first-calf heifers compared to mature cows.

(g) Growing versus purchasing of roughages.

(h) Increasing versus decreasing labour costs.

2.7.2 Discussion of results

In the present study feed intake and milk production responses by cows, when subjected to rations A, B, C and D (pellets priced at 6,6286; 6,7286; 6,8571 and 6,9714 c per kg respectively and maize silage at 1,2c per kg dry matter) were of such a degree that no large differences in the profit margin between ration treatments occurred (Table 25). Milk was priced at 11,94c per litre.

This indicated that cows were able to regulate their feed intake in relation to daily energy needs; energy for milk production becoming the dominant factor. As the metabolizable energy concentration increased the voluntary intake tended to decrease. The mean daily milk yield of the cows in each treatment group was related to the metabolizable energy intake of each group.

Table 25 Mean daily returns over cost of feed per cow when fresh milk is marketed

Variable description	A	B	C	D
	Ration treatment			
	maize silage +			
	80L:20C	60L:40C	40L:60C	20L:80C
Daily income from fresh milk/ cow[1]	R2,31	R2,36	R2,35	R2,51
Daily feed cost/cow				
maize silage[2]	R0,03	R0,03	R0,03	R0,03
pellets[3]	R1,19	R1,14	R1,11	R1,16
total	R1,22	R1,17	R1,14	R1,19
Daily returns over cost of feed per cow	R1,09	R1,19	R1,21	R1,32
Profit margin over feed cost c/l	5,6c	6,0c	6,1c	6,2c

Prices:

1 Fresh milk @ 11,94 c/l

2 Maize silage (DM) @ 1,2 c/kg

3 Pellets 80L:20C @ 6,6286 c/kg

60L:40C @ 6,7286 c/kg

40L:60C @ 6,8571 c/kg

20L:80C @ 6,9714 c/kg

The first-calf heifers consuming ration D (maize silage + 20L:80C) showed a higher profit margin over feed cost than the heifers consuming rations A, B or C (Table 26). This indicated that milk production responses may have been limited due to a possible limitation of dry matter intake when heifers were on rations A, B or C. The first-calf heifers could not overcome the limitation of the lower digestibility of rations A, B or C because of the smaller size of the digestive tract.

When fixed- and other milk production costs (excluding feed costs) of 2,48 c per litre (Ferreira, 1974, personal commu= nication) were added to the feed costs in this study, the profit margins over total milk production costs were 3,12; 3,52; 3,62 and 3,72 c per litre when cows were fed rations A, B, C and D respectively. In the case of the first-calf heifers the profit margins were 2,32; 2,22; 2,32 and 3,52 c per litre respectively when on ration A, B, C and D.

The profit margins over total production costs in the case of cows (irrespective of treatment) and first-calf heifers on ration D, compare favourably with the profit margins calculated by Ferreira (1974, personal communication); varying between 4,54 and 5,81 c per litre. The latter data were obtained from dairy farmers feeding farm-produced feeds to cows producing between 15 and 18 kg milk per cow daily. From the nutritional, milk production and economical point of view and at current milk and feed prices any one of the purchased pelleted feeds may be fed with great success to cows.

Table 26 Mean daily returns over cost of feed per first-calf heifer when fresh milk is marketed

Variable description	A	B	C	D
	Ration treatment			
	maize silage +			
	80L:20C	60L:40C	40L:60C	20L:80C
Daily income from fresh milk/heifer[1]	R1,69	R1,59	R1,65	R2,02
Daily feed cost per heifer				
maize silage[2]	R0,03	R0,03	R0,03	R0,03
pellets[3]	R0,98	R0,94	R0,96	R0,98
total	R1,01	R0,97	R0,99	R1,01
Daily returns over cost of feed per heifer	R0,68	R0,62	R0,66	R1,01
Profit margin over feed cost c/l	4,8c	4,7c	4,8c	6,0c

Prices:

1 Fresh milk @ 11,94 c/l

2 Maize silage (DM) @ 1,2 c/kg

3 Pellets 80L:20C @ 6,6286 c/kg
60L:40C @ 6,7286 c/kg
40L:60C @ 6,8571 c/kg
20L:80C @ 6,9714 c/kg

Since the production performance of first-calf heifers on ration D tended to be greater than that of heifers on ration A, B and C, its use should yield a higher profit margin. Based on current prices the profit margin on industrial milk, when using the experimental rations, is so low that it is an uneconomical proposition (Tables 27 and 28).

The profit margins over cost of pelleted feed (c/litre) for each experimental ration consumed by cows and first-calf heifers, varying with pellet feed costs and milk prices, are presented in Tables 29, 30, 31, 32, 33, 34, 35 and 36.

Profit margin over pelleted feed cost was calculated as follows:

Profit margin over pelleted feed cost (c/l) = milk price (c/l) x milk yield (l) - [pelleted feed cost (c/kg) x pellet intake (kg)] divided by milk yield (l).

Cost of maize silage was not taken into account in this equation, being three cents daily per cow.

Table 27 Mean daily returns over cost of feed per cow when industrial milk is marketed

Variable description	A	B	C	D
		maize silage +		
	80L:20C	60L:40C	40L:60C	20L:80C
Daily income from industrial milk per cow[1]	R1,41	R1,33	R1,32	R1,45
Daily feed cost per cow				
maize silage[2]	R0,03	R0,03	R0,03	R0,03
pellets[3]	R1,19	R1,14	R1,11	R1,16
total	R1,22	R1,17	R1,14	R1,19
Daily returns over cost of feed/cow	R0,19	R0,16	R0,18	R0,26
Profit margin over feed cost c/l	1,0c	0,81c	0,91c	1,24c

Prices

1 Industrial milk price calculated at 743 c/100 kg milk of 3,5% fat, ± 14 c/100 kg milk for each 0,1% above or below 3,5%

2 Maize silage (DM) @ 1,2 c/kg

3 Pellets 80L:20C @ 6,6286 c/kg
60L:40C @ 6,7286 c/kg
40L:60C @ 6,8571 c/kg
20L:80C @ 6,9714 c/kg

Table 28 Mean daily returns over cost of feed per first-calf heifer when industrial milk is marketed

Variable description	Ration treatment A	B	C	D
	maize silage +			
	80L:20C	60L:40C	40L:60C	20L:80C
Daily income from industrial milk per heifer[1]	R1,03	R0,97	R0,99	R1,16
Daily feed cost per heifer				
maize silage[2]	R0,03	R0,03	R0,03	R0,03
pellets[3]	R0,98	R0,94	R0,96	R0,98
total	R1,01	R0,97	R0,99	R1,01
Daily returns over cost of feed/heifer	R0,02	R0,00	R0,00	R0,15
Profit margin over feed cost c/l	0,14c	0	0	0,98c

Prices

1 Industrial milk price calculated at 743 c/100 kg milk of 3,5% fat, ± 14 c/100 kg milk for each 0,1% above or below 3,5%

2 Maize silage (DM) @ 1,2 c/kg

3 Pellets 80L:20C @ 6,6286 c/kg
60L:40C @ 6,7286 c/kg
40L:60C @ 6,8571 c/kg
20L:80C @ 6,9714 c/kg

Table 29 Profit margin over pelleted feed cost (c/litre): cows consuming 80L:20C pelleted ration

pelleted feed cost (c/kg)	Milk price c/litre 11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	6,32	6,59	6,84	7,09	7,34	7,59	7,84	8,09	8,34	8,59	8,84
5,10	6,22	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24	8,49	8,74
5,20	6,13	6,40	6,65	6,90	7,15	7,40	7,65	7,90	8,15	8,40	8,65
5,30	6,06	6,31	6,56	6,81	7,06	7,31	7,56	7,81	8,06	8,31	8,56
5,40	5,96	6,21	6,46	6,71	6,96	7,21	7,46	7,71	7,96	8,21	8,46
5,50	5,87	6,12	6,37	6,62	6,87	7,12	7,37	7,62	7,87	8,12	8,37
5,60	5,78	6,03	6,28	6,53	6,78	7,03	7,28	7,53	7,78	8,03	8,28
5,70	5,68	5,93	6,18	6,43	6,68	6,93	7,18	7,43	7,68	7,93	8,18
5,80	5,59	5,84	6,09	6,34	6,59	6,84	7,09	7,34	7,59	7,84	8,09
5,90	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25	7,50	7,75	8,00
6,00	5,40	5,65	5,90	6,15	6,40	6,65	6,90	7,15	7,40	7,65	7,90
6,10	5,31	5,56	5,81	6,06	6,31	6,56	6,81	7,06	7,31	7,56	7,81
6,20	5,22	5,47	5,72	5,97	6,22	6,47	6,72	6,97	7,22	7,47	7,72
6,30	5,12	5,37	5,62	5,87	6,12	6,37	6,62	6,87	7,12	7,37	7,62
6,40	5,03	5,28	5,53	5,78	6,03	6,28	6,53	6,78	7,03	7,28	7,53
6,50	4,94	5,19	5,44	5,69	5,94	6,19	6,44	6,69	6,94	7,19	7,44
6,60	4,84	5,09	5,34	5,59	5,84	6,09	6,34	6,59	6,84	7,09	7,34
6,70	4,75	5,00	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25
6,80	4,66	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16
6,90	4,56	4,81	5,06	5,31	5,56	5,81	6,06	6,31	6,56	6,81	7,06
7,00	4,47	4,72	4,97	5,22	5,47	5,72	5,97	6,22	6,47	6,73	6,97
7,10	4,38	4,63	4,88	5,13	5,38	5,63	5,88	6,13	6,38	6,63	6,88
7,20	4,28	4,53	4,78	5,03	5,28	5,53	5,78	6,03	6,28	6,53	6,78
7,30	4,19	4,44	4,69	4,94	5,19	5,44	5,69	5,94	6,19	6,44	6,69
7,40	4,10	4,35	4,60	4,85	5,10	5,35	5,60	5,84	6,10	6,35	6,60
7,50	4,01	4,26	4,50	4,76	5,01	5,26	5,50	5,76	6,00	6,26	6,50
7,60	3,91	4,16	4,41	4,66	4,91	5,16	5,41	5,66	5,91	6,16	6,41
7,70	3,82	4,07	4,32	4,57	4,82	5,07	5,32	5,57	5,82	6,07	6,32
7,80	3,72	3,98	4,22	4,48	4,72	4,98	5,22	5,48	5,72	5,98	6,22
7,90	3,63	3,88	4,13	4,38	4,63	4,88	5,13	5,38	5,63	5,88	6,13
8,00	3,54	3,79	4,04	4,29	4,54	4,79	5,04	5,29	5,54	5,79	6,04

Table 30 Profit margin over pelleted feed cost (c/litre): cows consuming 60L:40C pelleted rations

Pelleted feed cost (c/kg)	Milk price c/litre 11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	6,71	6,96	7,21	7,46	7,71	7,96	8,21	8,46	8,71	8,96	9,21
5,10	6,62	6,87	7,12	7,37	7,62	7,87	8,12	8,37	8,62	8,87	9,12
5,20	6,54	6,78	7,04	7,28	7,54	7,78	8,04	8,28	8,54	8,78	9,04
5,30	6,45	6,70	6,95	7,20	7,45	7,70	7,95	8,20	8,45	8,70	8,95
5,40	6,36	6,61	6,86	7,11	7,36	7,61	7,86	8,11	8,36	8,61	8,86
5,50	6,28	6,53	6,78	7,03	7,28	7,53	7,78	8,03	8,28	8,53	8,78
5,60	6,19	6,44	6,69	6,94	7,19	7,44	7,69	7,94	8,19	8,44	8,69
5,70	6,11	6,36	6,61	6,86	7,11	7,36	7,61	7,86	8,11	8,36	8,61
5,80	6,02	6,27	6,52	6,77	7,02	7,27	7,52	7,77	8,02	8,27	8,52
5,90	5,93	6,18	6,43	6,68	6,93	7,18	7,43	7,68	7,93	8,18	8,43
6,00	5,85	6,10	6,35	6,60	6,85	7,10	7,35	7,60	7,85	8,10	8,35
6,10	5,76	6,01	6,26	6,51	6,76	7,01	7,26	7,51	7,76	8,01	8,26
6,20	5,68	5,93	6,18	6,43	6,68	6,93	7,18	7,43	7,68	7,93	8,18
6,30	5,59	5,84	6,09	6,34	6,59	6,84	7,09	7,34	7,59	7,84	8,09
6,40	5,50	5,76	6,00	6,26	6,50	6,76	7,00	7,26	7,50	7,76	8,00
6,50	5,42	5,67	5,92	6,17	6,42	6,67	6,92	7,17	7,42	7,67	7,92
6,60	5,33	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58	7,83
6,70	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25	7,50	7,75
6,80	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66
6,90	5,08	5,32	5,58	5,82	6,08	6,32	6,58	6,82	7,08	7,32	7,58
7,00	4,99	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49
7,10	4,90	5,15	5,40	5,65	5,90	6,15	6,40	6,65	6,90	7,15	7,40
7,20	4,82	5,07	5,32	5,57	5,82	6,07	6,32	6,57	6,82	7,07	7,32
7,30	4,73	4,98	5,23	5,48	5,73	5,98	6,23	6,48	6,73	6,98	7,23
7,40	4,65	4,90	5,15	5,40	5,65	5,90	6,15	6,40	6,65	6,90	7,15
7,50	4,56	4,81	5,06	5,31	5,56	5,81	6,06	6,31	6,56	6,81	7,06
7,60	4,47	4,72	4,97	5,22	5,47	5,72	5,97	6,22	6,47	6,72	6,97
7,70	4,39	4,64	4,89	5,14	5,39	5,64	5,89	6,14	6,39	6,64	6,89
7,80	4,30	4,55	4,80	5,05	5,30	5,55	5,80	6,05	6,30	6,55	6,80
7,90	4,22	4,47	4,72	4,97	5,22	5,47	5,72	5,97	6,22	6,47	6,72
8,00	4,13	4,38	4,63	4,88	5,13	5,38	5,63	5,88	6,13	6,38	6,63

Table 31 Profit margin over pelleted feed cost (c/litre): cows consuming 40L:60C pelleted ration

pelleted feed cost (c/kg)	Milk price c/litre										
	11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	6,89	7,14	7,39	7,64	7,89	8,14	8,39	8,64	8,89	9,14	9,39
5,10	6,81	7,06	7,31	7,56	7,81	8,06	8,31	8,56	8,81	9,06	9,31
5,20	6,72	6,97	7,22	7,47	7,72	7,97	8,22	8,47	8,72	8,97	9,22
5,30	6,64	6,89	7,14	7,39	7,64	7,89	8,14	8,39	8,64	8,89	9,14
5,40	6,56	6,81	7,06	7,31	7,56	7,81	8,06	8,31	8,56	8,81	9,06
5,50	6,48	6,73	6,98	7,23	7,48	7,73	7,98	8,23	8,48	8,73	8,98
5,60	6,39	6,64	6,89	7,14	7,39	7,64	7,89	8,14	8,39	8,64	8,89
5,70	6,31	6,56	6,81	7,06	7,31	7,56	7,81	8,06	8,31	8,56	8,81
5,80	6,23	6,48	6,73	6,98	7,23	7,48	7,73	7,98	8,23	8,48	8,73
5,90	6,15	6,40	6,65	6,90	7,15	7,40	7,65	7,90	8,15	8,40	8,65
6,00	6,06	6,32	6,56	6,82	7,06	7,32	7,56	7,82	8,06	8,32	8,56
6,10	5,98	6,23	6,48	6,73	6,98	7,23	7,48	7,73	7,98	8,23	8,48
6,20	5,90	6,15	6,40	6,65	6,90	7,15	7,40	7,65	7,90	8,15	8,40
6,30	5,82	6,07	6,32	6,57	6,82	7,07	7,32	7,57	7,82	8,07	8,32
6,40	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24
6,50	5,65	5,90	6,15	6,40	6,65	6,90	7,15	7,40	7,65	7,90	8,15
6,60	5,57	5,82	6,07	6,32	6,57	6,82	7,07	7,32	7,57	7,82	8,07
6,70	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74	7,99
6,80	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66	7,91
6,90	5,32	5,58	5,82	6,08	6,32	6,58	6,82	7,08	7,32	7,58	7,82
7,00	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74
7,10	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66
7,20	5,08	5,33	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58
7,30	5,00	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25	7,50
7,40	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41
7,50	4,83	5,08	5,33	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33
7,60	4,75	5,00	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25
7,70	4,67	4,92	5,17	5,42	5,67	5,92	6,17	6,42	6,67	6,92	7,17
7,80	4,58	4,84	5,08	5,34	5,58	5,84	6,08	6,34	6,58	6,84	7,08
7,90	4,50	4,75	5,00	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00
8,00	4,42	4,67	4,92	5,17	5,42	5,67	5,92	6,17	6,42	6,67	6,92

Table 32 Profit margin over pelleted feed cost (c/litre): cows consuming 20L:80C pelleted ration

Pelleted feed cost (c/kg)	Milk price c/litre 11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	7,05	7,30	7,55	7,80	8,05	8,30	8,55	8,80	9,05	9,30	9,55
5,10	6,97	7,22	7,47	7,72	7,97	8,22	8,47	8,72	8,97	9,22	9,47
5,20	6,89	7,14	7,39	7,64	7,89	8,14	8,39	8,64	8,89	9,14	9,39
5,30	6,81	7,06	7,31	7,56	7,81	8,06	8,31	8,56	8,81	9,06	9,31
5,40	6,73	6,98	7,23	7,48	7,73	7,98	8,23	8,48	8,73	8,98	9,23
5,50	6,65	6,90	7,15	7,40	7,65	7,90	8,15	8,40	8,65	8,90	8,15
5,60	6,57	6,82	7,07	7,32	7,57	7,82	8,07	8,32	8,57	8,82	9,07
5,70	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24	8,49	8,74	8,99
5,80	6,42	6,66	6,92	7,16	7,42	7,66	7,92	8,16	8,42	8,66	8,92
5,90	6,34	6,59	6,84	7,09	7,34	7,59	7,84	8,09	8,34	8,59	8,84
6,00	6,26	6,51	6,76	7,01	7,26	7,51	7,76	8,01	8,26	8,51	8,76
6,10	6,18	6,43	6,68	6,93	7,18	7,43	7,68	7,93	8,18	8,43	8,68
6,20	6,10	6,35	6,60	6,85	7,10	7,35	7,60	7,85	8,10	8,35	8,60
6,30	6,02	6,27	6,52	6,77	7,02	7,27	7,52	7,77	8,02	8,27	8,52
6,40	5,94	6,19	6,44	6,69	6,94	7,19	7,44	7,69	7,94	8,19	8,44
6,50	5,86	6,11	6,36	6,61	6,86	7,11	7,36	7,61	7,86	8,11	8,36
6,60	5,78	6,03	6,28	6,53	6,78	7,03	7,28	7,53	7,78	8,03	8,28
6,70	5,70	5,95	6,20	6,45	6,70	6,95	7,20	7,45	7,70	7,95	8,20
6,80	5,62	5,87	6,12	6,37	6,62	6,87	7,12	7,37	7,62	7,87	8,12
6,90	5,54	5,80	6,04	6,30	6,54	6,80	7,04	7,30	7,54	7,80	8,04
7,00	5,47	5,72	5,97	6,22	6,47	6,72	6,97	7,22	7,47	7,72	7,97
7,10	5,39	5,64	5,89	6,14	6,39	6,64	6,89	7,14	7,39	7,64	7,89
7,20	5,31	5,56	5,81	6,06	6,31	6,56	6,81	7,06	7,31	7,56	7,81
7,30	5,23	5,48	5,73	5,98	6,23	6,48	6,73	6,98	7,23	7,48	7,73
7,40	5,15	5,40	5,65	5,90	6,15	6,40	6,65	6,90	7,15	7,40	7,65
7,50	5,07	5,32	5,57	5,82	6,07	6,32	6,57	6,82	7,07	7,32	7,57
7,60	4,99	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49
7,70	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41
7,80	4,83	5,08	5,33	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33
7,90	4,76	5,00	5,26	5,50	5,76	6,00	6,26	6,50	6,76	7,00	7,26
8,00	4,68	4,93	5,18	5,43	5,68	5,93	6,18	6,43	6,68	6,93	7,18

Table 33 Profit margin over pelleted feed cost (c/litre):first-calf heifers consuming 80L:20C pelleted rations

Pelleted feed cost (c/kg)	Milk price c/litre 11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	5,79	6,04	6,29	6,54	6,79	7,04	7,29	7,54	7,79	8,04	8,29
5,10	5,68	5,93	6,18	6,43	6,68	6,93	7,18	7,43	7,68	7,93	8,18
5,20	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58	7,83	8,08
5,30	5,48	5,73	5,98	6,23	6,48	6,73	6,98	7,23	7,48	7,73	7,98
5,40	5,37	5,62	5,87	6,12	6,37	6,62	6,87	7,12	7,37	7,62	7,87
5,50	5,27	5,52	5,77	6,02	6,27	6,52	6,77	7,02	7,27	7,52	7,77
5,60	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66
5,70	5,06	5,31	5,56	5,81	6,06	6,31	6,56	6,81	7,06	7,31	7,56
5,80	4,95	5,20	5,45	5,70	5,95	6,20	6,45	6,70	6,95	7,20	7,45
5,90	4,85	5,10	5,35	5,60	5,85	6,10	6,35	6,60	6,85	7,10	7,35
6,00	4,75	5,00	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25
6,10	4,64	4,89	5,14	5,39	5,65	5,89	6,14	6,39	6,64	6,89	7,14
6,20	4,54	4,79	5,04	5,29	5,54	5,79	6,04	6,29	6,54	6,79	7,04
6,30	4,43	4,68	4,93	5,18	5,43	5,68	5,93	6,18	6,43	6,68	6,93
6,40	4,33	4,58	4,83	5,08	5,33	5,58	5,83	6,08	6,33	6,58	6,83
6,50	4,22	4,48	4,73	4,98	5,22	5,48	5,73	5,98	6,22	6,48	6,73
6,60	4,12	4,37	4,62	4,87	5,12	5,37	5,62	5,87	6,12	6,37	6,62
6,70	4,02	4,27	4,52	4,77	5,02	5,27	5,52	5,77	6,02	6,27	6,52
6,80	3,91	4,16	4,41	4,66	4,91	5,16	5,41	5,66	5,91	6,16	6,41
6,90	3,81	4,06	4,31	4,56	4,81	5,06	5,31	5,56	5,81	6,06	6,31
7,00	3,70	3,95	4,20	4,45	4,70	4,95	5,20	5,45	5,70	5,95	6,20
7,10	3,60	3,85	4,10	4,35	4,60	4,85	5,10	5,35	5,60	5,85	6,10
7,20	3,50	3,74	4,00	4,24	4,50	4,74	5,00	5,24	5,50	5,74	6,00
7,30	3,39	3,64	3,89	4,14	4,39	4,64	4,89	5,14	5,39	5,64	5,89
7,40	3,29	3,54	3,79	4,04	4,29	4,54	4,79	5,04	5,29	5,54	5,79
7,50	3,18	3,43	3,68	3,93	4,18	4,43	4,68	4,93	5,18	5,43	5,68
7,60	3,08	3,33	3,58	3,83	4,08	4,33	4,58	4,83	5,08	5,33	5,58
7,70	2,97	3,22	3,47	3,72	3,97	4,22	4,47	4,72	4,97	5,22	5,47
7,80	2,87	3,12	3,37	3,62	3,87	4,12	4,37	4,62	4,87	5,12	5,37
7,90	2,77	3,02	3,27	3,52	3,77	4,02	4,27	4,52	4,77	5,02	5,27
8,00	2,66	2,91	3,16	3,41	3,66	3,91	4,16	4,41	4,66	4,91	5,16

Table 34 Profit margin over pelleted feed cost (c/litre):first-calf heifers consuming 60L:40C pelleted ration

pelleted feed cost (c/kg)	Milk price c/litre										
	11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	5,77	6,02	6,27	6,52	6,77	7,02	7,27	7,52	7,77	8,02	8,27
5,10	5,67	5,92	6,17	6,42	6,67	6,92	7,17	7,42	7,67	7,92	8,17
5,20	5,56	5,82	6,06	6,32	6,56	6,82	7,06	7,32	7,56	7,82	8,06
5,30	5,46	5,71	5,96	6,21	6,46	6,71	6,96	7,21	7,46	7,71	7,96
5,40	5,36	5,61	5,86	6,11	6,36	6,61	6,86	7,11	7,36	7,61	7,86
5,50	5,25	5,50	5,75	6,00	6,25	6,50	6,75	7,00	7,25	7,50	7,75
5,60	5,15	5,40	5,65	5,90	6,15	6,40	6,65	6,90	7,15	7,40	7,65
5,70	5,04	5,29	5,54	5,79	6,04	6,29	6,54	6,79	7,04	7,29	7,54
5,80	4,94	5,19	5,44	5,69	5,94	6,19	6,44	6,69	6,94	7,19	7,44
5,90	4,84	5,08	5,33	5,58	5,84	6,08	6,33	6,58	6,84	7,08	7,33
6,00	4,73	4,98	5,23	5,48	5,73	5,98	6,23	6,48	6,73	6,98	7,23
6,10	4,62	4,87	5,12	5,37	5,62	5,87	6,12	6,37	6,62	6,87	7,12
6,20	4,52	4,77	5,02	5,27	5,52	5,77	6,02	6,27	6,52	6,77	7,02
6,30	4,42	4,66	4,92	5,16	5,42	5,66	5,92	6,16	6,42	6,66	6,92
6,40	4,31	4,56	4,81	5,06	5,31	5,56	5,81	6,06	6,31	6,56	6,81
6,50	4,21	4,46	4,71	4,96	5,21	5,46	5,71	5,96	6,21	6,46	6,71
6,60	4,10	4,35	4,60	4,85	5,10	5,35	5,60	5,85	6,10	6,35	6,60
6,70	4,00	4,25	4,50	4,75	5,00	5,25	5,50	5,75	6,00	6,25	6,50
6,80	3,89	4,14	4,39	4,64	4,89	5,14	5,39	5,64	5,89	6,14	6,39
6,90	3,79	4,04	4,29	4,54	4,79	5,04	5,29	5,54	5,79	6,04	6,29
7,00	3,68	3,93	4,18	4,43	4,68	4,93	5,18	5,43	5,68	5,93	6,18
7,10	3,58	3,83	4,08	4,33	4,58	4,83	5,08	5,33	5,58	5,83	6,08
7,20	3,48	3,72	3,98	4,22	4,48	4,72	4,98	5,22	5,48	5,72	5,98
7,30	3,37	3,62	3,87	4,12	4,37	4,62	4,87	5,12	5,37	5,62	5,87
7,40	3,27	3,52	3,77	4,02	4,27	4,52	4,77	5,02	5,27	5,52	5,77
7,50	3,16	3,41	3,66	3,91	4,16	4,41	4,66	4,91	5,16	5,41	5,66
7,60	3,06	3,31	3,56	3,81	4,06	4,31	4,56	4,81	5,06	5,31	5,56
7,70	2,95	3,20	3,45	3,70	3,95	4,20	4,45	4,70	4,95	5,20	5,45
7,80	2,85	3,10	3,35	3,60	3,85	4,10	4,35	4,60	4,85	5,10	5,35
7,90	2,74	2,99	3,24	3,49	3,74	3,99	4,24	4,49	4,74	4,99	5,24
8,00	2,64	2,89	3,14	3,39	3,64	3,89	4,14	4,39	4,64	4,89	5,14

Table 35 Profit margin over pelleted feed cost (c/litre): first-calf heifers consuming 40L:60C pelleted ration

Pelleted feed cost (c/kg)	Milk price c/litre										
	11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	5,93	6,18	6,43	6,68	6,93	7,18	7,43	7,68	7,93	8,18	8,43
5,10	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58	7,83	8,08	8,33
5,20	5,72	5,97	6,22	6,47	6,72	6,97	7,22	7,47	7,72	7,97	8,22
5,30	5,62	5,87	6,12	6,37	6,62	6,87	7,12	7,37	7,62	7,87	8,12
5,40	5,52	5,77	6,02	6,27	6,52	6,77	7,02	7,27	7,52	7,77	8,02
5,50	5,42	5,67	5,92	6,17	6,42	6,67	6,92	7,17	7,42	7,67	7,92
5,60	5,32	5,57	5,82	6,07	6,32	6,57	6,82	7,07	7,32	7,57	7,82
5,70	5,22	5,47	5,72	5,97	6,22	6,47	6,72	6,97	7,22	7,47	7,72
5,80	5,12	5,36	5,62	5,86	6,12	6,36	6,62	6,86	7,12	7,36	7,62
5,90	5,01	5,26	5,51	5,76	6,01	6,26	6,51	6,76	7,01	7,26	7,51
6,00	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41
6,10	4,81	5,06	5,31	5,56	5,81	6,06	6,31	6,56	6,81	7,06	7,31
6,20	4,71	4,96	5,21	5,46	5,71	5,96	6,21	6,46	6,71	6,96	7,21
6,30	4,61	4,86	5,11	5,36	5,61	5,86	6,11	6,36	6,61	6,86	7,11
6,40	4,51	4,76	5,01	5,26	5,51	5,76	6,01	6,26	6,51	6,76	7,01
6,50	4,41	4,66	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91
6,60	4,30	4,55	4,80	5,05	5,30	5,55	5,80	6,05	6,30	6,55	6,80
6,70	4,20	4,45	4,70	4,95	5,20	5,45	5,70	5,95	6,20	6,45	6,70
6,80	4,10	4,35	4,60	4,85	5,10	5,35	5,60	5,85	6,10	6,35	6,60
6,90	4,00	4,25	4,50	4,75	5,00	5,25	5,50	5,75	6,00	6,25	6,50
7,00	3,90	4,15	4,40	4,65	4,90	5,15	5,40	5,65	5,90	6,15	6,40
7,10	3,80	4,05	4,30	4,55	4,80	5,05	5,30	5,55	5,80	6,05	6,30
7,20	3,70	3,95	4,20	4,44	4,70	4,95	5,20	5,44	5,70	5,95	6,20
7,30	3,59	3,84	4,09	4,34	4,59	4,84	5,09	5,34	5,69	5,84	6,09
7,40	3,49	3,74	3,99	4,24	4,49	4,74	4,99	5,24	5,49	5,74	5,99
7,50	3,39	3,64	3,89	4,14	4,39	4,64	4,89	5,14	5,39	5,64	5,89
7,60	3,29	3,54	3,79	4,04	4,29	4,54	4,79	5,04	5,29	5,54	5,79
7,70	3,19	3,44	3,69	3,94	4,19	4,04	4,69	4,94	5,19	5,44	5,69
7,80	3,09	3,34	3,59	3,84	4,09	4,34	4,59	4,84	5,09	5,34	5,59
7,90	2,98	3,24	3,49	3,74	3,98	4,24	4,49	4,74	4,98	5,24	5,49
8,00	2,88	3,13	3,38	3,63	3,88	4,13	4,38	4,63	4,88	5,13	5,38

Table 36 Profit margin over pelleted feed cost (c/litre): first-calf heifers consuming 20L:80C pelleted ration

Pelleted feed cost (c/kg)	Milk price c/litre										
	11,00	11,25	11,50	11,75	12,00	12,25	12,50	12,75	13,00	13,25	13,50
5,00	6,83	7,08	7,33	7,58	7,83	8,08	8,33	8,58	8,83	9,08	9,33
5,10	6,74	6,99	7,24	7,49	7,74	7,99	8,24	8,49	8,74	8,99	9,24
5,20	6,66	6,91	7,16	7,41	7,66	7,91	8,16	8,41	8,66	8,91	9,16
5,30	6,58	6,83	7,08	7,33	7,58	7,83	8,08	8,33	8,58	8,83	9,08
5,40	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24	8,49	8,74	8,99
5,50	6,41	6,66	6,91	7,16	7,41	7,66	7,91	8,16	8,41	8,66	8,91
5,60	6,33	6,58	6,83	7,08	7,33	7,58	7,83	8,08	8,33	8,58	8,83
5,70	6,24	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24	8,49	8,74
5,80	6,16	6,41	6,66	6,91	7,16	7,41	7,66	7,91	8,16	8,41	8,66
5,90	6,08	6,33	6,58	6,83	7,08	7,33	7,58	7,83	8,08	8,33	8,58
6,00	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24	8,49
6,10	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,56	7,91	8,16	8,41
6,20	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58	7,83	8,08	8,33
6,30	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74	7,99	8,24
6,40	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66	7,91	8,16
6,50	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58	7,83	8,08
6,60	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74	7,99
6,70	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66	7,91
6,80	5,33	5,58	5,83	6,08	6,33	6,58	5,83	7,08	7,33	7,58	7,83
6,90	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49	7,74
7,00	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41	7,66
7,10	5,08	5,33	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33	7,58
7,20	4,99	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24	7,49
7,30	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16	7,41
7,40	4,83	5,08	5,33	5,58	5,83	6,08	6,33	6,58	6,83	7,08	7,33
7,50	4,74	4,99	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99	7,24
7,60	4,66	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91	7,16
7,70	4,58	4,82	5,08	5,32	5,58	5,82	6,08	6,32	6,58	6,82	7,08
7,80	4,49	4,74	4,99	5,24	5,49	5,74	5,99	6,24	6,49	6,74	6,99
7,90	4,41	4,66	4,91	5,16	5,41	5,66	5,91	6,16	6,41	6,66	6,91
8,00	4,32	4,58	4,82	5,08	5,32	5,58	5,82	6,08	6,32	6,58	6,82

2.8 Reproduction and health

Reproduction data of cows and first-calf heifers receiving maize silage and varying lucern:concentrate pelleted rations are presented in Tables 37 and 38.

The ration treatments had no influence. A calving interval of 412,1 to 440,1 days in the case of cows and 401,0 to 456,8 days in the case of first-calf heifers may be considered normal under practical farming conditions.

The influence of pregnancy on body mass changes and milk production may be ignored in this study due to the fact that experimental animals were not pregnant for longer than 175,2 days during lactation. The influence of pregnancy on lactation is practically negligible until the fifth month (Gaines, cited by Smith, 1959). A cow carrying a calf over 200 days during lactation produces about three per cent less milk in comparison with a lactating cow carrying no calf (Ragsdale, Turner & Brody, 1924). It is only in the last third part of pregnancy (from the sixth month onwards) that it becomes necessary to make special provision in the diet for the growth of the foetus (McDonald et al., 1973).

Seventeen cases of mastitis occurred during the course of the experiment. The general health and condition of the animals were satisfactory. No experimental rations produced bloat, digestive disturbances or general stiffness. Foot rot was encountered in a few animals. The possibility that the use of complete feeds on a long term basis may result in health problems has been cited by a number of workers. Rumen para= keratosis (Cullison, 1961), liver abscesses (Ellis, 1965) and

Table 37 Reproduction data of experimental cows

Reproduction data	Units	Ration treatment A	B	C	D	Diff[1]
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
1st oestrus after partu=rition	days	41,1	58,5	65,1	52,0	NS
Re-breeding period after parturition	days	162,8	159,8	141,1	135,8	NS
Number of in=seminations per concep=tion	-	2,2	2,1	1,8	2,0	NS
Gestation period	days	277,3	270,2	276,8	276,3	NS
Period of lactation pregnant	days	137,2	140,2	158,9	164,2	NS
Intercalving period	days	440,1	430,0	417,9	412,1	NS

1 Differences: NS; non-significant (P>0,05)

Table 38 Reproduction data of experimental first-calf heifers

Reproduction data	Units	A	B	C	D	Diff[1]
		Ration treatment				
		maize silage +				
		80L:20C	60L:40C	40L:60C	20L:80C	
1st oestrus after partu=rition	days	48,5	52,1	49,9	50,8	NS
Re-breeding period after parturition	days	124,8	131,1	151,9	180,1	NS
Number of in=seminations per concep=tion	-	2,0	1,6	2,2	1,8	NS
Gestation period	days	276,2	276,8	276,7	276,7	NS
Period of lactation pregnant	days	175,2	168,9	148,1	119,9	NS
Intercalving period	days	401,0	407,9	428,6	456,8	NS

1 Differences: NS; non-significant (P>0,05)

joint stiffness (Komkris, Stanley & Morita, 1965) have been reported when feeding ruminants rations containing small amounts of roughage. Evaluation of the long term use of feeding complete rations with low roughage portions is needed.

2.9 Feeding of the experimental pelleted rations compared to the feeding of similar compiled rations in a non-pelleted form.

2.9.1 Introduction

Lucern is often ground and fed in this form or fed in pelleted form after grinding. When feeding the latter it is difficult to distinguish between differences due to grinding and diffe= rences due to pelleting.
Meyer, Weir, Dobie & Hull (1959) concluded from their study that fine grinding is probably the major factor causing in= creased feed consumption of pelleted hay and that the pellet= ing process serves to change a fine, dusty feed into a more palatable form. These workers noted a greater intake with chopped than finely ground material but by adding water to the finely ground alfalfa they increased its consumption almost to the consumption of pelleted rations.
The possibility of obtaining the same results with pelleted and non-pelleted but otherwise identical rations to those already described, was investigated in the present study.

2.9.2 Procedure and methods

2.9.2.1 The experimental design

The experimental design followed was the switchback type as described by Lucas (1960). The basic pattern (Table 39) in=volved four feeding trials consisting of two treatments per trial in a three experimental period pattern with two treat=ment sequences.

The experimental units in all trials were lactating cows. The treatments were four varying ratios of lucern:concentrate rations; each ration being fed ad lib. in a pelleted and non-pelleted form, in addition to restricted maize silage.

Table 39 The basic switchback pattern per trial

	Treatment sequence	
Comparison period	1	2
1	Tr 1+	Tr 2
2	Tr 2++	Tr 1
3	Tr 1	Tr 2

+ treatment: maize silage + pelleted ration

++ treatment: maize silage + non-pelleted ration

In the analysis for the switchback design use was made of the quadratic time trend on each subject for three periods (Brandt, 1938 and Federer, 1955) according to the example of Snedecor (1946).

2.9.2.2 The experimental animals

Sixteen lactating cows from the Glen Friesland herd were used for the experiment. During the pre-partum dry period all the animals received lucern hay and maize silage ad lib.for 60 days. Immediately after calving the cows were brought into the experimental feeding parlour and placed on a standard ration for a 60-day standardization period. The same procedures were followed in the standardization- and comparison periods. At the end of the standardization period two cows were allot= ted at random to each treatment sequence within each trial. Cows allotted to treatment sequence No.1 were started on the pelleted ration and switched to the non-pelleted ration during the second comparison period and returned to the pelleted ration during the third comparison period. The other group of cows were started on the non-pelleted ration (treat= ment sequence No.2) and switched to the pelleted ration during the second comparison period and returned to the non-pelleted ration during the third comparison period. No digestive, physiological, or palatability problems were notice= able when the cows were switched directly from the one ration to the other. Similar results were observed by Bath, Bishop, Hutton, Oliver & Dean (1968) and Howard, Albright, Cunningham, Harrington, Noller & Taylor (1968). The length of each comparison period was 30 days.

2.9.2.3 Housing and care

During the standardization- and comparison period cows were housed in a feeding parlour as shown in Fig.1.
Woodshavings were used for bedding. The cows were fed indi= vidually during both the standardization- and comparison period; at 08h00 and 13h30. Maize silage residue was collected and the mass determined daily before the morning feed. The lucern:concentrate ration residue was collected and its mass determined twice weekly. The animals were hand-milked at 15h30 - 06h00 and 15h00 - 15h30.
The animals were inspected regularly during the day and at night. Water was available ad lib. from automatic drinking troughs.
The mass of the animals was determined immediately after calving, at 30-day intervals and at the end of the trial.

2.9.2.4 Standardization- and experimental rations

The standardization ration was identical to that described under 1.4.1.
The experimental rations were 4,5 kg of maize silage per feeding plus varying lucern:concentrate ratios in a pelleted as well as non-pelleted form. The four pelleted rations were identical to those described under 1.4.2. The chemical com= position of the four non-pelleted rations was the same as that of the pelleted rations. The lucern portion of the non-pelleted rations was chaffed (2,5 cm lengths) and thoroughly mixed with the concentrate portion in the ration. In trial

No.1 the cows received maize silage + 80L:20C; in trial No.2 maize silage + 60L:40C; in trial No.3 maize silage + 40L:60C and in trial No.4 maize silage + 20L:80C, in both pelleted and non-pelleted form.

Dry matter analyses of the maize silage and experimental rations were carried out, as previously described.

Bone meal (64 g) was thoroughly mixed in the maize silage and supplied at each feeding.

2.9.2.5 Composition of milk

Total solids and solids-not-fat of milk, milk fat, milk energy, solids corrected milk and 4% fat corrected milk were determined as described under 1.6.

2.9.3 Discussion of results

The daily dry matter consumption of the pelleted ration did not differ significantly from that of the non-pelleted ration (Table 40).

These results are in agreement with those of Beardsley (1964) who found that the overall animal response to pelleting a pre-ground high roughage ration is relatively small. He suggested that the greatest influence of pelleting a roughage can be ascribed to the grinding and not to the pelleting.

There were no significant differences between actual milk production, solids-corrected milk and milk composition when animals were fed pelleted and non-pelleted rations A, B and C (Table 40).

Cows receiving ration D in non-pelleted form produced

Table 40 Effect of pelleted and non-pelleted complete rations on feed intake, milk production and milk composition

		Ration treatment means											
Trial No.		1			2			3			4		
Experimental ration		A			B			C			D		
Variable description	Units	maize silage +											
		80L : 20C			60L : 40 C			40L : 60C			20L : 80C		
		P[1]	NP[2]	Diff[3]	P	NP	Diff	P	NP	Diff	P	NP	Diff
Body mass	kg	543	523	NS	564	558	NS	610	602	NS	607	585	NS
Daily consumption (DM):													
Maize silage	kg	2,3	2,3	NS	2,2	2,0	NS	2,2	2,2	NS	2,3	2,1	NS
Lucern:concentrate	kg	15,1	14,6	NS	13,3	15,6	NS	16,4	17,7	NS	15,4	16,6	NS
Total	kg	17,4	16,9	NS	15,5	17,6	NS	18,6	19,9	NS	17,7	18,7	NS
Total	$g/W_{kg}^{0,75}$	155	154	NS	134	154	NS	155	164	NS	144	158	NS
Daily production:													
Milk	kg	17,4	18,3	NS	20,6	19,9	NS	20,3	18,8	NS	18,9	20,4	NS
SCM[4]	kg	16,3	16,7	NS	18,5	18,3	NS	17,3	16,9	NS	15,7	18,1	*
Milk fat	%	3,6	3,5	NS	3,3	3,3	NS	3,1	3,3	NS	2,9	3,2	NS
SNF	%	9,0	8,7	NS	8,8	9,0	NS	8,7	8,9	NS	9,0	8,9	NS
TS[5]	%	12,6	12,2	NS	12,1	12,3	NS	11,8	12,2	NS	11,9	12,1	*

1 Pelleted ration 2 Non-pelleted ration

3 Differences: *$P<0,05$, NS; non-significant ($P>0,05$)

4 Ration D: NP $\overset{*}{>}$ P 5 Ration D: NP $\overset{*}{>}$ P

significantly ($P<0,05$) more solids corrected milk and total solids in milk than cows fed the corresponding pelleted ration.

CHAPTER 3

GENERAL DISCUSSION AND CONCLUSIONS

More and more dairy farmers are feeding complete rations to reduce labour costs and to inaugurate automation. The feeding of complete rations eliminates the need of feeding concentrates. Consequently labour costs can be reduced. Since complete rations are adaptable to automation, manage= ment can be simplified by following this system. It is, however, important to achieve automation without sacrificing milk production.

If the response of the individual cow and first-calf heifer to variable levels of concentrates in complete rations is known, the most profitable feeding program can be adopted. Input-output data could be of great use to project the most profitable adjustment in concentrate feeding under different feed:milk price relationships. Due to the influence of the physical form of rations and body capacity differences between cows and first-calf heifers on dry matter intake, the most profitable complete ration for cows is not necessarily the most profitable ration for first-calf heifers. A study to investigate the roughage:concentrate relationship and resulting milk production response by cows and first-calf heifers was conducted at the Agricultural Research Institute, Glen.

Ration treatments were: 80% lucern:20% concentrate (ration A), 60% lucern:40% concentrate (ration B), 40% lucern:60% concentrate (ration C) and 20% lucern:80% concentrate (ration D). The crude fibre percentages of rations A, B, C and D were 23,16; 19,34; 16,11 and 12,01 respectively. These rations were pelleted and fed ad lib. in addition to 9 kg maize silage daily. Increasing the concentrate portion of the experimental pelleted rations from 20 to 80 per cent did not lead to a significant increase in actual milk production, solids corrected milk and 4% fat corrected milk of cows, probably because a very constant voluntary metabolizable energy intake was maintained. This was 36163; 36986; 36885 and 40362 kcal respectively for rations A, B, C and D. The differences were non-significant ($P>0,05$).

The mean daily milk yield of the cows in each treatment group varied with the mean metabolizable energy intake of each group, indicating that metabolizable energy intake was associated with body capacity, digestibility of dry matter and production of milk.

The digestibility of the four experimental rations (varying between 55,55 and 65,33 per cent), the physical form of the pelleted rations, adequate body capacity and relatively high milk production ability (19,32 to 21,04 kg) made it possible for the cows to regulate the amount of food consumed. This was related to daily energy requirements, where milk produc= tion requirements were the dominant factor. The composition of the experimental rations were such that the cows were able to consume sufficient metabolizable energy to meet their milk production requirements without being limited by rumen fill.

The first-calf heifers were probably unable to overcome the limitation of the lower digestibility of rations A,B and C due to the smaller size of the digestive tract. This finding is supported by the tendency (although non-signifi= cant) towards a higher milk yield and metabolizable energy intake when first-calf heifers were fed ration D. As the digestibility of the ration increased their metabolizable energy intake tended to increase (Table 18). One may conclude that cows overcame the limitation of lower digestibilities by consuming more of the specific ration whereas first-calf heifers probably could not overcome the body capacity problem. Irrespective of ration treatment the cows consumed signifi= cantly ($P<0,01$) more dry matter during the fifth to ninth month of lactation than the first-calf heifers. Similarly, during each stage of lactation in the comparison period cows consumed significantly ($P<0,01$) more metabolizable energy than the first-calf heifers, irrespective of ration treatment. It is therefore obvious that first-calf heifers need rations of the highest digestibility to produce milk at a level proportionate with their capacity during their first lacta= tion. The results indicate that digestibilities of the pelleted experimental rations below 65 per cent do not seem desirable for first-calf heifers if production in commensu= rate with their inherited ability, is desired.

The efficiency of use of metabolizable energy for milk production was highest for cows fed ration A (maize silage + 80L:20C) followed by cows fed the 60,40 and 20 per cent lucern diets. These percentages,which did not differ significantly from one another, were 55,04; 51,80; 50,47 and 49,74 for rations A, B, C and D respectively. If utilization and storage of body tissue, which affects the amount of energy required per unit of milk produced, had been taken into consi= deration efficiency may have been more homogeneous. The tendency towards the higher efficiency of use of metabolizable energy for milk production when cows consumed ration A may be attributed to the catabolism of body tissue which supplemented metabolizable energy intake. This change in body tissue reserves was not noticeable in the body mass of the cows. Likewise, body tissue deposition, when cows consumed ration B, C and D, probably took place without being reflected in body mass changes between treatments. Although non-significant, the small differences in metabolizable energy intake could have been an adjustment to the degree of body tissue utiliza= tion or deposition and the small non-significant differences in milk yield. This indicated that milk production influenced metabolizable energy intake to a certain extent.

The efficiency of metabolizable energy utilization for milk production by first-calf heifers (Table 24) followed almost the same pattern as that of the cows. Differences were non-significant. Ronning (1960) observed a similar tendency.

A significant ($P<0,05$) effect of stage of lactation on efficiency of use of metabolizable energy for milk production by cows during the comparison period, was recorded. Irre= spective of treatment cows produced milk significantly ($P<0,05$) more efficiently during the third and fourth month of lactation than during the later months. This indicates that the lactating cow is able to mobilize extremely large amounts of body tissue in early lactation and conversely during later lactation is able to deposit very large amounts of body tissue (Flatt et al., 1965).

The effect of stage of lactation on the efficiency of use of metabolizable energy for milk production by first-calf heifers (in comparison with cows) was less pronounced; differences being non-significant (P>0,05). Irrespective of treatment, the cows produced milk significantly (P<0,01) more efficiently in the comparison period, during the third and fourth month of lactation, than the first-calf heifers. Due to the higher body reserves cows utilized more body tissue during this stage of lactation whereas first-calf heifers were more dependent on dietary energy for milk pro= duction. Furthermore, first-calf heifers showed body mass gains within 60 days following parturition (compared to 90 - 120 days in the case of cows) indicating body tissue deposi= tion. During the fifth, sixth and seventh month of lactation, efficiency of milk production of cows and heifers was very similar. During the eighth and ninth month of lactation heifers were more efficient than the cows indicating that the cows utilized more metabolizable energy for body tissue depo= sition.

These findings indicate that complete rations containing high proportions of concentrates are suitable for first-calf heifers especially during early lactation when tissue reserves are low, body capacity is limited and dietary energy is the determining factor for production commensurate with inherited ability.

Although the combination of energy from body fat and feed should enable a cow to reach a high peak of milk production during the early stage of lactation this does not imply that cows can be fed less dietary energy in complete feeds at the expense of body reserves. The genetic ability of cows to produce high milk yields during early lactation exceeds the ability of the cow to consume sufficient feed to meet the requirements for energy, indicating the importance of both sufficient body tissue reserves and feed energy.

Irrespective of treatment milk production of cows declined gradually after the second month following parturition whereas the dry matter consumption only started to decrease gradually after the fifth or sixth month following calving. In practice this means that cows should be fed on a peak production level for at least a further three to four months following the apogee of the lactation curve to maintain a high daily milk yield.

Within each ration treatment first-calf heifers showed a significantly ($P<0,05$) lower peak production level than the cows, but maintained a more persistent level throughout lacta= tion. Following parturition the daily milk production of heifers on ration A, B and C tended to increase for 60 days after which production declined gradually. The heifers consuming ration D (maize silage + 20L:80C) did not reach maximum production until 120 to 150 days after parturition, after which production decreased slowly.

Cows on ration A, B and C produced significantly ($P<0,05$) more actual milk, 4% fat corrected milk and solids corrected milk during each stage of lactation than the first-calf heifers. Cows fed ration D showed a significantly ($P<0,05$) higher production than heifers during the third to fifth month of lactation and a non-significant difference during the sixth to tenth month.

A gradual increase in intake of dry matter by first-calf heifers occurred until the 60th day after calving, irrespective of ration treatment. From the 60th to 120th day consumption stayed at a constant level after which dry matter intake gradually began to decline. As in the case of the experimen= tal cows, first-calf heifers should be fed on a peak produc= tion level for at least the first four to five months after calving in order to attain the highest possible daily produc= tion.

During the comparison period small non-significant ($P>0,05$) differences in the average composition of milk occurred. Solids-not-fat content of milk produced by cows and first-calf heifers was normal, ranging from 8,69 to 9,02 per cent and from 8,80 to 9,16 per cent respectively. These figures are well above the minimum content of 8,5 per cent solids-not-fat in fresh milk as required by the Food, Drug and Disinfec= tants Act (Act, No.13 of 1929, Union of South Africa.)

The expected pattern of an increase in solids-not-fat and protein contents of milk with increased energy content in the ration (Hoogendoorn & Grieve, 1970) was not found in the present study. This finding is supported by reports from Bernett & Olson (1963) indicating no increase in the percentage solids-not-fat when the plane of energy in the ration was increased. The milk produced by first-calf heifers had a significantly ($P<0,01$) higher solids-not-fat content during all stages of lactation, irrespective of ration treatment, than that produced by the cows. This agrees with the findings of Waite et al.(1956) who stated that the percentage of all major constituents of milk probably decrease slightly with advancing age.

Although cows and first-calf heifers consuming ration A and first-calf heifers consuming ration B produced milk with a higher fat percentage than that produced by experimental animals consuming either ration B, C or D, the differences were non-significant ($P>0,05$).

However, the fat percentage of milk produced from all four diets, irrespective of age, was lower than that produced by cows fed conventional rations in the Glen herd; percentages being 2,97 to 3,41 for experimental animals compared to 3,82 for non-experimental animals. This decrease in fat percentage must be attributed mainly to the finely ground roughage in the pellets.

The average fat percentage of milk produced by the experi= mental animals in this study was slightly higher than the minimum of 3,0 per cent laid down by law (Act No.13, 1929) for fresh milk production.

In contrast to these findings Putnam & Davis (1961) using relatively low producing cows, noted no depression on milk fat when pelleted complete feeds containing 25 per cent grass hay were fed.

The depression of milk fat content observed in the present study may be the result of the higher milk production level of the animals used and by possible differences in forage quality, hardness-, size- and coarseness of the pellets fed.

Ration D had a crude fibre content of 13,21 per cent being below the recommended minimum of 15,6 per cent suggested by Lofgren & Warner (1970). The effect of hardness of the pellets on fat production is difficult to separate from other influences. A harder pellet may be advantageous because of its better physical form. In the present study hardness of the pellet was directly related to the lucern content which also tended to effect a corresponding increase in fat percentage, although differences were non-significant. However, the individual effects of the finely ground lucern (rations A, B, C and D), restricted roughage feeding (rations C and D), low fibre content (ration D) and the physical structure of the experimental pellets on depression of milk fat, are difficult to separate. The presence of more than one of these factors in a ration probably has an exaggerated depressive effect on milk fat.

There was a non-significant ($P>0,05$) difference between the fat percentage of milk produced by cows and first-calf heifers, irrespective of treatment. Depending on the experimental ration fed and the age group, the minimum per= centage of fat in milk produced by cows and first-calf heifers occurred between 90 and 210 days after parturition. The total solids of milk produced by cows ranged between 11,66 and 12,19 per cent and in the case of first-calf heifers between 12,15 and 12,57 per cent. On an average basis these figures are slightly lower than the value of 12,5 per cent total solids given by Smith (1970) for dairy cows. However, this fact should be of no practical signifi= cance as 11,5 per cent total solids is considered an accept= able percentage when marketing fresh milk provided it conforms to the minimum milk fat and solids-not-fat standards mentioned previously.

During all stages of the comparison period first-calf heifers produced milk with a significantly ($P<0,01$) higher percentage of total solids than milk produced by cows, irrespective of ration treatment. This agrees with the results of Waite _et al_.(1956).

In the present study feed consumption and milk production responses by cows when subjected to the experimental treat= ments were of such an order that no large differences in the profit margins between the treatment groups occurred. This indicated that cows were able to regulate feed intake in relation to daily energy needs. The first-calf heifers consuming ration D showed a higher profit margin (equal to that of the cows) than heifers consuming rations A, B and C

(Table 26). This indicated that milk production response may have been limited due to a possible limitation of dry matter intake when heifers were fed rations A, B and C. These first-calf heifers probably could not overcome the limitation of the lower digestibility of ration A, B and C due to a smaller body capacity compared to that of cows.

The profit margin over total milk production cost varied between 3,12 and 3,72 c per litre, in terms of fresh milk production, when cows were fed the experimental rations and first-calf heifers ration D. This compares well with the data obtained from studies by Ferreira (1974, personal communication), indicating profit margins of between 4,54 and 5,81 c per litre when cows were fed farm produced feeds and milk production varied between 15 and 18 kg daily.

One may conclude that the purchasing of lucern:concentrate pelleted rations is an economical proposition when produ= cing fresh milk. Seen from a production, nutritional and economical point of view any one of the experimental rations may be fed successfully to cows. Best results may be ob= tained when ration D(maize silage + 20L:80C) is fed to first-calf heifers.

The body mass of the cows and first-calf heifers were non-significantly affected by ration treatment. The effect of age on body mass changes, however, was highly significant ($P<0,01$).

The body mass differences between cows and first-calf heifers were most evident during the first 120 days after parturition. The mean body mass loss during the first 60 days after calving for all treatments was 13,7 kg per heifer. Mean individual gain of heifers during their first lactation was 80,4 kg. This indicates that heifers maintained constant growth throughout the lactation. On the other hand the mass of the cows did not stabilize until 90 to 120 days after calving. Irrespective of treatment, the mean mass loss was 66,1 kg per cow during this period while the mean mass gain was 9,9 kg per cow during lactation. The differences between body mass changes of cows and first-calf heifers is attributed to the utilization of body tissue reserves of older cows. Results similar to those observed with the four pelleted rations, were found when corresponding non-pelleted rations (lucern chaffed in 2,5 cm lengths), with a similar composition, were fed to cows.

The method of preparing the experimental rations by either pelleting or non-pelleting did not appreciably influence the daily dry matter consumption, milk production and composition of milk. However, cows receiving ration D in non-pelleted form, produced significantly more solids corrected milk and percentage total solids of milk.

These findings indicate that from an economical point of view feeding non-pelleted rations A, B, C and D to cows, is profitable. An even higher profit margin over cost of feed than that obtained with the pelleted rations is possible when non-pelleted rations are fed, due to the saving of pelleting costs. It is not clear what the situation would be when first-calf heifers receive the non-pelleted experimental rations. This aspect needs further investigation.

SUMMARY

1. In a single-lactation 240-day continuous trial, 64 lactating dairy animals were used to study input-output response to complete rations. Nine first-calf heifers and seven cows were allotted by the procedure of balancing to each of the four experimental treatments. Ration treatments were: 80% lucern:20% concentrate (ration A), 60% lucern:40% concentrate (ration B), 40% lucern:60% concentrate (ration C) and 20% lucern:80% concentrate (ration D). The crude fibre percentages of rations A, B, C and D were 23,16; 19,34; 16,11 and 12,01, respectively. These rations were pelleted and fed *ad lib.* in addition to 9 kg of maize silage daily. A digestibility trial with four additional lactating dairy animals was carried out simultaneously.

2. With decreasing proportions of lucern, digestibility of the dry matter increased from 55,55 to 65,33 per cent ($P<0,05$). Increasing the proportion of concentrates in the ration led to an increased concentration of metabolizable energy ($P<0,05$). The digestible protein in the rations varied very slightly ($P>0,05$).

3. Changes in body mass of cows and first-calf heifers due to ration treatment were non-significant ($P>0,05$). Age was the most important factor influencing body mass variations of experimental animals; differences between cows and first-calf heifers being highly significant ($P<0,01$) in favour of the cows. The individual mean body mass gain of the first-calf

heifers during their first lactation was 80,4 kg compared to 9,9 kg of the cows in their second and later lactations.

4. There were non-significant ($P>0,05$) differences, due to ration treatment, in the daily amount of actual milk, 4% fat corrected milk and solids corrected milk produced by cows. Although first-calf heifers on ration D produced 19,3 to 27,0 per cent more actual milk, 14,0 to 23,0 per cent more 4% fat corrected milk and 16,3 to 22,9 per cent more solids corrected milk than heifers on either the A, B or C rations, these differences were non-significant.
5. Cows on ration A, B and C produced more ($P<0,05$) milk, 4% fat corrected milk and solids corrected milk, during each stage of lactation, than the first-calf heifers. Cows fed ration D showed a significantly ($P<0,05$) higher production than heifers, during the third to fifth month of lactation and a non-significant difference during the sixth to tenth month.
6. Small non-significant ($P>0,05$) differences occurred in the mean solids-not-fat content of milk. Solids-not-fat content of milk produced by cows ranged from 8,69 to 9,02 per cent and from 8,90 to 9,16 per cent in the case of first-calf heifers. The milk produced by first-calf heifers had a sig= nificantly higher ($P<0,01$) solids-not-fat content than cows during all stages of lactation, irrespective of ration treat= ment.
7. Milk fat was non-significantly affected by ration treatment. Decreasing lucern content in the ration was accompanied by a decrease in the fat percentage of milk produced by cows (0,3) and by heifers (0,29).

8. The dry matter and gross energy consumption by cows tended to decrease as the dry matter digestibility of the ration in=creased, differences being non-significant. Similarly as the metabolizable energy concentration increased (increasing with a decreasing proportion of lucern) the voluntary intake by cows tended to decrease. Metabolizable energy intake between ration treatments was very constant and was related to the mean daily yield of the cows.

   The intake of dry matter and gross energy by first-calf heifers remained more or less the same for all rations ($P>0,05$). However, as the dry matter digestibility of the ration in=creased the metabolizable energy consumption by heifers tended to increase, differences being non-significant.

9. Cows consumed significantly ($P<0,01$) more dry matter, gross energy and metabolizable energy during certain stages of lactation than first-calf heifers, irrespective of ration treatment. In the case of cows the efficiency of metabolizable energy utilization for milk production increased as the lucern portion in the ration increased, differences being non-signi=ficant. A very similar tendency was noticed with the first-calf heifers. Irrespective of ration treatment cows produced milk more efficiently ($P<0,05$) during the third and fourth month of lactation than during the later months. The effect of stage of lactation on efficiency of use of metabolizable energy for milk production by heifers was less pronounced than that obtained with cows, but the differences were non-signi=ficant.

10. Irrespective of treatment the cows produced milk more efficiently ($P<0,01$) during the third and fourth month of lactation than the first-calf heifers. During the fifth, sixth and seventh month of lactation efficiency of milk production by cows and heifers was very similar. During the eighth and ninth month of lactation heifers were more efficient than the cows.

11. In terms of marketing fresh milk the profit margins over cost of feed was 5,6; 6,0;6,1 and 6,2 c per litre when cows were fed rations A, B, C and D respectively. The profit margins for first-calf heifers were 4,8; 4,7; 4,8 and 6,0 c per litre for the same rations. Reproduction of cows and first-calf heifers was non-significantly affected by ration treat=ment.

12. None of the experimental rations caused bloat-, digestive- or general stiffness problems. Seventeen cases of mastitis occurred during the course of three years and seven months.

13. In four switchback trials with 16 lactating dairy animals the pelleted experimental rations were compared with otherwise identical non-pelleted rations (lucern portion being chaffed in 2,5 cm lengths). The method of preparing the rations by either pelleting or non-pelleting did not appreciably in=fluence the dry matter consumption (g $DM/W_{kg}^{0,75}$), daily amounts of actual milk produced, solids corrected milk and composition of milk. However, animals receiving ration D in a non-pelleted form, produced significantly ($P<0,05$) more

solids corrected milk and total solids in milk than animals fed the corresponding pelleted ration.

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