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THE UTILIZATION OF MILK DIETS WITH DIFFERENT FAT CONTENT BY THE PRERUMINANT CALF
1. DIGESTIBILITY AND METABOLIZABILITY OF THE DIETS AND LIVE MASS GAIN OF THE CALVES*

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OPSOMMING: DIE BENUTTING VAN MELKDIËTE, MET VERSKILLENDE VETKONSENTRASIES, DEUR DIE VOORHERKOUER-KALF. I. BALANSPROEFRESULTATE EN MASSAVERANDERING

Agt-en-twintig Friesbulkalwers is op vier dae ouderdom by vier groepe ingedeel en tot die ouderdom van 21 dae in metabolismekratte gevoer op melkdiëte wat van 147g tot 444g bottervet per kalf per dag voorsien het. Hoewel volume-innames met slegs 18 %verhoog is vanaf die laagste tot die hoogste voedingspeil, het ME-innames meer as verdubbel vanaf 10,6 MJ tot 21,6 MJ. Die gemiddelde daaglikse N-innames het toegeneem vanaf 19,6 g (A) tot 20,7 g (D) per kalf terwyl proteïen:energie verhoudings verander het van 1 : 90 (A) tot 1 : 168 (D). Die metaboliseerbaarheid van die energie in die vier diëte was, onderskeidelik, 93,0 ±2,2; 94,2 ±3,1; 93,3 ±3,2 en 91,8 ±4,0 en die balansproefresultate het getoon dat die skynbare verteerbaarheid van vet verlaag is in die twee diëte met hoogste vetkonsentrasie. Dit het gepaard gegaan met 'n meer algemene voorkoms van buikloop onder kalwers in hierdie twee Groepe C en D. Energie- en stikstofverliese deur die urine het afgeneem namate energie-innames gestyg het. 'n Verhoogde doeltreffendheid van proteïenbenutting is aangetoon deur die stygende gemiddelde stikstofretensies, maar daar was 'n duidelike afplatting by die hoogste energiepeil op te merk. Die retensie van skynbaar verteerde proteïen het gestyg vanaf 65,9 % by Groep A tot 76,3 % by Groep C. Gemiddelde lewende massa toenames van 314 ±67,414 ±48, 557 ±78 en 567 ±133 g per kalf per dag is by die vier groepe onderskeidelik, vasgestel. Die positiewe verwantskap tussen lewende massa toenames (Y) en ME-innames (X) kon beskryf word met die vergelyking Y = 1,7747X – 18,9478 r = 0,8447.

SUMMARY

Twenty-eight Friesland bull calves, four days of age, were allotted to four groups and were offered milk diets which supplied 147 g to 444 g butterfat per calf per day for 21 days. Mean daily ME intakes increased from 10,6 MJ to 21,6 MJ while volume intakes differed by only 18 % from the lowest to the highest feeding level. Mean daily nitrogen intakes increased from 19,6 g (A) to 20,7 g (D) per calf while protein: energy ratios were widened from 1:90 to 1:168. Metabolizability of GE were 93,0 ±2,2; 94,2± 3,1; 93 ±3,2 and 91,8±4,0 in the four diets respectively and it was shown that apparent digestibility of fat was depressed on the two highest fat diets, mainly as a result of scouring which occurred with higher incidence in Groups C and D. Urinary energy- and urinary nitrogen losses decreased as energy intakes increased. A better utilization of dietary protein, at the higher levels of energy intake, was shown by an increased nitrogen retention by calves on the higher energy diets, although there was a levelling-off at the highest energy intake. Retention of apparently digested nitrogen increased from 65,9 % in Group A to 76,3 % in Group C. Mean live mass gains of 314 ±67, 414 ±48,557 ±78 and 567 ±133 g per calf per day were recorded in the four groups respectively. The highly significant regression equation describing the relationship between live mass gain (Y) and ME-intake (X) was Y = 1,7747X – 19,9478. r = 0,8447.

The ideal protein: energy ratio in milk replacers for veal calves still awaits confirmation. Cows' milk (low fat breeds) has on the average 25 % protein and 25–30 % fat in the dry matter while commercial milk replacers contain at least 20 % of protein and from 5–25 % of fat. There are strong indications that cows' whole milk is entirely adequate and perhaps even excessive in protein content in relation to its non-protein energy content (Blaxter & Wood, 1952; Blaxter, 1962) and that the latter places a restriction on growth rate and lowers effective utilization of the available protein. This will obviously be even more so in low-fat milk replacers.

In some studies with calves the energy intake was increased simply by increasing the quantity of milk offered (Blaxter, 1952; Van Es, Nijkamp, van Weerden & van Hellemond, 1969; Johnson & Elliot, 1972). However, the relatively small gut capacity of the calf limits the increase in energy intake which can be achieved in this manner while it still leaves the question of the optimum protein: energy ratio, begging.

On the other hand higher energy intakes and a widening of the protein:energy ratio can be effected by addition of fats, which the young calf can utilize provided that the fat is homogenized and of small globule size (Owen, Jacobson, Allan & Homeyer, 1958; Griffiths & McGarn, 1966; Ronning, Baldwin & Tennant, 1966; Roy, 1970b). As far as the composition of milk substitutes is concerned the available fat sources are plant oils and animal fats of slaughterhouse origin but while these have to be specially prepared for the young calf, milk fat (cream) offers an ideal product for a basic study of the principles involved.

The present study which comprised metabolism and comparative slaughter experiments with Friesland bull calves over the life span 4–25 days, was therefore under-

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taken to investigate the effects of the addition of milk fat to whole milk, on the utilization of energy and protein.

Procedure

Twenty-eight Friesland bull calves were randomly allotted to four dietary treatments (A, B, C and D) while a fifth group of eight calves (S), representative of the range in body mass at birth of the trial groups, were slaughtered as an initial control. After they were removed from their dams at not less than 24 and not more than 48 hr after birth, each calf received a standard antibiotic treatment and 3,5 kg whole milk (to equalize gut fill before mass was recorded) on the third day of life. On the morning of the fourth day calves of the S-groups were slaughtered while those allotted to the trial groups were transferred to individual metabolism cages, where they remained until slaughter on their 25th day of life. Water intake was restricted to 2,5 *l* offered in the afternoon, during the 21 day experimental period. The calves were bucket-fed daily at 08h00 and received their individual milk rations in a single feed. Live mass was recorded on the morning of the fourth and again on the 25th day of life, subsequent to a fasting period of 24 hr.

The four milk diets comprised a cow's whole milk control and three experimental diets prepared by adding different quantities of cream to whole milk. Energy concentrations of milk and cream were regularly determined and the means came to 2,926 and 17,598 kJ/g fluid respectively. Energy was rationed on the basis of initial metabolic mass. Group A received 836 kJ GE/kg$W^{0,73}$ per day as whole milk, while to this basic allowance 334, 669 and 1003 kJ GE/kg$W^{0,73}$ in the form of cream were added for Groups B, C and D respectively. All diets were sampled daily and seven-day bulk samples were analysed after being stored at 4°C, without preservative, for not longer than 10 days.

The total faecal excretion was collected daily on a pre-weighed tinfoil sheet which was used as lining for an adjustable faeces collection-pan behind the calf. Preliminary drying took place at 65°C in a forced draught oven. Seven-day bulk samples were stored for analysis and dried to constant weight before grinding through a one millimetre screen in a C & N Laboratory mill, using dry ice (according to the method described by Hofmeyr, Kroon, van Rensburg & van der Merwe, 1972) where necessary, with high-fat samples. Urine was collected in glass containers with $HgCl\text{-}K_2Cr_2O_7$ as a preservative. Seven-day bulked samples of a 2% daily aliquot, were stored at –4°C for analysis.

Milk- and urine samples were freeze-dried in bomb calorimeter crucibles, for dry matter and energy determinations. Because of the limited size (5 ml) of the crucibles and a low urine dry matter content, it was necessary to dry three quantities of each urine sample in the same crucible in order to obtain sufficient dry matter for combustion.

Energy content of samples was determined in an adiabatic bomb calorimeter (Gallenkamp & Co.). Nitrogen was determined by macro-kjeldahl procedure (for milk protein: N x 6,38; otherwise: N x 6,25) butterfat by the standard Gerber Method and ether extract in faeces by diethyl-ether extraction in a Goldfisch apparatus.

Results and discussion

Composition of the diets

The composition of the four milk diets is given in Table 1.

The addition of butterfat resulted in a progressive increase in energy- and decrease in nitrogen (protein) concentration on a DM basis. The protein:energy ratio widened from 1: 90 to 1: 168 while protein energy as a percentage of gross energy decreased from 26 to 14 kJ/100 kJ. With the exception of two calves in Group D, which did not succeed in taking in their allotted rations, no difficulties with intake were encountered.

Digestibility, metabolizability and nitrogen retention

No significant differences were found between the digestibilities obtained in the three consecutive seven-day collection periods within each treatment group. The mean digestibility values for the total collection period of 21 days were therefore used. These results are presented in Table 2.

Table 2 shows that, while volume of milk intake increased by only 18% from Group A to Group D, this resulted in a 105% increase in gross-energy and 103% in metabolizable energy intake. The mean values for the apparent digestibility of nitrogen and metabolizability of G.E. were similar for Groups A, B and C with little difference in the respective standard deviations. In the case of Group D these values were lower and more variable (larger standard deviation). The mean values for apparent digestibility of G.E. and fat were similar for Groups A and B with little difference in standard deviation. For Groups C and D these values were again lower and more variable.

Urinary energy losses decreased from Group A to Group D while urinary nitrogen losses decreased from Group A to Group C. This indicates an increase in efficiency of nitrogen utilization which is borne out by the mean values for nitrogen retention and percentage utilization of apparently digested nitrogen. It would appear that the increase in energy intake to a ratio of about 1 g protein: 150 kJ GE (Group C) resulted in a better utilization of available protein.

The effects of scouring on the digestibility of dietary components

The high fat concentrations of the diets was probably the main reason for the occurrence of scouring. The incidence of diarrhoea was recorded and all the experimental calves were divided into two groups, namely those that were affected and those that did not show any signs of diarrhoea. Table 3 gives an indication of the incidence of scouring and its effects on the apparent digestibility of energy, nitrogen and fat.

Table 1

Dry matter, fat, protein (N x 6,38), gross energy and protein:energy ratios of the milk diets

Diet		A	B	C	D
Diets as fed:					
Fat	(%)	3,95 ± 0,08	6,36 ± 0,19	8,40 ± 0,26	10,15 ± 0,42
Nitrogen	(%)	0,53 ± 0,02	0,51 ± 0,02	0,51 ± 0,02	0,50 ± 0,02
Gross energy	(kJ/g)	3,06 ± 0,092	4,11 ± 0,150	4,76 ± 0,124	5,35 ± 0,095
Dry matter	(%)	13,09 ± 0,20	15,39 ± 0,37	17,04 ± 0,26	18,57 ± 0,24
Diets – dry matter					
Fat	(%)	30,18	41,33	49,30	54,66
Protein	(%)	25,84	21,12	18,69	17,16
Gross energy	(kJ/g)	23,40	26,70	27,91	28,79
Protein: energy	(g:kJ)	1:90	1:126	1:149	1:168
Protein energy as %of GE	(kJ/100 kJ)	26,35	18,87	15,98	14,22

Table 2

Mean values for milk-, gross energy-, nitrogen- and fat intakes, faecal- and urinary energy- and nitrogen losses and apparent digestibility and metabolizability of gross energy

Group		A	B	C	D
n		7	7	7	7
Days on experiment		21	21	21	21
$W^{0,73}$ at 4 days	(kg)	13,0 ±0,8	13,2 ± 0,4	13,0 ± 1,2	13,4 ± 0,9
Total milk intake*	(kg)	78,3	84,2	88,5	91,9
Total G.E. intake	(MJ)	240	346	421	492
Faecal energy losses	(MJ)	9,1	13,8	21,9	33,1
D.E. intake	(MJ)	231	332	399	458
App. dig. of G.E.	(%)	96,2 ± 2,2	96,1 ± 2,9	94,7 ± 3,1	93,0 ± 3,7
Urinary energy losses	(MJ)	7,7	6,4	5,9	5,6
Urinary energy as %of G.E.	(%)	2,4	1,8	1,4	1,1
ME intake	(MJ)	223	326	393	453
Metabolizability of G.E.**	(%)	93,0 ± 2,2	94,2 ± 3,1	93,3 ± 3,2	91,8 ± 4,0
Total Nitrogen intake	(g)	413	430	443	456
Faecal nitrogen losses	(g)	32	31	33	47
App. dig. of nitrogen	(%)	92,3 ± 2,9	92,8 ± 2,4	92,4 ± 2,9	89,3 ± 4,3
Urinary nitrogen losses	(g)	131	113	97	101
Nitrogen retention	(g)	250	286	313	308
Utilization of A.D.N.***	(%)	3092	5352	7436	9332
Faecal fat losses	(g)	72	162	331	531
App. dig. of fat	(%)	97,6 ± 2,8	97,0 ± 3,3	95,5 ± 3,2	94,0 ± 3,7

* Total intakes of milk, gross energy, etc. per calf over 21 days;

** The negligible methane production by the preruminant calf (Van Es *et al.*, 1969) was ignored and metabolizability of G.E. was taken as the difference between apparently digested energy and urinary energy losses; a highly significant relationship ($Y = 7{,}1622 + 94{,}7812X$; $F = 96{,}9$; $r = 0{,}88$; $S_{y.x} = \pm 7{,}28$) was found between nitrogen concentration (x) in urine (g N/100 ml) and G.E.-content (Y) of urine (J/ml). A covariance analysis showed that the energy concentration of the diets had no significant effects on this relationship;

*** A.D.N. = apparently digested nitrogen.

Table 3

Scouring in calves during three seven-day collection periods and the influence of diarrhoea on the digestibility of energy, nitrogen and fat

Group	A		B		C		D	
Calves	7		7		7		7	
Total collection periods (days)	21		21		21		21	
	Days without scouring				Days with scouring			
Group	A	B	C	D	A	B	C	D
Collection period a	5	5	3	3	2	2	4	5
b	6	5	6	3	1	2	1	4
c	7	7	6	4	0	0	1	3
Total	18	17	15	9	3	4	6	12
App. digest. of Energy (%)								
Period a	97,0	97,6	97,8	97,0	85,2	76,1	78,1	82,8
b	97,5	97,9	97,4	97,6	94,7	94,2	92,0	88,3
c	97,2	98,0	97,8	97,8	–	–	97,9	94,0
Mean	97,4	97,8	97,6	97,5	90,0	85,2	89,3	88,4
App. digest. of Nitrogen (%)								
Period a	93,1	93,7	94,8	92,8	82,0	76,8	78,1	75,4
b	93,6	93,9	94,2	94,2	91,5	89,5	93,8	85,1
c	93,0	95,2	94,6	94,6	–	–	96,2	91,5
Mean	93,2	94,3	94,5	93,9	87,8	83,2	89,4	84,0
App. digest. of Fat (%)								
Period a	98,7	99,1	98,8	98,3	82,4	73,2	78,8	84,6
b	99,2	99,0	98,4	98,7	95,8	96,1	92,0	89,3
c	99,1	99,0	98,9	98,6	–	–	98,4	95,0
Mean	99,0	99,0	98,7	98,5	89,1	84,7	89,7	89,6

The data in Table 3 show rather conclusively that the incidence of scouring increased with an increase in fat concentration of the diet and that it occurred more frequently during the first seven days of the experimental period. The calves appeared to adapt to the high-fat diets during the second- and third week.

There is little doubt that the scouring had a nutritional origin. It is also clear that scouring had a considerable effect on the digestibility of the different milk diets. This is in accordance with the finding of other workers (Blaxter & Wood, 1951; 1953; Parrish, Bartley, Burris and McIntyre, 1953; Mylrea, 1966; Tagari & Roy, 1969). The scouring resulted in an increase in the quantity of faeces excreted as well as an increase in the fat content of the faeces. One calf from Group D, excreted faeces with a fat content of 58 per cent on a DM basis.

The mean apparent digestibility of energy, nitrogen and fat, for calves with no scouring were 97,6 (± 0,36); 94,0 (± 0,78) and 98,8 (± 0,30) per cent respectively while the mean values for calves with scouring were 88,3 (± 7,5); 86,1 (± 7,5) and 88,6 (± 8,5) respectively. The apparent digestibility of nitrogen found in this study compares favourably with the 93,8% determined by Blaxter & Wood (1952). The apparent digestibility of fat (98,8%) is higher than the value of 95,6% determined by these workers. Blaxter & Wood (1952) ascribe their high value for the digestibility of fat to the fact that saponified fats normally present in large quantities in calf faeces, would not be recovered in the total fat excretion because the fat determinations were done on dried unacidified faeces and soaps are not extracted by ether. Roy (1970b), who fed a milk-substitute with a high fat content (margarine, up to 27% of DM) to calves, found that the high fat intake decreased the apparent digestibility of fat and protein from 95,6 to 92,7 and 94,4 to 91,8% respectively. The higher values obtained in the present study are probably due to the nature of the fat source. The apparent digestibility of energy (96,6%) determined in this study is in agreement with the value obtained by Johnson & Elliot (1972) in an experiment where the energy intakes of preruminant calves were increased by an increase in the volume of whole-milk.

Changes in live-mass

The mean initial live-mass of the calves (Table 4) differed very little between the groups but there was a marked

Table 4

Mean live-mass at four and 25 days and daily live-mass gain of the experimental calves

Group	A	B	C	D
Live-mass at				
4 days (kg)	33,7 (±2,9)	34,2 (±1,4)	33,6 (±4,3)	35,2 (±3,3)
24 days (kg)	40,3 (±3,4)	42,9 (±1,7)	45,6 (±5,8)	47,2 (±3,3)
Live-mass gain (g/day)	314 (±67)	414(±48)	557 (±78)	567 (±133)

difference at 25 days of age. The influence of the diets on live-mass is shown by the systematic increase in live-mass from Group A to Group D.

The linear regression of live-mass (Y) on ME intake (X) is presented in Fig. 1.

The individual points in Figure 1 show the variation between calves in each group. A definite separation between the points of the different groups indicates the effect of the experimental treatments. The ME intake of two calves in Group D were not as planned. They received the same energy concentration fed to the other calves in Group D, but total ME intakes were the same as those for the calves in Group B and Group C, respectively. From Figure 1 it is evident that the live-mass gains of these two calves were in excellent agreement with their total ME intake. It would appear that the concentration of energy in the diet consumed is not as important as the total ME intake.

It is rather difficult to place the live-mass gains obtained in this study into proper perspective. With Friesland bull calves over the age-span of 4–25 days (similar to the

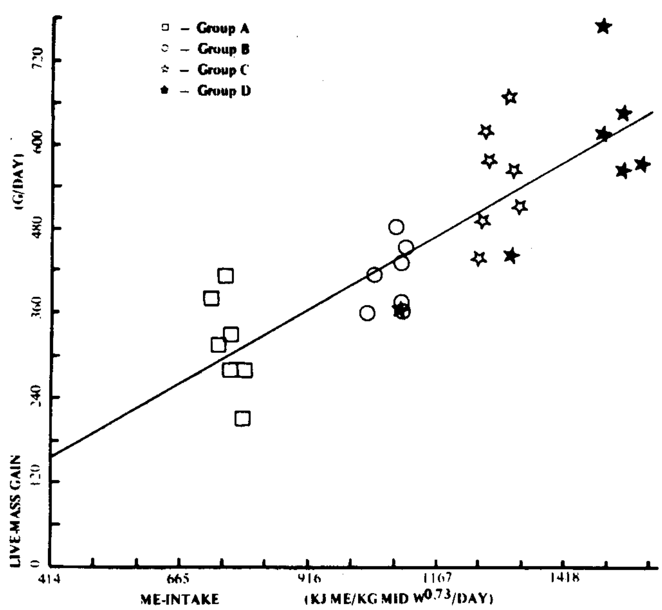

Fig. 1. *The relation between live-mass gain and ME intake for all the experimental calves*

$Y = 1{,}774X - 18{,}948 \quad S_{y.x} = 70{,}8 \quad r = 0{,}8447$

present study) Johnson & Elliot (1972) obtained daily live-mass gains of up to 690 g per calf with a group which had an intake of 6,36 kg whole milk per day. This gave a G.E.-intake of about 420 MJ over 21 days, which corresponds closely with the G.E.-intake of Group C in the present study. Group C showed a mean daily live-mass gain of 557 ± 78 g. As a percentage of initial live-mass, the mean gains obtained in the present study come to 0,93; 1,21; 1,66 and 1,61% for Groups A, B, C and D, respectively. Roy (1970a) is of the opinion that .... "higher planes of nutrition than that for a weight gain of 1% per day are at the present time only obtained in practice with calves single-suckling their dams on pasture, and even here the milk yield of the dam usually limits the performance to well below a weight gain of 1,5% per day during the first three months of life". Even if live-mass gains in the present study are expressed as a percentage of mid live-mass i.e. $\frac{\text{Initial live-mass} + \text{final live-mass,}}{2}$ they come to 0,84; 1,07; 1,40 and 1,37% which in Groups C and D approach Roy's maximum 1,5%.

Conclusions

The results show that nitrogen utilization and live-mass gains of calves on liquid diets can be improved by increasing the fat concentration of the diet and thus widening the protein:energy ratio. The diets containing 30 and 41% fat in the DM, respectively, (Groups A and B) presented virtually no problems with scouring and even on Diet C (49% fat in DM) scouring was practically absent over the second and third weeks. On the highest fat diet (D) with 55% fat in DM, scouring was a problem and digestibility of energy was noticeably depressed. In this study urinary energy content was so closely related to urinary nitrogen content that the former can be predicted from the latter which would obviate the laborious drying of calf urine of low DM content.

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