Pre-weaning growth and feed intake of dairy calves receiving different combinations of soybean flour, whey powder and colostrum

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Five groups of seven Friesian bull calves received different combinations of soybean flour (S), whey powder (W), and preserved colostrum (C). On a dry matter basis, the experimental diets consisted of 20% S, 60% W, and 20% C (Treatment 1); 10% S, 60% W, and 30% C (Treatment 2); 20% S, 40% W, and 40% C (Treatment 3); 10% S, 40% W, and 50% C (Treatment 4); and whole milk as control (Treatment 5). A complete ration, consisting of 48,5% maize meal, 30% of a commercial high-protein concentrate (42% crude protein), 20% ground lucerne hay and 1,5% salt was available *ad libitum* from 4 days of age. Calves received the (liquid) experimental diets at a rate of 12 g dry matter (DM)/kg birthmass, reconstituted to 15% DM, and the control group received whole milk at a rate of 10% of birthmass. All calves were weaned at 30 days of age. Bodymass gain (kg) and dry-feed intake (kg) for calves in Treatments 1 – 5 were 5,7 and 7,2; 6,1 and 6,2; 9,3 and 8,9; 8,7 and 10,8; 10,5 and 5,4 respectively. Total DM intake (kg) and feed-efficiency ratio (kg DM intake/kg bodymass gain) were 18,6 and 4,8; 18,7 and 3,6; 20,5 and 2,4; 22,1 and 2,7; 18,2 and 1,8 respectively for calves in Treatments 1 – 5. It was concluded that dairy calves can be reared successfully until weaning on mixtures of soybean flour, whey powder, and colostrum, with a considerable saving (67 – 70%) in feeding costs compared to whole milk. The best results can be expected when the liquid diet mixture contains at least 40% colostrum and less than 60% whey powder on a dry matter basis.
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Vyf groepe van sewe Friesbulkalwers per groep het verskillende kombinasies van sojameel (S), weipoeier (W) en gepreserveerde kolostrum (K) ontvang. Op 'n droë basis het die proefrantsoene bestaan uit 20% S, 60% W en 20% K (Behandeling 1); 10% S, 60% W en 30% K (Behandeling 2); 20% S, 40% W en 40% K (Behandeling 3); 10% S, 40% W en 50% K (Behandeling 4) en volmelk as kontrole (Behandeling 5). 'n Volledige rantsoen, bestaande uit 48,5% mieliemeel, 30% van 'n kommersiële hoëproteïenkonsentraat (42% ruproteïen), 20% gemaalde lusernhooi en 1,5% sout was vryelik beskikbaar vanaf 4-dae-ouderdom. Kalwers het die (vloeistof) proefrantsoene ontvang teen 'n hoeveelheid van 12 g droëmateriaal (DM)/kg geboortemassa, gerekonstitueer tot 15% DM en die kontrolegroep het volmelk teen 10% van geboortemassa ontvang. Al die kalwers is op 30-dae-ouderdom gespeen. Massatoename (kg) en droë voerinname (kg) vir kalwers in Behandelings 1 – 5 was onderskeidelik 5,7 en 7,2; 6,1 en 6,2; 9,3 en 8,9; 8,7 en 10,8; 10,5 en 5,4. Totale DM-inname (kg) en doeltreffendheid van voeromsetting (kg DM inname/kg massatoename) was onderskeidelik 18,6 en 4,8; 18,7 en 3,6; 20,5 en 2,4; 22,1 en 2,7; 18,2 en 1,8 vir kalwers in Behandelings 1 – 5. Die gevolgtrekking is gemaak dat suiwelkalwers suksesvol tot op speenouderdom grootgemaak kan word op mengsels van sojameel, weipoeier en kolostrum, met 'n aansienlike besparing (67 – 70%) in voedingskoste in vergelyking met volmelk. Die beste resultate kan verwag word wanneer die vloeistofdieetmengsel minstens 40% kolostrum en minder as 60% weipoeier op 'n droë basis bevat.
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Introduction

Pre-weaning feeding costs of dairy calves are relatively high and numerous research papers deal with the concept of replacing whole milk with alternative liquid diets. Protein sources of vegetable origin, such as soybean flour and soybean-protein concentrate, are often included in milk-replacer formulae with varying degrees of success (Gorrill & Nicholson, 1969; Gorrill, Cameron & Nicholson, 1971; Erbersdobler & Gropp, 1973; Campos, Huber & Bergen, 1982; Campos, Huber, Morrill, Brownson, Dayton, Harrison & Warner, 1982; Akinyele & Harshbarger, 1983). Although skimmed milk-powder is an outstanding protein source of animal origin, it is very expensive, but whey powder is often included successfully in large amounts in milk replacers for calves (Morrill, Melton, Dayton, Guy & Pallansch, 1971; Bouchard, Brisson & Julien, 1973; Volcani & Ben-Asher, 1974; Volcani, Gordin & Nitsan, 1974). Since plant proteins and animal protein sources (except those containing casein, such as skimmed milk-powder) lack the ability to clot in the abomasum of calves, the quality of milk replacers consisting primarily of these products is often questioned.

It has been shown that surplus colostrum can be preserved successfully with the addition of formaldehyde (Rindsig & Bodoh, 1977) and fed in combination with soybean flour and whey powder until calves are weaned at 30 days of age (Cruywagen, 1982). In the above-mentioned trial, calves received liquid diets only, and bodymass gains were not according to expectation, probably because of insufficient energy intake. According to Griffiths & McGann (1966) and Raven (1970), calves consume more concentrates as the energy content of milk replacers is lowered. In the present study, a complete ration was available from 4 days of age to examine the effect of an additional energy source to liquid diets on pre-weaning performance of calves.

Procedure

Thirty-five Friesian bull calves were allotted (according to birthmass) to five treatments in a randomized block design. Initial bodymass of each calf was determined at the commencement of the trial, which was immediately after the colostrum feeding period, at 2 days of age. The composition of the liquid experimental diets (ratios of components) is presented in Table 1.

Treatments 1 – 4 represent four divergent treatments from a previous trial in which the present Treatment 4 resulted in the highest gains, while Treatment 1 resulted in negative pre-weaning gains (Cruywagen, 1982). In the trial referred to, calves received no extra concentrates and the poor gains were

Table 1 Physical composition (ratios of components) of liquid experimental diets, expressed on a dry-matter basis

Component	Treatment 1	2	3	4	5
Soybean flour	20	10	20	10	–
Whey powder	60	60	40	40	–
Preserved colostrum	20	30	40	50	–
Whole milk	–	–	–	–	100

attributed to insufficient energy intake.

Colostrum from the first eight milkings post-partum was preserved, according to the method described by Rindsig & Bodoh (1977), with 1,25 ml formaldehyde/l colostrum. The total amount of colostrum required was collected before commencement of the trial and then mixed in a bulk tank to obtain a homogeneous composition. It was then stored in 75 l polythene drums at 4°C until required. The soybean flour was a defatted product of which the trypsin inhibitor was inactivated by heat treatment.

A chemical analysis of the diet components (as determined by Cruywagen, 1979) is presented in Table 2, and the calculated chemical composition of the final diet mixtures is presented in Table 3.

For the determination of nitrogen, samples were prepared according to the micro-Kjeldahl digestion technique and nitrogen determined colorimetrically with the aid of an automatic analyser according to the method described by Clare & Stevenson (1964). The Gerber test for butterfat (as described by Newlander & Atherton, 1964) was used to determine the butterfat content of colostrum. Fat in the soybean flour and whey powder was determined by ether extraction according to the Weende method.

Liquid diets (Treatments 1 – 4) were offered in such a way that each calf received 12 g of dry matter (DM)/kg initial bodymass daily. This represented a DM intake comparable with a calf receiving whole milk at a rate of 10% of its bodymass, as was the case in Treatment 5 (assuming the mean DM content of whole milk (WM) to be 12%). The diets were prepared daily by reconstituting the calculated amount of soybean flour and whey powder to obtain a DM content of 15%. Hot water (*ca* 50°C) was used for reconstitution. The correct amount of colostrum, which also had a DM content of 15%, was then added and the mixture well-stirred. The final temperature of the mixture was about 30°C.

A complete ration consisting of 48,5% maize meal, 30% of a commercial high-protein concentrate (42% crude protein (CP)), 20% ground lucerne hay, and 1,5% NaCl (calculated crude protein and metabolizable energy values of 21% and 10,4 MJ/kg respectively), was available *ad libitum* from 4 days of age.

Table 3 Calculated chemical composition of final diet mixtures, expressed on a DM basis

Item	Treatment 1	2	3	4	5
Crude protein (%)	24,6	22,8	28,9	27,1	26,8
Gross energy (MJ/kg)	18,4	18,9	19,9	20,3	19,6
Metabolizable energy (MJ/kg)[a]	15,1	16,4	17,5	18,8	18,4

[a]Treatments 1 – 4; Cruywagen, 1979. Treatment 5; based on Liebenberg, 1973.

Calves were weaned at 30 days of age and bodymass gain was determined weekly.

Results and Discussion

Changes in bodymass

Total empty bodymass gains during the experimental period are presented in Table 4, and weekly changes in bodymass are indicated in Figure 1.

It is evident from Table 4 that calves receiving whole milk (Treatment 5) had the highest gains, followed by calves in Treatments 3 and 4. There were no significant differences ($P \leq 0,05$) in gain between calves in Treatments 3, 4 and 5, but calves in Treatment 5 showed a highly significant ($P \leq 0,01$) better bodymass gain than those in Treatments 1 and 2. Calves in Treatment 3 gained significantly ($P \leq 0,05$) better than those in Treatment 1. Apart from whole milk, the best results (>300 g daily gain) were obtained when the minimum colostrum and maximum whey powder contents of the diet were both 40%. This tendency is in accordance with previous results (Cruywagen, 1979). It should be kept in mind, however, that only two levels of whey powder were

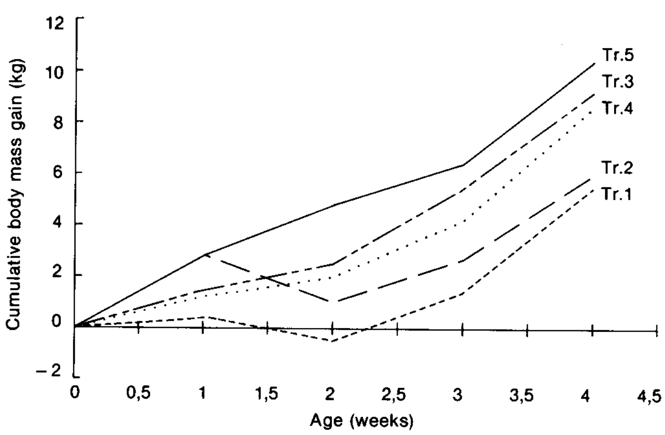

Figure 1 Change in bodymass of calves (mean per group) during the 28-day period

Table 2 Chemical analysis of diet components

Item	Soybean flour (DM)	Whey powder (DM)	Colostrum (DM)	Colostrum (Wet)	Whole milk (DM)	Whole milk (Wet)
Nitrogen (%)	8,3	2,0	5,3	0,8	4,2	0,5
Fat (%)	2,25	0,46	–	–	–	–
Butterfat (%)	–	–	25,0	3,7	30,8	3,7
Gross energy (MJ/kg)	19,1	16,5	23,6	3,5	19,6	2,35

Table 4 Total bodymass gains of calves (mean per group) during the 28-day experimental period (n = 7)

Mean gain (kg)	ADG (g)	Treatment number	Significance of difference for treatment number 1	2	3	4
5,67	203	1				
6,07	217	2	NS			
9,26	331	3	a	NS		
8,74	312	4	NS	NS	NS	
10,51	375	5	b	b	NS	NS

NS Difference not significant
[a] Difference significant, LSD = 3,32 kg ($P \leq 0,05$)
[b] Difference highly significant, LSD = 4,40 kg ($P \leq 0,01$)

Table 6 Total dry matter (DM) intake by calves (mean per group) during the 28-day experimental period (n = 7)

Mean DM intake (kg)	Treatment number	Significance of difference for treatment number 1	2	3	4
18,64	1				
18,66	2	NS			
20,54	3	NS	NS		
22,10	4	NS	NS	NS	
18,17	5	NS	NS	NS	a

NS Difference not significant
[a] Difference significant, LSD = 3,62 kg ($P \leq 0,05$)

included in the present study, namely 40 and 60%. Thus it cannot be stated that the maximum whey powder level should be 40%, but all calves receiving the 60% level, gained less than 300 g/day. Various researchers have reported satisfying results with milk replacers containing between 60 and 77% whey powder (Morrill, *et al.*, 1971; Bouchard, *et al.*, 1973; Volcani & Ben-Asher, 1974; Volcani, *et al.*, 1974).

As can be seen in Figure 1, calves in Treatments 1 and 2 had negative gains during the second week of the trial. The same tendency was observed by Downes, Cruywagen, Smith & Pelster (1982) for calves receiving milk replacers containing significant amounts of non-milk proteins from either animal or vegetable origin. However, it can be calculated from Figure 1 that all calves showed an average daily gain (ADG) of more than 350 g during the last 14 days of the trial, whilst for calves in Treatments 3 and 4 the ADG during this period was more than 475 g. Campos, Huber & Bergen (1982) found an ADG of 18 g and 395 g respectively with calves receiving a 19% CP milk replacer where soy protein contributed to about one-third of the total protein, as compared to a 19% CP all-milk protein replacer. In the present study, about one-third of the crude protein in Treatment 3 was supplied by soybean flour, resulting in an ADG of more than 330 g.

Dry feed intake of calves is presented in Table 5, and total dry matter intake in Table 6.

Calves receiving whole milk consumed less dry feed than calves in any other treatment. However, statistical significance ($P \leq 0,01$) could only be proved for Treatments 3 and 4 (Table 5). According to Griffiths & McGann (1966), Raven (1970), and Downes, *et al.* (1982), calves consume less concentrate as the energy content of a milk replacer increases. It would therefore have been expected that calves in Treatments 4 and 5 would have consumed similar amounts of dry feed since the calculated energy contents of their liquid diets were comparable. However, calves in Treatment 4 ate twice as much of the complete ration than those in Treatment 5. With the exception of the whole-milk treatment there was a tendency for calves to consume more dry feed as the energy content of the liquid diets increased. It can also be seen from Table 6 that the only significant difference ($P \leq 0,05$) in total DM intake occurred between calves in Treatments 4 and 5.

Efficiency of feed conversion (EFC) is presented in Table 7.

The EFC ratio of calves in Treatments 5 (WM) was highly significantly ($P \leq 0,01$) better and that of calves in Treatments 3 and 4 significantly ($P \leq 0,05$) better than that of calves in Treatment 1. The EFC ratio (1,82) of calves on whole milk and a complete ration, was similar to the EFC ratio (1,77) reported by Downes, *et al.* (1983).

Table 5 Dry feed intake by calves (mean per group) during the 28-day experimental period (n = 7)

Total intake (kg)	Mean daily intake (g)	Treatment number	Significance of difference for treatment number 1	2	3	4
7,21	25,8	1				
6,21	22,2	2	NS			
8,96	32,0	3	NS	a		
10,79	38,5	4	a	b	NS	
5,4	1,9	5	NS	NS	b	b

NS Difference not significant
[a] Difference significant, LSD = 2,57 kg ($P \leq 0,05$)
[b] Difference highly significant, LSD = 2,49 kg ($P \leq 0,01$)

Feeding costs

The following prices were applicable (June 1984):

Liquid diet components:
Soybean flour : R1,33/kg
Whey powder : R0,65/kg
Colostrum (production cost) : 12c/l (80c/kg DM)
Whole milk : 34c/l (R2,83/kg DM)

Dry feed components:
Maize meal : 22,0c/kg
High protein concentrate (42% CP) : 50,9c/kg
Lucerne hay : 18,0c/kg
Salt : 3,2c/kg

Table 7 Efficiency of feed conversion (EFC) by calves during the 28-day experimental period (kg DM/kg bodymass gain) (n = 7)

Mean EFC ratio	Treatment number	Significance of difference for treatment number 1	2	3	4
4,81	1				
3,56	2	NS			
2,43	3	a	NS		
2,73	4	a	NS	NS	
1,82	5	b	NS	NS	NS

NS Difference not significant
[a] Difference significant, LSD = 1,95 ($P \leq 0,05$)
[b] Difference highly significant, LSD = 2,64 ($P \leq 0,01$)

Table 8 Cost of diets, total pre-weaning feeding costs, percentage saving and cost/kg gain, calculated at current prices (June 1984)

Item	Cost for Treatments				
	1	2	3	4	5
Liquid diets (c/kg DM)	81,6	76,3	84,6	79,3	283,0
Concentrate (c/kg)	29,6	29,6	29,6	29,6	29,6
Total pre-weaning feeding costs (R)	11,46	11,34	12,45	12,16	37,74
Percentage saving compared to whole milk	69,6	70,0	67,0	67,8	0
Cost/kg gain (R)	2,02	1,87	1,35	1,39	3,59

Feeding expenses are indicated in Table 8.

It is evident that the cost of the liquid diet for Treatment 5 (283c/kg DM) was much higher than that of any other treatment (81,6; 76,3; 84,6; and 79,3c/kg DM for Treatments 1 – 4 respectively). It is also clear that Treatment 5 resulted in the highest pre-weaning feeding cost R37,74), being at least three times more expensive than any other treatment, and although calves receiving whole milk had the highest bodymass gain, the cost/kg gain of these calves (R3,59) was considerably higher than for calves in Treatments 1 – 4 (R2,02; R1,87; R1,35 and R1,39 respectively). The percentage saving in pre-weaning feeding costs of Treatments 1 – 4, compared to whole milk, was 69,6; 70,0; 67,0; and 67,8% respectively.

In conclusion, dairy calves can be reared successfully until weaning on mixtures of soybean flour, whey powder and colostrum with a considerable saving in feeding costs compared to whole milk. A complete ration should be available *ad libitum* from 4 days of age, and the best results can be expected when the liquid diet mixture contains at least 40% colostrum and less than 60% whey powder on a dry matter basis.

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