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OPTIMIZING SOYBEAN FLOUR-, WHEY POWDER- AND COLOSTRUM RATIOS FOR REARING DAIRY CALVES

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(Sleutelwoorde: *Kalwers, melkvervangers, sojameel, weipoeier, kolostrum)*

OPSOMMING: OPTIMISERING VAN SOJAMEEL-, WEIPOEIER- EN KOLOSTRUMVERHOUDINGS VIR DIE GROOTMAAK VAN SUIWELKALWERS

Die doel van die ondersoek was om rantsoenkombinasies bestaande uit sojameel, weipoeier en kolostrum te bepaal wat in die praktyk aangewend kan word om die voorspeense grootmaakkostes van suiwelkalwers te verlaag. In 'n mengselontwerp het die sojameelinhoud van die vloeistofrantsoene gevarieer van 10 tot 20%, die weipoeier-inhoud van 40 tot 60% en die kolostruminhoud van 20 tot 50%, op 'n droëmassabasis. Dertig Friesbulkalwers het elk 'n ander rantsoenkombinasie gedurende die 28 dae voorspeense periode ontvang. Massatoenames gedurende die laaste 14 dae van die proef, skynbare verteerbaarheid van droëmateriaal, stikstof en bruto-energie, asook stikstofretensies het stelselmatig verhoog namate die sojameel- en weipoeierinhoud van die rantsoen afgeneem het en die kolostruminhoud ooreenstemmend toegeneem het. Vergelykbare resultate is verkry by spesifieke kolostrumpeile, maar verskillende sojameel- en weipoeierpeile. In vergelyking met volmelk het al die proefrantsoene 'n energietekort getoon en, aangesien geen kragvoer aangebied is nie, was massatoenames oor die algemeen swak. Die hoogste gemiddelde daaglikse toename, naamlik 186 g het voorgekom op 'n rantsoen bestaande uit 10% sojameel, 40% weipoeier en 50% kolostrum. Voorspeense voedingskostes was 82 tot 89% laer in vergelyking met volmelk.

SUMMARY:

The object of the study was to determine diet combinations consisting of soybean flour, whey powder and colostrum that can be employed in practice to decrease the pre-weaning rearing costs of dairy calves. In a mixture design experiment the soybean flour content of the liquid diets varied from 10 to 20%, the whey powder content from 40 to 60% and the colostrum content from 20 to 50%, on a dry mass basis. Each of 30 Friesian bull calves received a different diet combination during the pre-weaning period of 28 days. Body mass gains during the last 14 days of the trial, apparent digestibilities of dry matter, nitrogen and gross energy, as well as nitrogen retention increased systematically in proportion to decreasing soybean flour- and whey powder contents of the diet and a corresponding increase of the colostrum content. An important observation was that comparable results were obtained with specific colostrum levels, but different soybean flour- and whey powder levels. Compared with whole milk, all the experimental diets indicated an energy deficiency and as no concentrate was offered, mass gains were generally poor. The highest average daily gain, viz. 186 g occurred with a ration consisting of 10% soybean flour, 40% whey powder and 50% colostrum. Pre-weaning feeding costs were 82 to 89% lower in comparison with whole milk.

Because of the high rearing costs of dairy calves on whole milk the need exists for milk replacers that are less expensive than whole milk. Colostrum is initially the most important calf nourishment and it could be utilized for a longer period than the first 2 or 3 days *post partum*.

The amount of colostrum produced by an average dairy cow during the first 4 days *post partum* is not sufficient to feed her calf during the total pre-weaning period of approximately 4 weeks. According to Foley & Otterby (1978) enough surplus colostrum should be available in each dairy herd to feed calves for at least 14 days. If preserved colostrum could be supplemented with reconstituted soybean flour and whey powder, the period of colostrum feeding could be extended to 4 weeks.

Various researchers reported the successful inclusion of soybean flour and/or soybean protein concentrate in milk replacers (Schmutz, Cravens, Soldner & Hughes, 1967; Gorrill & Nicholson, 1969; Gorrill, Cameron & Nicholson, 1971; Erbersdobler & Gropp, 1973), although some form of pre-treatment is necessary, for example heat treatment (Nitsan, Volcani, Gordin & Hasdai, 1971; Thompson, Kakade, Engelstad, Fowler & Friedrich, 1974), acid treatment (Colvin & Ramsey, 1968) or alkali treatment (Colvin & Ramsey, 1969).

Whey powder has been included in milk replacers with satisfactory results. Standard milk replacers contain 10 to 30% whey powder (Volcani, Gordin & Nitsan, 1974; Liebenberg, 1975), although greater amounts (60 to 77%) have been included successfully (Morrill, Melton, Dayton, Guy & Pallansch, 1971; Bouchard, Brisson & Julien, 1973; Volcani & Ben-Asher, 1974; Volcani, Gordin & Nitsan, 1974).

An experiment was conducted to examine the supplementation of surplus colostrum with soybean flour and whey powder in an attempt to decrease the total rearing costs of dairy calves.

Procedure

Each of 30 Friesian bull calves, with birth masses varying from 30 to 40 kg, was allotted to a different treatment in a mixture design experiment. The mass of each calf was determined at the commencement of the experiment, which was immediately after the 2 days colostrum feeding period. The 30 experimental diets consisted of different ratios of soybean flour, whey powder and colostrum. The ratios are presented in Table 1 and the treatment numbers appear in parenthesis.

For example, Treatment 1 consisted of 10% soybean flour, 60% whey powder and 30% colostrum, all on a dry matter basis.

The soybean flour was a defatted product of which the trypsin inhibitor was inactivated by heat treatment.

Colostrum from the first 8 milkings *post partum* was preserved according to the method of Rindsig & Bodoh (1977), with 1,35 g formaldehyde/ℓ colostrum. The total required amount of colostrum (950ℓ) was collected before commencement of the trial and then mixed in a bulk tank to obtain a homogeneous composition. It was then stored in 75ℓ polythene drums at 4 °C until required.

A chemical analysis of the diet components (as determined by Cruywagen, 1979) is presented in Table 2.

Table 1

Percentage colostrum at different ratios of soybean flour and whey powder. Treatment numbers appear in paranthesis

Whey powder (%)	Soybean flour (%)					
	10	12	14	16	18	20
60	30 (1)	28 (2)	26 (3)	24 (4)	22 (5)	20 (6)
55	35 (7)	33 (8)	31 (9)	29 (10)	27 (11)	25 (12)
50	40 (13)	38 (14)	36 (15)	34 (16)	32 (17)	30 (18)
45	45 (19)	43 (20)	41 (21)	39 (22)	37 (23)	35 (24)
40	50 (25)	48 (26)	46 (27)	44 (28)	42 (29)	40 (30)

Table 2

Chemical composition of diet components

Item	Soybean flour (dry matter)	Whey powder (dry matter)	Colostrum (dry matter)	Colostrum (wet)
Nitrogen content (%)	8,3	2,0	5,3	0,8
Fat content (%)	2,25	0,46	–	–
Butterfat content (%)	–	–	25,0	3,7
Gross energy content (MJ/kg)	19,1	16,5	23,6	3,5

The diets were offered in such a way that each calf received 12 g of dry matter (DM) per kilogram of initial body mass daily. This represented a DM intake comparable with a calf receiving whole milk at a rate of 10% of its body mass (assuming the mean DM content of milk is 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.

Results and Discussions

Experimental diets

A calculated chemical analysis of the experimental diets is presented in Table 3.

From Table 3 it is clear that the nitrogen (N) content of the diets increased in 2 directions: firstly there was an increase relevant to elevated levels of soybean flour and secondly an increase relevant to decreasing whey powder levels, thus increasing levels of colostrum in the diet.

Moreover it can be seen from Table 3 that the gross energy (GE) content of the diets also increased in 2 directions, although not so markedly as was the case for N: firstly there was an increase relevant to decreasing soybean flour levels and secondly an increase relevant to increasing levels of colostrum in the diet.

Average whole milk with a DM content of 12%, a protein content of 3,2% and a butter fat content of 4%, contains about 4,3 % N and 24 MJ GE/kg on a dry matter basis. As can be seen from Table 3 the N content of the experimental diets varied between 3,62 and 4,59%, while the GE content varied between 18,4 and 20,3 MJ/kg.

Balance trial

Apparent digestibility of DM, N, GE, as well as N retention over the last 7 days of the trial are presented in Table 4.

It can be observed from Table 4 that an increase in colostrum increased the apparent digestibilities of all these parameters.

Quadratic response surfaces were fitted to the data and calculated regression equations describing the parameters are presented with the contour maps in Figures 1 to 4 and Figure 6. The same principle applies to all the Figures, viz. although only soybean flour and whey powder are indicated, colostrum is implicated as the 3 variables proportionally added to 1. The contour maps indicate optimum diet combinations (for all the parameters) to be found with minimum soybean flour and whey powder contents of the diet, in other words maximum colostrum levels. An important observation from all the contour maps was, however, that similar results were obtained with specific colostrum levels, but different soybean flour and whey powder contents of the diets.

The effect of diet combinations on apparent N digestibility can be seen from Table 4. As the soybean flour and whey powder contents of the diet decreased, apparent N digestibility increased systematically, relevant to increasing colostrum content. Gorrill & Nicholson (1969) reported N digestibility to be 81,6 % when calves received a milk replacer containing 21,5 % soybean flour and 23 % whey powder. Toullec, Mathieu, Vassal & Pion (1969) formulated a milk replacer where all the nitrogen was derived from whey proteins and found a N digestibility of 55,2% in one case and 65,8% in another with calves under 28 days of age. As the calves grew older, higher N digestibilities were obtained.

The higher N retentions relevant to decreasing levels of whey powder in the diet (Table 4) might be attributed to the collective effect of both N and GE that increased correspondingly. However, the higher N retentions relevant to decreasing levels of soybean flour cannot be explained likewise. In this case N retention increased systematically, while the N content of the diets decreased and the GE content increased.

Table 3

*Chemical analysis of the experimental diets**

Treatment number	** Ratio of diet components (%) Soybean flour	(%) Whey powder	(%) Colos-trum	Nitrogen content (%)	GE content (MJ/kg)
1	10	60	30	3,6	18,9
2	12	60	28	3,6	18,8
3	14	60	26	3,7	18,7
4	16	60	24	3,8	18,6
5	18	60	22	3,8	18,5
6	20	60	20	3,9	18,4
7	10	55	35	3,7	19,2
8	12	55	33	3,8	19,2
9	14	55	31	3,9	19,1
10	16	55	29	3,9	19,0
11	18	55	27	4,0	18,9
12	20	55	25	4,1	18,8
13	10	50	40	3,9	19,6
14	12	50	38	4,0	19,5
15	14	50	36	4,1	19,4
16	16	50	34	4,1	19,3
17	18	50	32	4,2	19,2
18	20	50	30	4,2	19,2
19	10	45	45	4,1	20,0
20	12	45	43	4,2	19,9
21	14	45	41	4,2	19,8
22	16	45	39	4,3	19,7
23	18	45	37	4,3	19,6
24	20	45	35	4,4	19,5
25	10	40	50	4,3	20,3
26	12	40	48	4,3	20,2
27	14	40	46	4,4	20,1
28	16	40	44	4,4	20,0
29	18	40	42	4,5	20,0
30	20	40	40	4,6	19,9

* Calculated from the values presented inTable 2

** Ratio of diet components expressed on a dry matter basis.

Table 4

Balance trial results

Treatment number	Apparent DM digestibility (%)	Apparent N digestibility (%)	Apparent N retention (last week) (%)	Apparent digestibility of GE (%)
1	92,6	80,2	24,3	92,2
2	92,3	78,1	18,8	92,6
3	89,4	74,7	14,6	88,4
4	90,4	76,1	16,0	90,3
5	89,4	73,1	8,6	88,9
6	88,9	73,4	4,3	88,9
7	93,6	81,0	33,1	93,4
8	91,9	80,3	33,6	92,8
9	92,4	79,5	26,2	92,4
10	93,1	79,5	28,7	92,1
11	88,5	75,8	22,4	87,9
12	88,9	74,1	18,2	88,8
13	94,4	85,0	40,4	93,9
14	95,2	85,8	38,2	94,9
15	94,3	83,3	32,1	94,3
16	93,1	83,5	31,7	92,5
17	91,9	80,2	27,4	92,1
18	91,8	79,7	26,6	91,6
19	95,3	88,6	48,5	95,3
20	94,8	87,1	41,4	95,0
21	95,5	88,3	45,4	95,5
22	93,8	84,4	36,6	93,1
23	94,3	83,7	34,4	93,5
24	92,9	80,8	35,8	91,5
25	96,5	91,3	57,3	96,2
26	96,1	89,3	55,7	95,9
27	95,1	88,0	48,8	94,4
28	94,8	88,4	52,9	94,7
29	94,2	85,7	43,1	94,1
30	93,3	84,1	37,2	93,1

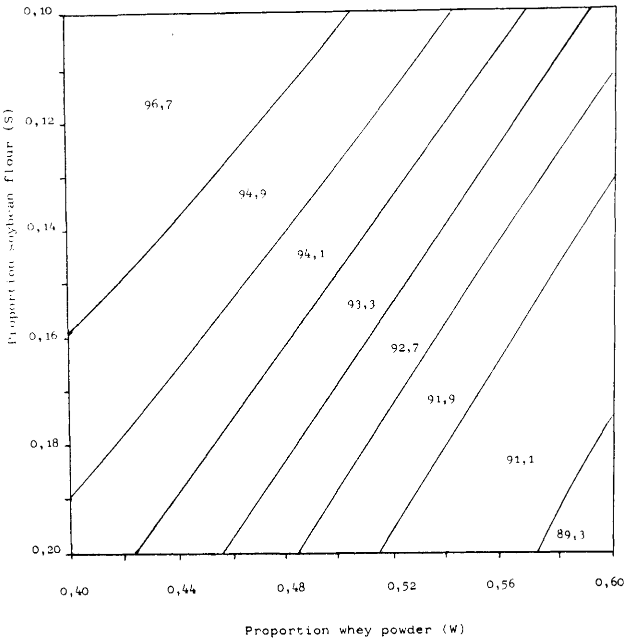

Fig. 1 *Apparent DM digestibility of experimental diets (%) during the last 7 days of the trial*

$$Y = 37{,}109\ W - 50{,}857\ W^2 - 68{,}615\ WS + 92{,}562$$

($R = 0{,}937$; $SF = 0{,}832$, $F = 62{,}612$)

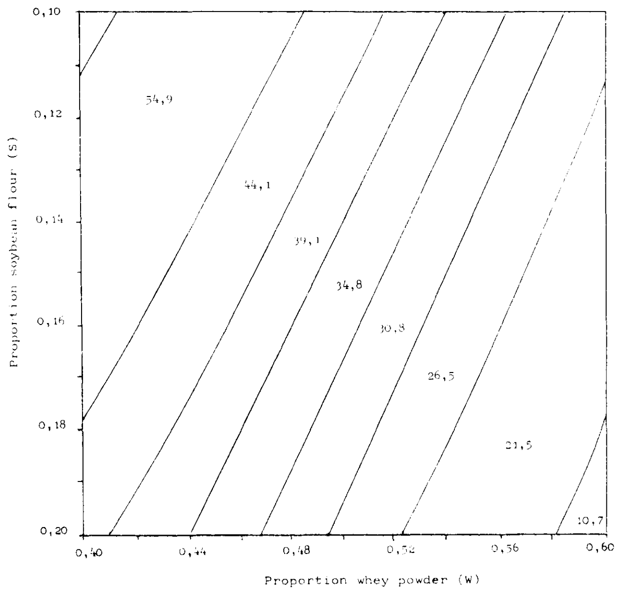

Fig. 3 *Apparent N retentions (g) by calves during the last 7 days of the trial*

$$Y = 161{,}00\ S - 165{,}690\ W^2 + 99{,}191$$

($R = 0{,}981$; $SF = 2{,}717$; $F = 341{,}469$)

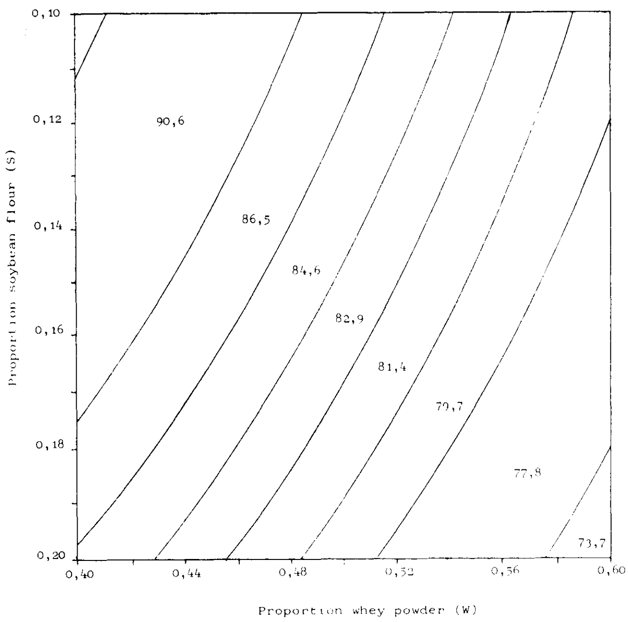

Fig. 2 *Apparent N digestibility of the experimental diets (%) during the last 7 days of the trial*

$$Y = 226{,}347\ S^2 - 61{,}579\ W^2 + 103{,}199$$

($R = 0{,}981$; $SF = 1{,}037$; $F = 340{,}941$)

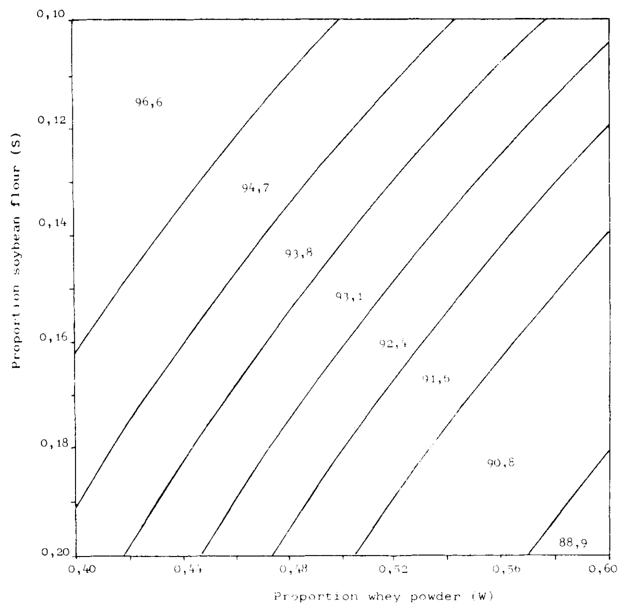

Fig. 4 *Apparent GE digestibility of the experimental diets (%) during the last 7 days of the trial*

$$Y = 12{,}572\ W^2 - 74{,}846\ WS + 101{,}546$$

($R = 0{,}926$; $SF = 0{,}909$; $F = 81{,}716$)

Table 5

Changes in body mass of calves and daily intake of nitrogen and apparent digestible energy

Treatment number	*ADG: Total period (g)	ADG: last 2 weeks (g)	Daily N intake (gN/kg M**)	Daily DE intake (MJ DE/kg M)
1	35,7	85,7	2,71	0,20
2	96,4	64,3	2,75	0,20
3	–32,1	50,0	2,80	0,19
4	42,9	57,1	2,85	0,20
5	53,6	28,6	2,89	0,19
6	–42,9	14,3	2,94	0,19
7	78,6	114,3	2,83	0,21
8	46,4	114,3	2,88	0,21
9	89,3	92,9	2,92	0,21
10	28,6	100,0	2,97	0,21
11	107,1	78,6	3,02	0,19
12	78,6	64,3	3,06	0,20
13	142,9	135,7	2,96	0,22
14	85,7	128,6	3,01	0,22
15	75,0	107,1	3,01	0,22
16	139,3	107,1	3,10	0,21
17	53,6	92,9	3,14	0,21
18	85,7	92,9	3,18	0,21
19	0	157,1	3,08	0,22
20	96,4	135,7	3,13	0,22
21	100,0	150,0	3,18	0,22
22	121,4	121,4	3,22	0,22
23	46,4	114,3	3,27	0,22
24	178,6	121,4	3,31	0,21
25	135,7	185,7	3,21	0,23
26	92,9	178,6	3,25	0,23
27	114,3	157,1	3,30	0,22
28	53,6	171,4	3,35	0,22
29	117,9	142,9	3,39	0,22
30	89,3	121,4	3,44	0,22

* ADG = Average daily gain

** M = Body mass

Apparent digestibility of GE in the experimental diets varied between 87,9% and 96,3%. Gorril & Nicholson (1969) reported values of 88,0% with calves receiving milk replacers containing 21,5% soybean protein concentrate and 23% whey powder – these diets contained no colostrum. In the present study GE digestibility of diet combinations containing 20% soybean flour increased from 89% (at a 60% whey powder level) to 93% (at a 40% whey powder level).

Change in body mass

Mass gains, as well as daily intake of total N and digestible energy (DE), are presented in Table 5.

No clear pattern could be discerned with respect to total body mass gain during 28 days experimental period, but there was a tendency for elevated gains corresponding with high colostrum and low whey powder contents of the diet. The only 2 calves that showed negative gains over the total period (treatments 3 and 6) both received diet combinations containing 60% whey powder.

As can be seen from Table 5, in most cases average daily gains were greater during the last 2 weeks than over the total experimental period.

It is of interest that the calves reacted more or less according to the growth in Figure 5.

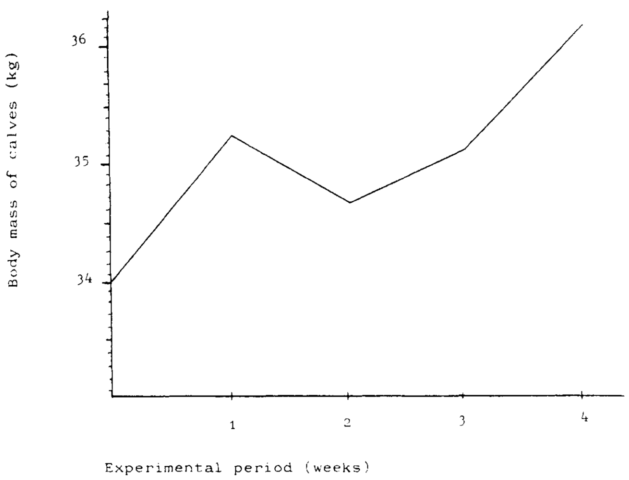

Fig. 5 *Growth pattern of calves during the experimental period. (Determined according to the average gains of 30 calves)*

There appeared to be an adaptation between 1 and 2 weeks after commencement of the trial.

Since all the experimental diets contained soybean flour and whey powder, adaptation problems could be expected. The question is however, why these problems were encountered and only after 8 to 10 days. The following findings by various researchers may contribute to explanation:

(i) Volume secretions of pancreatic juice at 4 and 21 days of age were 0,16 and 0,29 ml/hour/kg body mass, respectively (Gorrill, Thomas, Stewart & Morrill, 1967). Although pancreatic juice flow rates increased with age irrespective of diet, trypsin concentrations reached a maximum at 7 days. It is possible that total trypsin secretion was reduced temporary after 7 days, but increased again, since pancreatic juice secretion increased with age.

(ii) It was found that milk replacers containing high levels of soybean protein resulted in reduced pancreatic secretion rate (Gorrill, Schingoethe & Thomas, 1968). This reduction in secretion rate might be manifested only after 7 days.

(iii) Gastric protease secretion reached a maximum level at 8 days of age and then decreased with age (Huber, Jacobson, Allen & Hartman, 1961).

(iv) Gorrill, Jones & Nicholson (1974) found a general tendency for lambs to digest more of the nutrients in soybean protein containing milk replacers at 22 or 35 days of age, compared with younger ones. This confirmed similar age effect with calves found by Nitsan, Volcani, Gordin & Hasdai (1971).

(v) After several feedings of a milk replacer containing heated soybean flour, calves developed a sensitivity. The resultant disturbance in digestive function was not caused by abnormal bacterial growth and may have been due to a gastrointestinal allergy (Sissons & Smith, 1976). Smith & Wynn (1971) reported that the feeding of diets containing soybean flour or soybean protein concentrate rapidly resulted in high circulating antibody titres.

The suggested daily N intake of calves up to 4 weeks of of age is 0,71 g/kg body mass (NRC, 1978). As can be seen from Table 5 all the calves received more than the suggested amount. However, in all cases the daily DE intake was less than the NRC standards of 0,40 MJ/kg body mass. Various researchers indicated energy requirements of calves to be substantially higher than suggested by the NRC. For example, Bryant, Foreman, Jacobson

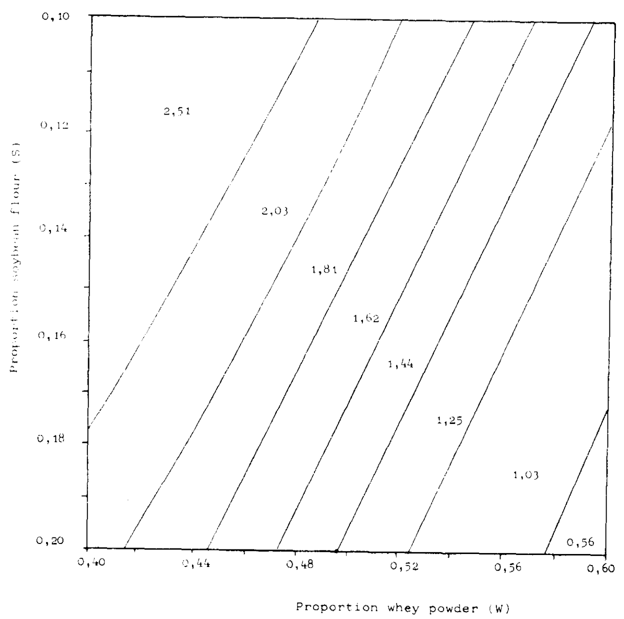

Fig. 6 *Mass gains of calves during the last 2 weeks of the trial (kg)*

$$Y = 6{,}825\,W - 11{,}905\,W^2 - 14{,}359\,WS + 2{,}233$$
$$(R = 0{,}975;\ SF = 0{,}139;\ F = 167{,}860)$$

& Mc Gilliard (1967) assert that calves require 1,75 MJ DE/kg body mass/day for maintenance plus a daily gain of 100 g and 3,30 MJ/kg body mass/day for maintenance plus a daily gain of 200 g.

Feeding costs

At the time of the experiment, the following prices were applicable:

Soybean flour.	60c/kg
Whey powder:	45c/kg
Whole milk	26c/ℓ (ca 217c/kg DM)

No price was attached to colostrum since it has no market value. The cost of the most expensive diet combination (S20W60C20) was 39c/kg and that of the cheapest (S10W40C50) was 24c/kg on a DM basis, compared with 217c/kg for whole milk on a DM basis.

The following pre-weaning costs were calculated for calves weighing 40 kg at birth and weaned at 28 days of age:

Whole milk:	R25,00
Most expensive experimental diet:	R 4,49
Least expensive experimental diet:	R 2,77

A saving thus of 82 to 89%. The cheapest diet combination was also the best one.

Conclusion

Although it could be expected that results with respect to mass gains, DM-, GE-, and N digestibility, as well as N retention would improve relevant to increasing colostrum content of the diet, the experimental design was efficient since it could be indicated that similar results were obtained with specific colostrum levels, but different soybean flour and whey powder levels. In those cases where an alternative exists, the least cost diet combination can be used in practice.

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