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A polyol mixture and molasses-treated beed pulp in the silage based diet of dairy cows

III The effect on the utilization of minerals

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Abstract. The effect of sugar alcohol (polyol) mixture feeding on the utilization of Ca, Mg, Na, K and P was studied in a balance trial with 12 dairy cows. The cows were divided into 3 groups: Group I received a grain concentrate mixed with 26 % of polyoltreated beet pulp, Group II the concentrate mixed with 29 % of molasses beet pulp, and Group III only the grain concentrate. Cows were given 7—8 kg/d of concentrate, 2 kg/d of hay, and silage at almost ad lib. level.

The intake of sugar alcohols was 484 g/d in Group I and total intake of sugars was 461, 736 and 435 g in Groups I, II and IIII, respectively. No polyols were secreted in the faeces, and in the urine only 0.7 % of the intake, most of which was xylitol, rhamnitol and arabinitol. Small amounts of polyols were also secreted in the urine of the molasses beet pulp group. There were no clear effects of polyol feeding on the apparent digestibility or utilization of minerals. However, the readily fermentable carbohydrates in the diet tends to increase the apparent absorption and utilization of magnesium. Secretion of potassium was significantly ($P < 0.05$) lower in the polyol beet pulp group than in the molasses beet pulp group.

Introduction

Many carbohydrates such as lactose, xylose and arabinose, improve the absorption and retention of calcium in monogastric animals (Fournier et al. 1955, Wasserman et al. 1956, Atkinson et al. 1957). In pigs lactose also improves the absorption of magnesium (Entringer et al. 1975). With dairy cows lactose has no effect on the absorbtion of either calcium or magnesium (Shingoethe and Rook 1976). Paquay et al. (1968) observed that cereal feeding, especially of barley, has a positive influence on the utilization of calcium by dairy cows. Glucose and saccharose have improved the absorption of magnesium in sheep (Madsen et al. 1976, House and Mayland 1976).

Sugar alcohols, or polyols also have an effect on the absorption of minerals. Xylitol and sorbitol have improved the absorption of calcium in rats (Schalk 1969, Fournier et al. 1973). Polyols are fermented slowly by rumen microbes in vitro (Poutiainen et al. 1976) and part of the polyols escapes the rumen.

The possible effect of a polyol mixture, a by-product of xylitol production from birch trees, on the utilization of some minerals is studied in this report.

Experimental procedures

In a balance trial, performed with the total collection method, 12 dairy cows (10 Ayrshires and 2 Friesians) were divided into 3 groups. At the commencement the cows had been on the experimental diets 10—12 weeks in a milk production trial (Tuori and Poutiainen 1977). The average time from calving to the start of the collection period was 113 days (95—120). In the grain concentrate mixture Group I received 26 % polyol-treated beet pulp and Group II 29 % molasses-treated beet pulp. There were no additions to the concentrate mixture (oat-barley) of Group III. Cows were given 7—8 kg/d of grain concentrate, 2 kg/d hay, and fresh grass silage at 95 % of ad lib. consumption.

The collection period was 7 days. Urine was collected by a rubber urinal strapped to the cow. The faeces were collected in a box lined with a plastic sheet at the end of the stall.

Feeds, faeces, urine and milk were weighed and sampled daily except for silage, from which a representative sample was taken before the collection period. Feed and milk analyses were carried out as described earlier (Tuori and Poutiainen 1977). Calcium, magnesium, sodium and potassium were determined with a Varian Techtron 1 000 atomic absorption spectrophotometer (Heckman 1967) and phosphorus was determined colorimetrically (Taussky and Shorr 1953). Sulphur and chlorine were not determined, but feed table values were used in calculating the alkali-alkanity of the diets.

Polyols were determined with a Carlo Erba 180 gas chromatograph (Norrman 1978) at the Finnish Sugar Co. Ten millimetres urine, added to 10 mg erythritol as the internal standard, was eluted through a mixed bed ion-exchange resin, evaporated to dryness with ethanol, and acetylated by adding 1 ml pyridine and 1 ml acetanhydride. The mixture was then boiled under reflux for one hour. The solid phase in the 1.8 m glass column was Chromosorb V AV 100—120 mesh and the liquid phase was 3 % Silicon OV-275. The samples of 3 μl were injected at 250° C and detection was made at 275° C. The temperature program was 2 min at 180° C, an increase of 5° C/min to 220° C, and 12 min at 220° C isothermically.

The faeces samples were pretreated for polyol determination as follows: the dried, ground sample was extracted by Soxhlet and polyols and sugars were separated by sodium cation exhange. Separation was followed with a differential refractometer. Polyols were determined as acetate as earlier reported. Sugars were determined chromatographically as trimethylsilyl derivates (Norrman 1978).

The total amount of polyols from polyol beet pulp was determined by periodate titration (Tegge and Bergthaller 1970) and the separate polyols were analyzed chromatographically. Two grams dried, ground samples were shaken with 150 ml water for 2 hours. The liquid was filtrated into 200-ml volumetric flasks which were then filled to the mark; 10 ml of the filtrate was taken for titration.

The data were treated by variance or covariance analysis (Steel and Torrie 1969).

Results and discussion

Intake of concentrate and milk yield were lower in the molasses beet pulp group than the other groups (Table 2). The apparent digestibility and retention of calcium were on the same level in all groups (Table 3 and 4). The utilization of magnesium was highest in the molasses beet pulp group, but the difference was not significant. This group also had the highest intake of magnesium and potassium, as the concentrate mixture with molasses beet pulp contained more of these minerals (Table 1). The retention and utilization of potassium was slightly higher in the polyol beet pulp group than in the others, the difference being insignificant, however. The secretion of potassium in urine was significantly ($P < 0.05$) lower in the polyol than the molasses beet pulp group even after the effect of potassium intake was eliminated by covariance analysis. The diets had no effect on the apparent digestibility and utilization of sodium and phosphorus.

Table 1. The chemical composition of feeds.

	Ensilage	Hay	Polyol beet pulp, concn.	Molasses beet pulp concn.	Control conc.
DM, %	28.3	78.7	88.3	87.1	88.3
Crude protein, g/kg DM	216	98	118	136	136
Crude fibre, »	250	340	87	91	71
Sugars, »	14	67	45	93	38
Polyols[1]) »	—	—	73	—	—
Feed units[2]) /kg DM	0.731	0.514	1.016	0.986	1.050
g DCP/ »	147	55	87	97	104
Ca, g/kg DM	3.36	2.25	9.56	11.47	10.16
Mg »	0.93	0.66	1.78	3.12	1.77
K »	20.82	20.04	4.20	10.00	3.90
Na »	0.35	3.28	3.09	4.34	2.67
P »	2.57	2.17	5.51	6.39	6.21

[1]) Composition of polyols: Arabinitol 11.3 %, xylitol 27.0%, rhamnitol 4.0 %, mannitol 10.0 %, sorbitol 8.0 %, galactitol 3.2 % ,short chain polyols and reducing sugars 36.5 %.

[2]) fattening feed unit = 0.7 kg starch equivalents

No polyols were secreted in the faeces. Minute amounts of glucose and xylose and, from some cows, mannose and galactose were found.

The secretion of polyols in urine was also slight, only 0.7 % of the total intake (Table 5). Of the total quantity of secreted polyols 60 % were identifiable, the remainder being »others» (reducing sugars and short chain polyols). Xylitol, rhamnitol and arabinitol were the most common of these. The molasses beet pulp group also excreted some polyols in the urine and one control cow excreted xylitol.

In order to improve the absorption of calcium the sugars must be present with calcium at the absorption site. Injections of glucose, fructose and sac-

Table 2. Feed consumption and milk production during collection period.

	Group					
	Polyol beet pulp		Molasses beet pulp		Control	
	x̄	SD	x̄	SD	x̄	SD
Feed consumption, kg DM/day:						
Ensilage	6.3	1.4	6.7	1.6	6.5	1.7
Hay	1.1	0.3	1.4	0.3	1.5	0.1
Grain concentrate	6.7	0.2	5.8	1.6	6.4	0.4
Total	14.1	1.4	14.0	1.4	14.4	2.0
Feed units/day	11.9	1.1	11.4	2.0	12.2	1.6
g DCP/day	1566	204	1627	283	1713	292
g crude fibre/day	2544	370	2668	313	2593	508
g sugars/day	461	34	736	159	435	30
g polyols/day	484	22				
Milk yield, kg/day	18.3	0.7	17.4	4.0	18.5	2.2
Fat-%	4.51	0.28	3.98	0.26	4.12	0.55
Live weight, kg	481	38	528	53	478	58

charose into the jejenum increase the absorption of calcium but given into the adjacent segment or per os they have no effect (LENGEMAN 1959, VAUGHAN & FILER 1960).

The effect of sugars is relative to their concentration in the intestinal tract. ARMBRECHT and WASSERMAN (1976) noticed that the effect of lactose on the absorption of calcium in rats decreased when the lactose concentration fell below 160 mM. A lactose concentration of 10 mM had no effect on the calcium absorption (URBAN and PENA 1977). The intake of polyols in our experiment was only 3.4 % in the feed dry matter and part of this fermented in the rumen, which may partly explain why the diets had no effect on the calcium.

The alkali-alkalinity ratio of the diet, (Na + K) — (Cl + S), influences the calcium absorption (ENDER et al. 1971, DISHINGTON 1975, LOMBA et al. 1978). The alkali-alkalinity ratio of the polyol beet pulp, molasses beet pulp and control groups was 550, 1 830, and 520 meq., respectively.

LOMBA et al. (1978) noticed a negative correlation between the apparent absorption and the alkali-alkalinity of the diet of cows with a positive calcium balance. In our data the partial correlation with a constant intake of Ca and (Na + K) was −0.645 ($P < 0.05$) after the elimination of 3 cows with negative Ca-balances (one in each group).

Magnesium absorption, recently reviewed by MARTENS (1978), occurs mainly in the forestomachs of the ruminant. The readily fermentable carbohydrates may increase the absorption by changing the conditions in the rumen, for instance hydrogen ion concentration.

The magnesium balance was negative or zero in two cows (Groups I and II). After the elimination of these results the apparent digestibility was 29.2, 30.2 and 21.6 % in Group I, II and III, respectively. Mg-retention was 9.0, 14.6, 3.8 % with the difference between groups almost statistically significant. This is in accordance with the results of MADSEN et al. (1976) who found that

Table 3. Mineral intake and utilization (g/day).

		Group			SEM[2])
		Polyol beet pulp	Molasses beet pulp	Control	
Ca					
Intake		85.0	94.2	90.2	6.7
Excretion:	Faecal	50.5	58.0	55.2	4.5
	Urinary	2.3	1.0	4.2	1.0
	Milk	21.9	21.4	22.6	2.0
Balance		10.2	13.8	8.3	5.7
Utilized[1])		32.2	35.2	30.9	4.9
Mg					
Intake		18.5	25.3	18.3	1.9
Excretion:	Faecal	13.6	18.2	14.4	1.2
	Urinary	2.6	2.6	1.7	0.4
	Milk	1.6	1.4	1.5	0.1
Balance		0.7	3.1	0.7	1.0
Utilized		2.3	4.5	2.2	1.0
K					
Intake		184	230	188	21
Excretion:	Faecal	23	22	30	4
	Urinary	98^{a}	166^{b}	126^{ab}	12
	Milk	21	21	21	3
Balance		41	21	10	16
Utilized		63	42	32	15
Na					
Intake		28.1	30.8	24.1	2.7
Excretion:	Faecal	5.5	5.5	5.3	1.1
	Urinary	12.8	15.6	11.0	1.9
	Milk	8.2	9.6	9.8	0.5
Balance		1.8	0.1	−2.1	2.6
Utilized		10.0	9.7	7.7	2.5
P					
Intake		55.8	58.1	59.0	4.4
Excretion:	Faecal	39.7	37.4	43.8	3.8
	Urinary	0.2	3.0	0.2	1.5
	Milk	14.3	13.8	14.8	1.2
Balance		1.7	3.8	0.2	2.9
Utilized		15.9	17.6	15.0	2.5

[1]) Balance + mineral in milk

[2]) Standard error of the means

Table 4. The apparent digestibility, retention and utilization of minerals (% of the mineral intake).

	Polyol beet pulp	Molases beet pulp	Control	SEM
Ca				
Apparent digestibility, %	40.8	37.5	38.5	4.4
Retention, %	12.2	12.2	8.9	6.4
Utilization, %	38.1	36.4	34.0	4.0
Mg				
Apparent digestibility, %	26.1	27.1	21.6	11.4
Retention, %	3.5	11.0	3.8	4.3
Utilization, %	12.1	17.1	12.3	4.2
K				
Apparent digestibility, %	86.9	90.3	84.2	1.5
Retention, %	21.6	8.1	3.6	6.9
Utilization, %	33.7	17.6	15.3	5.6
Na				
Apparent digestibility, %	80.4	82.4	78.0	3.2
Retention, %	5.0	−1.8	−11.1	9.3
Utilization, %	34.4	30.6	31.9	6.9
P				
Apparent digestibility, %	28.6	35.2	26.2	3.9
Retention, %	2.4	4.9	0.5	4.8
Utilization, %	28.3	30.2	25.9	3.6

Table 5. The secretion of polyols in urine.

Group		Urine kg/d	Polyols, g/d						
			total	arabinitol	xylitol	rhamnitol	mannitol	sorbitol	others
Polyol	$\bar{x}$	15.32	3.24	0.351	0.784	0.587	0.092	0.088	1.341
beet pulp	SD	3.33	1.35	0.124	0.440	0.217	0.106	0.176	0.519
Molases	$\bar{x}$	22.89	1.82	0.195	0.426	0.505	0.020	0.123	0.551
beet pulp	SD	4.33	0.45	0.114	0.254	0.345	0.026	0.205	0.297
Control	$\bar{x}$	17.96	1.33	—	0.049	—	—	—	1.286
	SD	5.34	1.20		0.098	—	—	—	1.246

adding 0—18 % of glucose to the diets of sheep increased the apparent absorption of magnesium linearly. The opinion is thereby supported that readily fermentable carbohydrates in the diet of ruminants improve the absorption of magnesium.

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SELOSTUS

Sokerialkoholiseoksella käsitelty tai melassoitu juurikasleike lypsylehmillä säilörehuruokinnalla

III Vaikutus kivennäisaineiden hyväksikäyttöön

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Tasekokeessa oli 12 lypsylehmää jaettuna kolmeen ryhmään. Ryhmällä I väkirehussa oli 26 % sokerialkoholiseosta sisältävää juurikasleikettä, ryhmällä II melassileikettä 29 % ja ryhmällä III pelkästään viljaseosta (ohra—kaura). Väkirehua annettiin 7—8 kg/d, heinää 2 kg/d ja nurmisäilörehua rajoitettuna lähelle ad lib. määrää. Sokerialkoholien kokonaismäärä ryhmällä I oli 484 g/d. Sokerien saanti ryhmissä I, II ja III oli 461, 736 ja 435 g/d. Sonnassa ei erittynyt sokerialkoholeja lainkaan, ja virtsassakin vain n. 0.7 %. Eniten esiintyi ksylitolia, ramnitolia ja arabinitolia. Myös melassileikeryhmällä esiintyi sokerialkoholeja virtsassa vähäisiä määriä. Kivennäisten imeytymiseen ja hyväksikäyttöön sokerialkoholiruokinnalla ei ollut selvää vaikutusta. Kuitenkin helppoliukoisten hiilihydraattien sisällyttäminen rehuvalioon vaikutti positiivisesti magnesiumin imeytymiseen ja hyväksikäyttöön. Kaliumin eritys virtsassa oli polyolileikettä saaneella ryhmällä merkitsevästi ($P < 0.05$) pienempi kuin melassileikettä saaneella ryhmällä.