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Xylitol, polyol molasses and glucose in the diet of newborn calves I. Effect on growth and some blood values

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Abstract. In a feeding trial with 18 calves, three carbohydrate additions were compared in a liquid milk replacer diet: glucose, xylitol and polyol molasses (PM). The average consumption of substrates was 41, 42 and 48 g dry matter of glucose, xylitol or polyol molasses per day. After one week of colostrum and whole milk feeding, liquid milk replacer was given 12 % of live weight. The trial lasted to the age of 5 weeks. Daily live weight gain was 452, 479 and 425 g in the glucose, xylitol and PM groups (n.s.), respectively. Intake of concentrates was greater in female than male calves ($P < 0.05$). There was no significant difference in the feed conversion rate between the groups: 1.83, 1.88 and 1.98 kg dry matter/kg live weight gain in the glucose, xylitol and PM groups, respectively. Venous blood samples were taken before the first feeding after birth, then 1, 2, and 4 days, and 1, 3 and 5 weeks after birth. Haemoglobin and haematocrit were higher in the glucose than in the xylitol and PM groups, and higher in female than male calves ($P < 0.05$). There were no differences between the groups in plasma glucose, calcium or magnesium contents. Plasma urea-N was lower in the xylitol than in the glucose group ($P < 0.05$). Plasma inorganic phosphorus was higher in the xylitol than in the glucose group on week one and three after birth, the difference being significant at 3 weeks of age ($P < 0.05$).

Introduction

Xylitol is a five-carbon polyol or sugar alcohol. The metabolism of xylitol differs from that of glucose in that the first steps of xylitol metabolism do not require insulin and that xylitol is metabolized mainly in the liver. The main end product is, however, glucose (McCormick & Touster 1957, Lang 1971). Xylitol has also some physiological effects: it may be used as a sweetener for diabetics, to prevent caries and in parenteral nutrition (Mellinghoff 1961, Mühlemann et al. 1970, Lang 1971, Scheinin & Mäkinen 1975).

Xylitol is produced from xylans of birch tree. Xylan is hydrolyzed to xylose which is then hydrogenated to xylitol. The purification, concentration and crystallization processes of xylitol produce as byproduct a liquid mixture of polyols (Melaja & Hämäläinen 1977, Hyvönen et al. 1982). The effect of this polyol molasses has been studied in dairy cows (Tuori & Poutiainen 1977),

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sows and piglets (NÄSI & ALAVIUHKOLA 1980), and minks (KIISKINEN 1977). The purpose of the present experiment was to study the effects of polyol molasses, xylitol and glucose on the growth and some blood values of calves up the age of five weeks.

Material and methods

Eighteen newborn calves were fed from birth to the age of 35 days a diet supplemented with glucose, xylitol or polyol molasses (PM) dry matter 1 g/kg live weight. The calves, 11 male and 7 female, were Ayrshire breed, with the exception of one Friestian and two Ayrshire × Hereford heifer calves. The calves were divided into three equal groups in the order they were born. The xylitol group included 3 female calves, the other groups only two females. Liquid feeding was given according to Table 1. Concentrate, hay and water were offered ad libitum.

The polyol molasses used in this trial was a byproduct of xylitol production (Sokerikemia Oy, Kotka, Finland, owned by Xyrofin Ltd.). Composition of polyols in PM (% dry matter) was: xylitol 15.5, arabinitol 23.5, galactitol 5.5, mannitol 11.5, sorbitol 13.0, rhamnitol 6.0, reducing sugars and others 25.0 (short-chain polyols, degradation products, monosaccharides). The dry matter content of PM was 57.0 %.

Colostrum, which was given during the first 4 days, was collected in advance from the first six milkings postpartum of several cows, pooled and frozen. Whole milk, which was given during 4 days after colostrum feeding, was taken from the milk tank at a time, packed into daily portions and frozen. The concentrate mixture contained oat, barley, wheat and minerals. The commercial milk replacer contained 44 % skim milk powder, 25 % whey powder, 12 % fat mixture, 6 % soya bean meal, 6 % yeast and the rest was grass meal and minerals. Milk replacer was mixed with water (140 g/l) and fed to calves individually 12 % of live weight twice a day. The quantities of milk replacer and substrates were adjusted once a week. Feed intake was recorded daily and calves were weighed weekly. The calves were housed in individual pens with slatted floors (1.0 m × 1.2 m). Faeces were checked daily for incidence of scours, and rectal grab samples were taken weekly for dry matter determination.

Samples of colostrum and whole milk were taken when collecting milk from pooled portions. Samples of milk replacer, concentrate and hay were collected weekly and pooled.

Feed analyses (Table 2) were made on

Table 1. Feeding scheme.

Days after birth	Colostrum, % of live weight	Whole milk, % of live weight	Test substrate g/kg live weight[1]	Total amount of liquid feed, % of live weight[2]
1	7	—	0.5	7
2	7	—	0.5	7
3	7	—	0.5	7
4	8	—	0.5	8
5	4	3	0.75	9
6	0	6	0.75	10
7	—	4	1.0	11
8	—	4	1.0	12
9—35	—	—	1.0	12

[1] Test substrates were glucose, xylitol or polyol molasses (PM) dry matter.

[2] Including colostrum, whole milk and milk replacer diluted to 140 g per 1 litre of water.

Table 2. Composition of feeds.

	DM-%	In dry matter, %					DCP, g/ kg DM	FFU/kg DM[1]
		Ash	Crude protein	Ether extract	Crude fibre	NFE		
Colostrum	14.5	5.8	33.6	29.0	—	31.6	32.2	1.89
Whole milk	12.4	5.9	26.2	26.6	—	41.3	25.2	1.84
Milk replacer	94.6	8.1	24.9	13.4	3.0	50.6	22.4	1.45
Concentrate	87.5	6.2	13.5	3.1	5.9	71.3	10.6	1.07
Hay	91.9	5.3	8.6	2.0	34.3	49.8	4.8	0.55

[1] Fattening feed unit (0.7 kg starch equivalent).

samples dried in vacuum owens at +50°C by the Weende method. Composition of polyols in the polyol molasses was determined with a Carlo Erba gas chromatograph in the laboratory of Finnish Sugar Co. Blood samples were taken from the jugular vein into heparinized tubes. The first sample was taken on the day of birth, before the first meal, then 1, 2 and 4 days and 1, 3, and 5 weeks after the birth before morning feeding. Haematocrit and haemoglobin were determined from whole blood and glucose from plasma by the o-toluidine method (HULTMANN 1959, HYVÄRINEN & NIKKILÄ 1962). Minerals were determined with an atomic absorption spectrophotometer (Varian Techtron AA-1000) and phosphorus by the method of TAUSSKY and SHORR (1953). Plasma urea-N was determined by hydrolyzing urea to ammonia which was measured by the indophenol reaction (CHANEY & MARBACH 1962).

The effects of supplements and sex were tested on all parameters by the least square analysis (HARVEY 1970). No significant interactions between supplements and sex were observed; therefore the means of main effects only are presented. The effect of supplements on the incidence of scouring was tested with the chi-square test (STEEL & TORRIE 1960).

Table 3. Total feed intake from birth to the age of five weeks.

	Supplement		
	Glucose	Xylitol	Polyol molasses
Colostrum + whole milk, l	19.3	20.8	19.1
Milk replacer, kg	19.8	20.0	18.6
Concentrate, kg	2.9	4.6	3.3
Hay, kg	1.0	1.5	1.5

Results and discussion

Feed intake and growth

Total feed intake from birth to 35 days of age (Table 3) shows that the calves in the xylitol group tended to consume more concentrate than the calves in the other groups. Heifer calves consumed significantly ($P < 0.05$) more concentrate than bull calves (146 and 92 g DM/d over a period of 1 to 5 weeks, Table 4). Intake of carbohydrate substrates during the same period was 41 g glucose, 42 g xylitol and 48 g PM dry matter per day and substrates represented 5.0, 4.7 and 5.9 % of total dry matter intake, respectively. The higher intake of PM dry matter than other substrates was due to underestimated dry matter content of the liquid polyol molasses.

Live weight gain during the first week was negligible or even negative. From the second to the end of the fifth week the live weight gain was 452, 479 and 425 g/d in the glucose, xylitol and PM groups, respectively. Live weight gain of bull calves was 462 and that of heifer calves 442 g/d.

According to growth data in the literature, it may be mentioned that oral xylitol

administration (10 % of the diet) gave the same weight gain and efficiency of protein in rats as glucose (KIECKEBUCH et al. 1961). In piglets, 4 or 5 % polyol molasses dry matter in feed gave the same or slightly better weight gain and feed conversion rate than the same quantity saccharose or glucose-fructose mixture (NÄSI & ALAVIUHKOLA 1980, 1981). In young minks, feeding of polyol molasses (1 % of fresh matter) had no effect when given at less than 2 months of age. At a later age polyol molasses decreased growth rate and size of fur (KIISKINEN 1977).

The PM group consumed on the average 6.2 g sorbitol per day. Sorbitol orally 20 g/day has been found to increase weight gain in calves (DANIELS et al. 1981). Sorbitol 6 or 9 g/d increased weight gain by 7.8 and 9.0 %, respectively (THIVEND 1983). THIVEND et al. (1984) have shown sorbitol to increase biliary secretion. The present polyol molasses contained in addition to sorbitol also arabinitol and short-chain polyols which are poorly utilized and may have a negative effect on growth.

The feed conversion rate was 1.83, 1.88 and 1.98 kg DM/kg live weight gain in the glucose, xylitol and PM groups, respectively, but the differences were not significant (Table 4).

Table 4. Effects of supplements and sex on live weight changes and feed intake (adjusted means).

	Supplement			Sex		S.E.[1]
	Glucose	Xylitol	Polyol molasses	Male	Female	
Live weight at birth, kg	38.2	38.7	35.2	37.7	37.1	2.6
Live weight on week 1	38.0	38.7	36.2	38.1	37.1	2.6
Live weight on week 5	50.7	52.1	48.1	51.0	49.5	3.0
Live weight gain from week 1 to week 5, g/d	452	479	425	462	442	31
Concentrate intake, g DM/d	100	146	111	92[a]	146[b]	17
Total DM intake, g DM/d	822	900	819	835	859	52
FFU intake /d	1.11	1.18	1.10	1.12	1.14	0.07
DCP intake, g/d	158	166	153	159	158	10
Feed conversion rate:						
kg DM/kg live weight gain	1.83	1.88	1.98	1.83	1.96	0.11
FFU/kg live weight gain	2.48	2.49	2.65	2.47	2.61	0.16

[1] standard error of the supplement means.

[a, b] means within rows and main effects without letters or marked with common letters were not significantly different ($P < 0.05$).

Table 5. Effect of supplements and sex on consistency of faeces (adjusted means) and incidence of scouring.

Time	Scouring days			DM content of faeces, %					
	Supplement			Supplement			Sex		S.E.
	Glucose	Xylitol	Pol.mol.	Glucose	Xylitol	Pol.mol.	Male	Female	
Week 1	—	—	—	20.7	19.5	18.8	18.4	20.9	1.2
Week 2	5	3	4	22.5	23.2	22.0	23.4	21.7	1.5
Week 3	1	—	4	23.5	22.4	23.4	21.9	24.3	1.0
Week 4	—	—	—	23.5	23.8	22.1	23.2	23.0	1.1
Week 5	—	—	—	23.4	24.2	22.8	23.5	23.4	0.7
Total	6	3	8	22.6	22.6	21.8	22.1	22.6	1.1

Table 6. Effects of supplements and sex on blood values (adjusted means).

	Supplement			Sex		S.E.
	Glucose	Xylitol	Polyol molasses	Male	Female	
In whole blood:						
Haemoglobin, g/l	121[ac]	109[bcd]	108[bd]	107[c]	118[d]	3
Haematocrit, %	37.7[c]	33.0[ad]	34.1[ad]	33.7[a]	36.2[b]	0.8
In plasma:						
Glucose, mmol/l	5.01	5.12	5.38	5.24	5.10	0.16
Urea-N, mmol/l	2.58[a]	2.19[b]	2.48[ab]	2.45	2.38	0.11
P_i, mmol/l	2.31	2.27	2.22	2.19	2.34	0.07
Ca, mmol/l	2.46	2.43	2.41	2.39	2.49	0.06
Mg, mmol/l	0.74	0.72	0.72	0.74	0.72	0.02

Means within rows and main effects without letters or marked with common letters were not statistically significant:
[a, b] ($P < 0.05$)
[c, d] ($P < 0.01$)

Consistency of faeces and incidence of scouring

The dry matter content of faeces was slightly lower in the PM than in the other groups. The total number of scouring days was 6, 3 and 8 in the glucose, xylitol and PM-groups, respectively, but the differences were not significant (Table 5). However, the calves in the xylitol group seemed to be healthier than the calves in the other groups. Xylitol and PM doses were increased in three steps to the final level of 1 g/kg live weight during the first week of life (Table 1), and this adaptation time was sufficient, because no cases of scours were detected during the first week. On the second week, however, diarrhoea occurred in all groups (Table 5). Whole milk was probably too rapidly switched to milk replacer.

Xylitol is relatively slowly absorbed via the passive or facilitated diffusion. Adaptation to xylitol will enhance absorption, but if the unabsorbed xylitol reaches colon, diarrhoea will occur (BÄSSLER 1969). In man, the ability to tolerate xylitol is individual. DUBACH et al. (1970) did not notice in normal subjects intolerance to xylitol 75 g/d with daily increases of 5 grams. MERTZ et al. (1972) increased oral administration of xylitol from 15 g to 50 g in a week with no side effects in normal adults. Daily doses of 20—30 g caused gastric disorders to some, but most

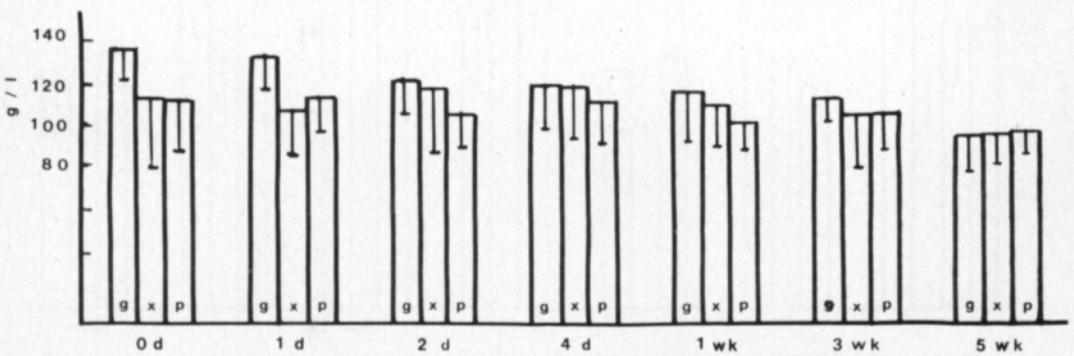

Fig. 1. Haemoglobin (means and standard deviations) in different groups from birth to the age of 5 weeks. g = glucose, x = xylitol and p = polyol molasses group.

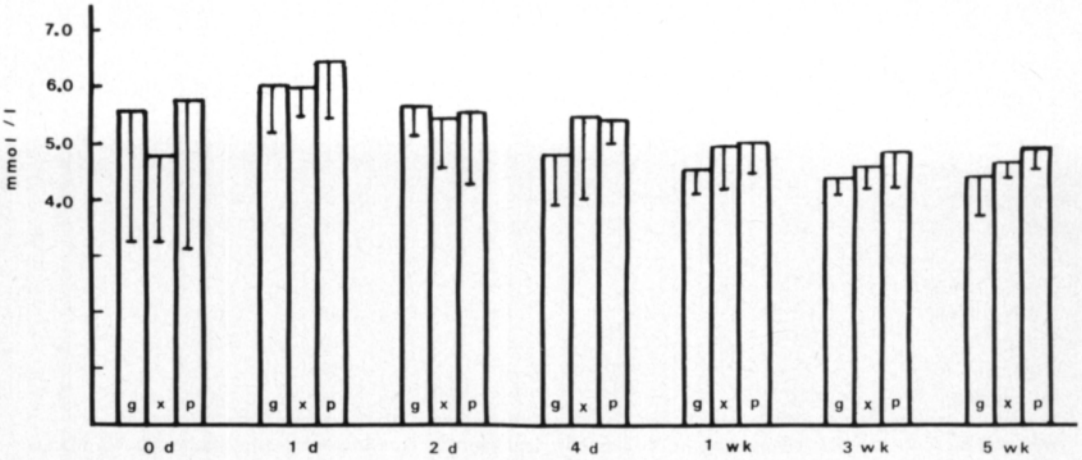

Fig. 2. Plasma glucose (means and standard deviations) in different groups from birth to the age of 5 weeks. g = glucose, x = xylitol and p = polyol molasses group.

subjects tolerated 50—100 g/d, some as much as 100—200 g/d. The highest calculated dose without adverse effects was 430 g/d (MÄKINEN 1978).

Blood values

Haemoglobin and haematocrit values (Table 6) were higher in the glucose than in the other groups ($P < 0.01$). The difference existed already in the first sample before the first feeding, and values decreased during the experiment in all groups (Figure 1). The heifer calves had higher haemoglobin and haematocrit values than bull calves ($P < 0.05$). The difference was greatest during the first week of life, decreasing towards the end of the trial.

In plasma glucose (Figure 2) there were no differences between the groups. Postnatal plasma glucose was 5.35 mmol/l, and it rose to 6.13 mmol/l in one day. Lower glucose values (3.3 mmol/l) have been observed by YOUNG et al. (1970) and DANIELS et al. (1974). Sampling time of the first blood sample varied from 2 to 6 hours, depending on the time of birth, and some calves may have suckled their dams before the first sampling.

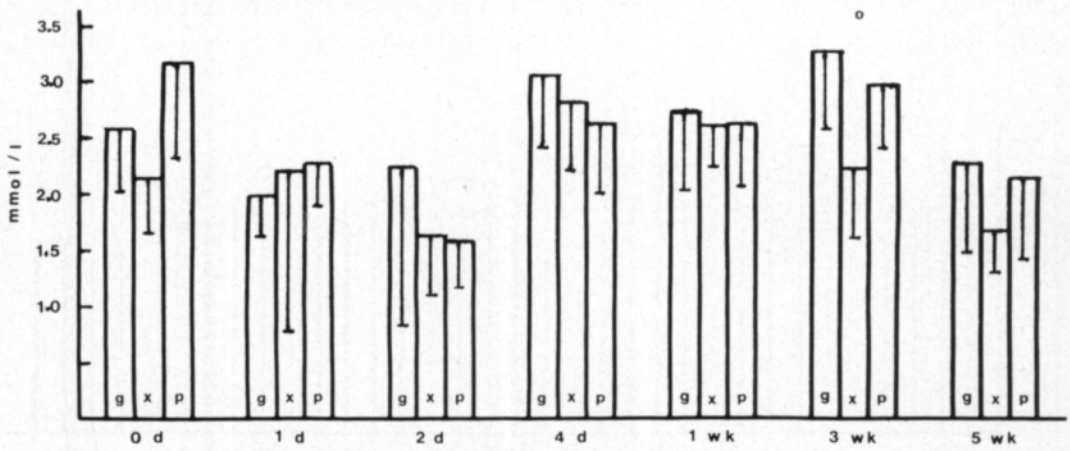

Fig. 3. Plasma urea-N (means and standard deviations) in different groups from birth to the age of 5 weeks. g = glucose, x = xylitol and p = polyol molasses group. ○ The xylitol group differs from the glucose group ($P < 0.05$).

The effect of xylitol on blood glucose depends on the route of administration, the dose given and animal species. In man, a xylitol infusion of 0.8 g/kg live weight only slightly increased serum insulin and the effect on glucose was seen after two hours post-infusion when the glucose level was significantly lower than the original value (GESER et al. 1967). Compared to sucrose or fructose, long-term, oral treatments at a dosage of 50 g/d of xylitol did not change the plasma glucose level (HUTTUNEN et al. 1975). Increasing oral xylitol doses to 220 g/d in normal subjects did not change fasting blood glucose concentrations (DUBACH et al. 1969).

In dogs, plasma insulin increased more after xylitol than after glucose, and oral xylitol 1 g/kg live weight caused a consistent hypoglycemia in dogs (KUZUYA et al. 1969). In lambs weighing 32—33 kg, intravenous injection of xylitol (c. 100 g) lowered blood glucose from 70 to 49.6 mg/100 ml (ESKELAND & PFANDER 1973). In cows, intravenous xylitol 0.2 g/kg had no influence on the blood glucose level (KUZUYA et al. 1971). In ketotic cows, 100 g of intravenous xylitol tended to increase blood glucose (HAMADA et al. 1982).

Plasma urea-N was lowest in the xylitol group and highest in the glucose group ($P < 0.05$). The difference was more pronounced from week 3 to week 5 (Figure 3), and the difference was significant on week 3 ($P < 0.05$) (Table 6).

It is possible that this was a reflection of the N-sparing effect (FÖRSTER 1974), although the xylitol group displayed higher feed intake during that period (3—5 weeks): 882, 984 and 894 g dry matter per day in the glucose, xylitol and PM groups, respectively. Live weight gain during the same period was 480, 561, and 502 g/d, respectively, and the digestible crude protein intake 167, 176 and 164 g/d, respectively. It may be calculated from these figures that the feed conversion rate (kg DM/kg gain) was 5 % higher and DCP consumption per kg gain was 10 % lower in the xylitol group than in the glucose group. The N-sparing effect of xylitol in man is due to glucose increasing the insulin level more than does xylitol. Insulin affects lipogenically, and in the absence of free fatty acids more amino acids are used for oxydation (FROESCH 1975).

Plasma calcium, magnesium and inorganic phosphorus (P_i) varied within the normal range. On week one and three, P_i was highest in the xylitol group (Figure 4), and the difference to the glucose group on week 3 was significant ($P < 0.01$). MERTZ et al. (1972) have noticed an elevation of plasma P_i in man after one week of oral administration of xylitol, and suggest that it may reflect

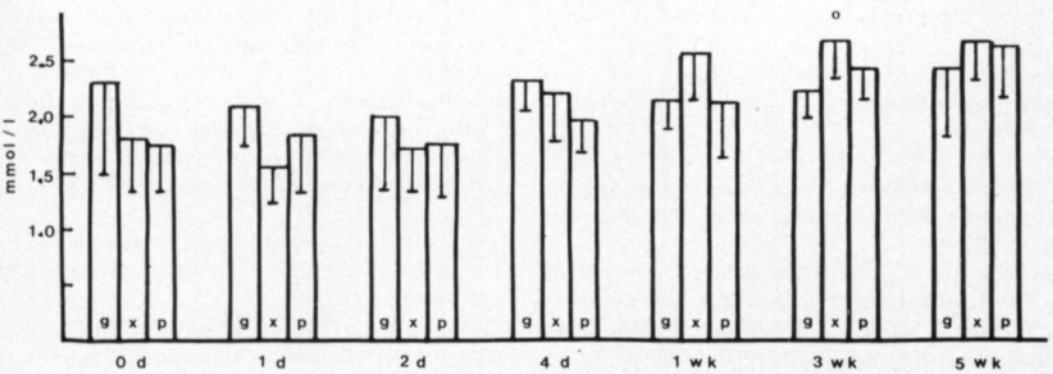

Fig. 4. Plasma P_i (means and standard deviations) in different groups from birth to the age of 5 weeks. g = glucose, x = xylitol and p = polyol molasses group. ○ The xylitol group differs from the glucose group ($P < 0.01$).

an adaptation of phosphorus supply to increased phosphorus turnover.

There were no differences in plasma calcium and magnesium concentrations (Table 6) between the groups and no indications of a better calcium utilization due to administration of xylitol or polyols. Some authors have shown previously that in addition to lactose also some monosaccharides and polyols enhance the absorption of calcium in the duodenum (ANON. 1970, FOURNIER et al. 1973).

Conclusion

Decreased urea-N content in plasma and slightly increased live weight gain in the xylitol group compared to the glucose group seems to be an indication of the better protein utilization. Inclusion of polyol molasses did not, however, offer any advantages over glucose.

Although polyol molasses contains sorbitol which has been shown beneficial on the growth and feed efficiency, polyol molasses did not improve live weight gain. Apparently, the other polyols and degradation products are poorly utilized and thus interfere with the possible positive effect of xylitol and sorbitol.

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SELOSTUS

Ksylitoli, polyolimelassi ja glukoosi vastasyntyneiden vasikoiden dieetissä I. Vaikutus kasvuun ja veriarvoihin

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Juottokokeessa oli 18 vasikkaa (11 sonni- ja 7 lehmävasikkaa) syntymästä 5 viikon ikään. Juomarehun lisäksi vasikat saivat ksylitolia, polyolimelassia (PM) tai glukoosia n. 1 g/elopainokilo.

Keskimääräinen lisäkasvu glukoosi-, ksylitoli- ja PM-ryhmissä oli 452, 479 ja 425 g/d. Lehmävasikat söivät enemmän väkirehua ($P < 0.05$), mutta kasvu oli lievästi heikompi kuin sonnivasikoilla. Vaikka ripulipäivien määrässä ryhmien välillä ei ollut tilastollista eroa (6, 3 ja 8 päivää glukoosi-, ksylitoli- ja PM-ryhmissä), tuntuivat ksylitoliryhmän vasikat terveimmiltä.

Laskimoverinäytteitä otettiin syntymän jälkeen ennen ensimmäistä ruokintaa, sitten 1, 2 ja 4 päivän sekä 1, 3 ja 5 viikon iässä. Hemoglobiini- (hb) ja hematokriittiarvot (hkr) olivat glukoosiryhmässä keskimäärin korkeammat kuin muissa ryhmissä, mutta erot tasaantuivat kokeen lopulla. Lehmävasikoilla hb- ja hkr-arvot olivat korkeammat kuin sonnivasikoilla ($P < 0.05$). Plasman glukoosissa, kalsiumissa tai magnesiumissa ei ollut eroja ryhmien tai sukupuolten välillä. Plasman urea-N oli keskimäärin alin ksylitoliryhmällä ja ero glukoosiryhmään oli merkitsevä ($P < 0.05$). Yhden ja kolmen viikon iässä plasman epäorgaaninen fosfori oli ksylitoliryhmässä korkein, ja ero glukoosiryhmään oli viikolla 3 merkitsevä ($P < 0.05$).

Tulokset viittaavat ksylitolilisän positiiviseen vaikutukseen valkuaisen hyväksikäytössä ja yleisessä elinvoimassa verrattuna glukoosi- tai polyolimelassilisään.