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Original article

Utilization of raw or heat-treated starch fed in liquid diet to pre-ruminants. 1. Calves *

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Summary — Five-7 day-old Friesen bull calves, raised in Israel received twice a day a mixture of 40 g of soybean concentrate (65% protein) and 80 g of one of the following carbohydrates : glucose (G), expanded (heat-treated) (ES) or untreated (US) corn starch. In the afternoon the calves received in addition 400 g of milk replacer. Until weaning at experimental day 25, ES calves showed better growth and food utilization than their counterparts. Daily weight gain for the entire growing period up to slaughter was higher for the starch than for the glucose-fed group ($P < 0.05$ for ES *vs* G). Heat treatment of starch increased its *in vitro* availability to amylase and its *in vivo* digestibility. Bypass of the rumen was complete in all G calves. In the ES and US groups, partial diversion of the liquid feed into the rumen was evident. The G group showed hyperglycemia after meals, while almost no increase in blood glucose level was observed after soy-starch meals (either US or ES).

calf / milk replacer / soy-protein / starch / digestiblity / blood glucose

Résumé — Utilisation de l'amidon cru ou traité à la chaleur chez les préruminants. 1. Veaux. *Des veaux israéliens de race Frisonne âgés de 5–7 j ont reçu 2 fois par jour un mélange liquide contenant 40 g de concentré de soja (65% de protides) et 80 g d'un des glucides suivants : glucose (G), amidon de maïs traité à la chaleur (ES) ou non traité à la chaleur (US). Dans l'après-midi, les veaux ont reçu en supplément 400 g d'un aliment d'allaitement. Au sevrage, les veaux ES étaient plus lourds que les veaux G ou US et leur indice de consommation meilleur. Le gain de poids moyen quotidien durant toute la période de croissance, jusqu'à l'abattage, était supérieur dans le groupe ES. Le traitement thermique appliqué à l'amidon de maïs a amélioré sa digestibilité* in vivo *et* in vitro. *La fermeture de la gouttière œsophagienne était complète chez les veaux du groupe G contrairement aux veaux recevant de l'amidon. Dans le groupe G, une hyperglycémie postprandiale a été constatée, alors que chez les veaux ES et US la concentration du glucose dans le sang n'a pas augmenté après le repas.*

veau / aliment d'allaitement / protéine de soja / amidon / digestibilité / glycémie

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INTRODUCTION

The effect of expanding or pelleting the feed on digestibility in ruminants is well documented (Haenlein *et al,* 1962; Theurer, 1986). The effect of starch from different sources, as well as the effect of heat treatment of starch included in milk replacers for veal calves, is also known (Mathieu and Thivend, 1968; Toullec *et al,* 1973, 1979), but the above studies began with calves weighing 60 kg or more and fed about 2 kg of milk replacers daily. The effect of including different starches in milk replacers for perinatal pre-ruminants consuming about 0.5 kg milk replacer daily is not as well known. Improving the utilization of feeds of plant origin used in milk replacers may be of economical value. Dried milk products are used extensively in the production of commercial milk replacers for rearing calves, kids and lambs. Young calves fed milk or milk replacers *ad libitum* can consume and digest enough nutrients to achieve a daily average growth of 1 kg (Marshall and Smith, 1970). The amount of milk replacers fed in practice is limited due to economic reasons.

The cost of milk replacers can be reduced in substituting feeds of plant origin for some of the milk ingredients.

The digestive system of pre-ruminants is adapted to the efficient digestion and utilization of milk components. It was shown by direct and indirect methods that the capacity of young pre-ruminants to digest and utilize ingredients from sources other than milk is limited (Huber *et al,* 1961; Siddons, 1968; Siddons *et al,* 1969; Ben-Asher *et al,* 1981).

Toasted soybean concentrate (65% protein) may replace part of the milk proteins; this results in some reduction of calf performance. This reduction may be compensated after weaning, when dry feeds are given (Nitsan *et al,* 1972).

Contradictory reports exist regarding the utilization of starch by pre-ruminants when fed in liquid form with milk replacer. Poor growth of suckling calves fed milk replacers containing more than 10% of raw corn starch was reported by Flipse *et al* (1950) and by Noller *et al* (1956). Including 18.5% starch in milk replacer for calves slightly reduced the digestiblity of organic matter compared with whole milk, but growth was similar in the 2 groups (Burt and Irvine, 1970). Thivend (1978) reported good performance of calves fed milk replacers containing about 20% starch, especially from 8 weeks of age onward. It was also shown that substituting part of the lipids in milk replacer by starch improved growth and reduced adiposity (Thivend *et al,* 1979). The utilization of starch from various sources may differ and be affected by cooking. Heat treatment of starch, which causes partial gelatinization, increases solubility and availability to amylolytic enzymes (Schoch and Maywald, 1967).

The purpose of this work was to compare the effects of the addition of raw *vs* heat-treated corn starch in milk replacer for young calves on growth, digestibility of nutrients, and rate of glucose absorption.

MATERIALS AND METHODS

Animals and feeds

Twelve Friesian bull calves, raised in Israel were purchased from various dairy farms after they had received colostrum for 3 d, followed by a commercial milk replacer. At 5–7 d of age, the calves were allotted to 3 experimental groups of 4 calves each according to body weight and kept in individual metabolic pens with wooden slatted floors.

For the morning meal (07 00 h), the calves received a mixture of 40 g of soybean concentrate (65% protein) and 80 g of one of the following carbohydrate sources: glucose (G), raw corn

starch (US) or expanded (heat-treated) corn starch (ES) (Galam Ltd, Maanit, Israel), mixed in 1.5 l of lukewarm (37 °C) water. At 17 00 h, 400 g of commercial milk replacer and 120 g of one of the soy-carbohydrate mixtures, described for the morning meal, were offered in 2.5 l of water. The commercial milk replacer was prepared from milk products (skim milk and whey powder). The composition of the milk replacer (% as fed) was: dry matter; 95.6, crude protein; 26.3, fat; 16.5, ash; 7.8, Mcal/kg; 4.7. Digestible energy was calculated using the following factors: 4, 9, 4 kcal/g for protein, fat and N-free extracts, respectively.

The calves were weighed at the beginning of the experiment and on days 10, 17 and 25. After weaning, they received a commercial concentrate (16% crude protein; 2 600 kcal/kg). Its consumption during the first 3 d was recorded for each calf. Later on, the calves were kept in 1 group; they received a concentrate *(ad libitum)* and hay (150 g/d), and their weights and age at slaughter were recorded.

On d 13–20 of the experiment, the faeces were collected in plastic bags, which were changed twice daily, and their contents frozen at –20 °C. On the same days, urine was collected in plastic bottles containing 200 ml of 5% sulfuric acid to prevent nitrogen loss. The pooled faecal samples of each calf were homogenized with water (1/1, bw/w) in a Waring Blender. Water intake was measured on the same days as the faeces and urine were collected.

In order to determine whether all liquid feed by-passed the rumen, iron oxide (2 g/kg dry food) was mixed with the diets and rumen liquor was obtained with a plastic tube connected to a suction bottle, before and 15 min after feeding on the 21st d of the experiment. The pH of the rumen liquor was determined immediately and the presence of red colour was recorded.

On d 22 of the experiment, blood samples were drawn from the jugular vein before the morning meal and at various intervals up to 120 min following the afternoon meal.

Chemical analyses

Dry matter, ash, total nitrogen, fat and starch in the feeds and the faeces, and total nitrogen in the urine were determined as described earlier (Ben-Asher *et al,* 1981). Blood glucose was determined by a glucose-oxidase method (Hestrin-Lerner and Ben-Yonah, 1963).

In vitro digestion of raw and heat-treated starch was determined by using pancreatic amylase (Type 1–A, Sigma Chemical Co, St Louis, Mo, USA) at a concentration of 0.5 mg/ml distilled water. The starch samples were prepared in phosphate buffer (pH 6.9, 0.1 mol/l) at a concentration of 0.5%. After incubation for 10 min at 37 °C, the amount of reducing sugars was determined with Summer reagent (Bernfeld, 1955).

Statistical analysis

Differences between means were assessed by Duncan's multiple range test (Duncan, 1955).

RESULTS

The body weight of ES calves increased linearly, from the beginning of the experiment, while that of G and US calves increased more slowly during the first 10 d. Later on, the growth of all groups was parallel (fig 1).

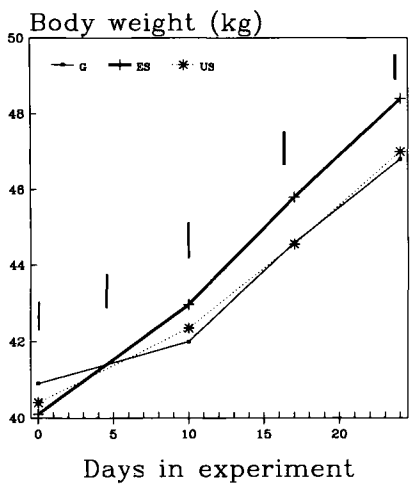

Fig 1. Body weights of calves fed milk replacer and a mixture of soy concentrate and glucose, (G), heat-treated starch, (ES) or untreated starch (US). Vertical lines = SEM.

There were no statistically significant differences in the performance of calves in the different groups up to weaning. However, the ES calves grew and utilized dietary energy and protein better than the other 2 groups (table I). For 3 d after weaning the ES calves consumed the highest amounts of dry concentrate feed. The calves were slaughtered when they reached a mean body weight of about 420 kg. The ES calves reached slaughter weight 23 d earlier than the G group ($P < 0.05$) and 11 d before the US group (NS).

Apparent digestibility of the dry matter was highest in the G group; no significant difference was observed between the ES and US groups. Expanded starch was digested better than raw starch ($P < 0.05$). Apparent digestibility of protein was similar in the G and ES groups and about 7% lower in the US group (NS). There were no statistically significant differences among the groups in fat or in ash apparent digestibility. Nitrogen retention was highest in the G group and lowest in the US group ($P < 0.05$). The ES group was intermediate and did not differ significantly from either group (table II).

Water intake of the calves was about 5.3 l/d or about 9 l/kg of dry matter intake and did not differ between the groups.

Diarrhoea was not observed and water concentration in the faeces was 16–20% in the different groups.

The pH of the rumen liquor was similar in all groups before the morning meal. Fifteen min following the meal, the pH was unchanged in the G group but dropped markedly in the ES one. In the US calves this drop was moderate (table III). The drop in rumen liquor pH occurred when the liquid feed did not completely by-pass the rumen. No marker was detected in the rumen liquor in any of the G calves. In the ES group the marker was detected in all the calves and in the US group in 2 out of 4 calves.

The faeces pH was lower in the calves fed diets containing US or ES compared with the G one, and the difference was statistically significant in the evening. There

Table I. Growth, food intake and utilization of calves fed milk replacer and a mixture of soy-concentrate and glucose (G), heat-treated starch (ES) or untreated starch (US) (means of 4 calves/group).

	G	*ES*	*US*	*SEM*
Initial body weight (kg)	40.9	40.1	40.7	2.35
Final body weight (kg)	46.8	48.4	47.0	2.31
Daily gain (g)	236	332	250	52
Intake:				
Digestible energy (Mcal)	66.9	67.5	67.2	
Crude protein (kg)	3.58	3.58	3.58	
Utilization:				
Mcal/kg wt gain	11.3	8.1	10.7	1.65
Protein kg/kg wt gain	0.61	0.43	0.57	0.11
Dry concentrate intake				
3 d after weaning (g)	456^{b}	887^{a}	541^{ab}	143

Means in the same raw with different superscript letters differ significantly ($P < 0.05$)

Table II. Apparent digestibility (%) of feed ingredients by calves fed milk replacer and a mixture of soy-concentrate and glucose (G), heat-treated (ES) or raw (US) starch (means of 4 calves/group).

	G	*ES*	*US*	*SEM*
Dry matter	92.4[a]	88.1[b]	86.0[b]	1.48
Crude protein	82.2	82.2	76.9	3.07
Fat	91.1	90.7	87.4	2.96
Starch	–	95.4[a]	87.0[b]	2.50
Ash	81.7	80.8	81.8	2.39
Nitrogen retention	60.6[a]	55.8[ab]	48.0[b]	3.14

Means in the same raw with different superscript letters differ significantly ($P < 0.05$)

Table III. PH of rumen liquor and faeces of calves fed milk replacer and a mixture of soy-concentrate and glucose, heat treated starch or raw starch (means of 4 calves/group ± SE).

	Rumor liquor pH		*Faeces pH*	
	before meal	*after meal*	*morning*	*evening*
Glucose	7.3 ± 0.16	7.2[a] ± 0.06	6.3 ± 0.33	7.3[a] ± 0.28
Treated starch	7.2 ± 0.23	4.9[b] ± 0.18	5.6 ± 0.14	6.0[b] ± 0.13
Raw starch	7.3 ± 0.06	6.3[ab] ± 0.43	5.9 ± 0.31	5.8[b] ± 0.17

Means in the same column with different superscripts differ significantly ($P < 0.05$)

were no differences between the ES and US groups in this respect (table III).

Blood glucose levels before the morning meal were 80–90 mg/100 ml in all calves (fig 2). After the morning meal, blood glucose level in the G group increased markedly and reached 196 mg/100 ml 2.5 h post feeding. It resumed the basal level 6 h post feeding. In the ES and US groups, which were fed soy-starch mixtures in the morning meal, the changes in blood glucose levels were non-significant. In the second meal, 6 h after the morning meal, all groups received 400 g of milk replacer in addition to 120 g of soy-carbohydrate mixture. Blood glucose levels increased markedly in all groups; 60 min after the meal these levels were highest in the ES group and lowest in the US one (NS), they increased further 120 min following the meal in the G group and reached 200 mg/100 ml, similar to the peak reached in the morning. In the 2 groups that received soy-starch mixtures, the peaks were below 150 mg/100 ml.

Hyperglycemia in the G group was accompanied by higher secretion of glucose in the urine compared with the ES and US

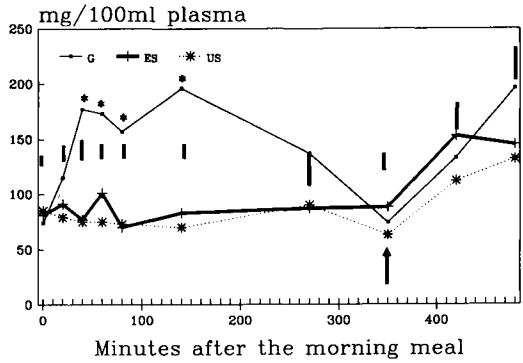

Fig 2. Blood glucose levels before and after meals of calves fed the following diets: in the morning, soy + glucose (G); soy + heat – treated starch (ES); and soy + untreated starch (US). In the afternoon, milk replacer + one of the respective diets. Arrow indicates time of afternoon meal. Vertical lines indicate SEM. * Statistically significant from the other treatments within periods, $P < 0.05$.

groups: 120 ± 5.4, 15 ± 1.7 and 20 ± 2.4 mg/100 ml of urine in the G, ES, and US groups, respectively, the difference between the G and the 2 other groups being statistically significant ($P < 0.05$).

In vitro digestion of the treated starch by pancreatic amylase was about 3-fold higher than that of raw starch. The amount of reducing sugars released from 1 g of starch during 3 min of incubation was 250 and 82 mg, respectively.

DISCUSSION

The daily gains of the calves were 230–330 g. These gains were low since the calves received limited amounts of liquid feeds, according to the amounts fed to calves designed for beef production. However, while in practice calves are fed dry concentrate and hay in addition to milk replacers, the calves in the present experiment did not receive any dry feeds in order to evaluate the digestibility, utilization and glycemia obtained by the liquid diets.

Heat treatment of starch increased its *in vitro* availability to amylase. This was concurrent to about 10% improved digestibility of starch *in vivo*, confirming the previous results of Mathieu *et al* (1970). Improved digestibility of starch was accompanied by a 7% increase in protein digestibility and retention which was not statistically significant. A relationship between starch and protein digestion was also reported by Huber *et al* (1968) and by Thivend *et al* (1979). The lower pH of the faeces of calves fed starch could indicate that part of the starch escaped digestion and absorption in the small intestine and was fermented in the caecum or colon. Intense fermentation and thus high bacterial proliferation could cause an underestimate of protein apparent digestibility. A similar phenomenon was observed in kids fed milk replacers containing starch (Nitsan *et al,* 1985).

In young calves, milk by-passes the rumen and is diverted to the abomasum due to the closure of the œsophageal groove. Liquids other than milk may cause incomplete closure of this groove (Guilhermet *et al,* 1973), and part of the liquid feed may pass into the rumen. In the present experiment using iron oxide as a marker, it was found that inclusion of the starch-soy mixtures was accompanied by incomplete closure of the œsophageal groove. This was also evident from the lower pH in the rumen liquor of the ES calves compared to the other group as was reported for kids (Nitsan *et al,* 1990). The passage of small amounts of liquid feed into the rumen could enhance the development of this site. Indeed, during the first 3 d after weaning, when food intake was still recorded for each calf individually, the ES calves consumed far more dry concentrate than the

other groups (table I). This early effect on food intake probably persisted since the ES calves reached a slaughter weight of about 420 kg 23 d earlier than the G group, while the US calves were intermediate in this respect.

The post-feeding increase in blood glucose levels in the G group was quite similar to that reported by Thivend and Martin-Rosset (1971) for calves fed milk replacer containing a mixture of glucides. Blood glucose levels did not differ between the ES and the US groups and were considerably lower than in the G group, in accordance with Natrajan *et al* (1972).

Although the *in vitro* study showed a 3-fold increase in the digestibility of the treated, compared with the untreated raw starch, the post-feeding changes in blood glucose levels did not differ between the 2 groups. This could be related to the higher amounts of ES trapped in the curd, causing slower release to the small intestine and delayed evacuation from the gastrointestinal tract compared with the US (Coombe and Smith, 1974; Golan *et al*, 1990). When calves were fed a glucose-soy mixture, the high solubility of the glucose was accompanied by a rapid flow of glucose to the intestine, inducing a substantial rise in glycemia. It seems that post-feeding blood glucose levels may reflect the rate of absorption of soluble carbohydrates but are not a reliable measurement of total absorption or utilization of less soluble carbohydrates, such as various starches. The absorption of glucose from starches may be delayed due to their slower release from the abomasum or slower breakdown by amylase. Moreover, rapid absorption of glucose did not relate to a better growth rate.

In conclusion, suckling calves receiving 160 g of corn starch daily, or 250 g of starch per 1 kg of dry feed grew and utilized feed as well as their counterparts receiving a similar amount of glucose, without showing any ill effects or diarrhoea. Heat treatment improved the apparent digestibility of starch ($P < 0.05$). In the present study suckling calves absorbed about 152 g of ES and 139 g of US per d.

REFERENCES

Ben-Asher A, Nitsan Z, Nir I (1981) Comparison of ruminal and post-ruminal digestion of a concentrate feed in the young calf. *Reprod Nutr Dev* 21, 999-1007

Bernfeld P (1955) Amylase, α and β. *In: Methods in Enzymology* (Calowick SD, Kaplan NO, eds) Academic Press, New-York, 149-158

Burt AWA, Irvine SM (1970) Carbohydrates in milk replacers for calves. *J Sci Food Agric* 21, 342-346

Coombe NB, Smith RH (1974) Digestion and absorption of starch, maltose and lactose by the preruminant calf. *Br J Nutr* 31, 227-235

Duncan DB (1955) Multiple range and multiple F tests. *Biometrics* 11, 1-44

Flipse RJ, Huffman CF, Webster HD, Duncan CW (1950) Carbohydrate utilization in the young calf. 2. Nutritive value of starch and the effect of lactose on the nutritive values of starch and syrup in synthetic milk. *J Dairy Sci* 33, 557-564

Golan M, Nitsan Z, Nir I (1990) The utilization of raw or heat treated starch fed in liquid diet to preruminants. 3. Lambs. *Small Rumin Res* (in press)

Guilhermet R, Mathieu CM, Toullec G (1973) Observations sur le transit des aliments liquides au niveau de la gouttière œsophagienne chez le veau préruminant et ruminant. *Ann Biol Anim Biochim Biophys* 13, 715-718

Haenlein GFW, Burton DW, Hoyt HC, Mitchell WH, Richards CR (1962) Effects of expanding or pelleting upon feed digestibility and heifer growth. *J Dairy Sci* 45, 754-758

Hestrin-Lerner S, Ben-Yonah S (1963) Routine determination of blood glucose with glucose oxidase. *Bull Res Counc Isr* 10E, 188-191

Huber JT, Jacobson NL, McGilliard AD, Morrill JL, Allen RS (1961) Digestibilities and diurnal excretion patterns of several carbohydrates fed to calves by nipple pail. *J Dairy Sci* 44, 1484-1493

Huber JT, Natrajan S, Polan CE (1968) Varying levels of starch in calf milk replacers. *J Dairy Sci* 51, 1081-1084

Marshall SP, Smith KL (1970) Effect of kinds of milk and levels of intake upon growth of young dairy calves. *J Dairy Sci* 53, 1622-1626

Mathieu CM, Thivend P (1968) Digestion et utilisation des aliments par le veau préruminant à l'engrais. III. Remplacement des matières grasses du lait par différents amidons. *Ann Biol Anim Biochim Biophys* 8, 249-271

Mathieu CM, Thivend P, Barre PE (1970) Digestion et utilisation des aliments par le veau préruminant à l'engrais. *Ann Biol Anim Biochim Biophys* 10, 253-269

Natrajan S, Polan CE, Chandler PT, Jahn E, Huber JT (1972) Ruminal and post ruminal utilization of starch in the young bovine. *J Dairy Sci* 55, 238-244

Nitsan Z, Volcani R, Hasdai A, Gordin S (1972) Soybean protein substitute for milk protein in milk replacers for suckling calves. *J Dairy Sci* 55, 811-821

Nitsan Z, Carasso Y, Nir I (1985) The use of starch and soybean protein in intensive rearing of veal-type kids. *Ann Zootech* 34, 487-488

Nitsan Z, Golan M, Nir I (1990) The utilization of raw or heat treated starch fed in liquid diet to preruminants. 2. Kids. *Small Rumin Res* (in press)

Noller CH, Ward GM, McGilliard A, Huffman CF, Duncan CW (1956) The effect of age of the calf on the availability of nutrients in vegetable milk replacer rations. *J Dairy Sci* 42, 920

Schoch TJ, Maywald EC (1967) Industrial microscopy of starches. *In: Starch Chemistry and Technology* (Whistler RC, Paschall EF, eds) Academic Press, London

Siddons RC (1968) Carbohydrase activities in the bovine digestive tract. *Biochem J* 108, 839-844

Siddons RC, Smith RH, Henschel MJ, Hill WB, Porter JWG (1969) Carbohydrate utilization in the preruminant calf. *Br J Nutr* 23, 333-341

Theurer CB (1986) Grain processing effects on starch utilization by ruminants. *J Anim Sci* 63, 1649-1662

Thivend P (1978) Utilisation des amidons et des autres glucides d'origine végétale par le veau préruminant. *In: Le Veau de Boucherie*. INRA Publications, Versailles, France, 55-61

Thivend P, Fiona C, Clark S, Orskov ER, Kay RNB (1979) Digestion of partially hydrolysed starch in milk replacers by the young lamb. *Ann Rech Vét* 10, 422-424

Thivend P, Martin-Rosset W (1971) Étude des variations postprandiales de la glycémie mésentérique chez le veau préruminant. *Ann Biol Anim Bioch Biophys* 11, 350-351

Toullec R, Thivend P, Mathieu CM (1973) Production de veaux à l'engrais de poids élevé : Influence du remplacement d'une partie des lipides de l'aliment d'allaitement par des glucides. *Ann Zootech (Paris)* 22, 121-126

Toullec R, Guyon R, Thivend P (1979) Influence du remplacement d'une partie du lait écrémé par des levures d'alcanes et des produits amylaces dans les aliments d'allaitement destinés au veau de boucherie. *Ann Zootech* (Paris) 28, 219-230