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EFFECTS OF CONSUMPTION OF HYDROGENATED SACCHARIDES AND SUCROSE ON THE BLOOD SUGAR CONCENTRATION

by

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INTRODUCTION

The sugar alcohol sorbitol has long been used as a substitute for sucrose and other fermentable sugars in diets for diabetics, since it is known that it is slowly absorbed from the intestine and does not rise the blood sugar level to the same extent as for example sucrose. Sorbitol is slowly fermented by oral microorganisms (*Grubb*, 1945; *Shay*, 1954; *Shockley et al.*, 1956; *Crowley et al.*, 1956), does not cause pH-decreases in the dental plaques in contrast to sucrose (*Fosdick et al.*, 1957; *Frostell*, 1965; *Mühlemann*, 1969) and appears to be less cariogenic in animal experiments than sucrose (*Klapper & Volker*, 1954, 1955; *Shaw & Griffiths*, 1960; *Frostell et al.*, 1967). For these reasons sorbitol is often suggested as a substitute for sucrose in candy.

Sorbitol is a natural constituent of many fruits, for example prunes and rowan berries. It is commercially produced by hydrogenation of D-glucose. It is readily soluble in water, is colourless and has a sweet taste which is about 60 per cent of that of sucrose. It is very hygroscopic.

Sorbitol is slowly absorbed from the intestine and is transformed to fructose in the liver. For these reasons it does not rise blood sugar concentration appreciably. Sorbitol has a laxatory effect if given in does exceeding 30—40 gram per day. Some people are extremely sensitive to sorbitol, however, and experience gastrointestinal symptoms after small doses of sorbitol.

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Lycasin*® or Product 6563 is a new raw product used as a substitute for sucrose and other easily fermentable sugars in candy production. Such candy has been available in Sweden under the name of A-plus and Lov. Lycasin is produced from starch by partial hydrolysis and subsequent hydrogenation at high temperature and pressure. Chromatographic studies have revealed that Lycasin contains sorbitol, maltitol, maltotriitol, maltotetraitol, maltopentaitol, maltohexaitol, and other higher hydrogenated saccharides and dextrins, with a mean molecule weight corresponding to 3—4 saccharide units. It contains less than 10 per cent free sorbitol and over 90 per cent saccharides with one or several glucose units and a sorbitol unit at one end of the chain. On contact with salivary and pancreatic amylase, the higher saccharides are rapidly hydrolyzed into oligosaccharides, which are then further hydrolyzed to glucose by the small-intestinal maltase. The hydrolysis of the smallest sorbitol-containing oligosaccharide (maltitol, which has a molecular size corresponding to a disaccharide) proceeds, however, very slowly (*Dahlqvist & Telenius*, 1965).

Lycasin is readily soluble in water, is colourless and has a sweet taste representing approximately 25 per cent of the sweetness of sucrose. It is rather hygroscopic and must be protected from contact with the air.

Lycasin is manufactured as a sirup or as a spray-dried powder, which may be used as a sugar substitute in candy, beverages, bisquits and bread. If so desired the sweet taste is supplemented by saccharine.

If consumed in large amounts, Lycasin candy may give diarrhéa, due to its content of sorbitol.

When tested by the method of *Frostell* (1965, 1969) Lycasin candy caused no, or only minute, pH-decreases in the dental plaques in contrast to sucrose candy. Sorbitol candy caused pH-increases in these experiments. *Mühlemann* (1969), however, measuring interdental plaque pH found, that Lycasin candy lowered the pH to 5.0 or below but more slowly than sucrose candy.

In animal experiments on hamsters and rats *Frostell et al.* (1967) found that Lycasin was less cariogenic than sucrose, starch, and fermentable sugars.

Lycasin candy is now advertised as a low-cariogenic product. Moreover, in spite of the fact that the present authors have warned against it, Lycasin candy has been widely used by diabetic patients as a »sugar-free» substitute for conventional candy. A widespread opinion among such patients in Sweden seems to be that Lycasin candy is better tolerated than conventional candy. Pilot tests, however, in diabetics and in healthy individuals have indicated that the glucose concentration of the blood rises considerably after Lycasin consumption as well as after consumption of conventional candy.

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The object of the present investigation is to study the effect of intake of large doses of Lycasin and sucrose on the blood sugar concentration of a number of young, healthy volounteers.

MATERIAL AND METHODS

Ten dental students and nurses at the age of 20—30 years and one of the present authors (S.B.) participated as volounteers in the study. They were all healthy and in good condition.

A subject, who was going to participate in an experiment appeared in the laboratory in the morning without having eaten or drunk anything but perhaps tap water since 24°° o'clock the previous day. A blood sample was taken from a finger and 0.05 ml of blood was immediately transferred to the reagent.

The subject was then given 1.0 gram per kg body weight of sucrose or Lycasin to drink, as a 10 per cent solution in water, which was consumed as quickly as possible.

Then after 30, 60, 90 and 120 minutes new blood samples were taken and treated as described.

In some experiments 3—5 ml of blood was drawn from the cubital vein and the serum was used for determination of fructose and sorbitol.

Determination of glucose in blood. In several experiments blood sugar concentration was determined both with a reducing sugar method (*Folin*, 1928, 1929 and 1930) and with glucose oxidase (*Huggett & Nixon* 1957). The determination according to *Folin & Wu* was carried out as described in a manual (ASTRA, 1947). The determinations with glucose oxidase were performed with a commercially available reagent kit (KABI-reagens, 1962)*. Protein precipitation was performed with perchloric acid.

Determination of fructose and sorbitol. One ml of serum was precipitated 1:1 with *Somogyi*'s (1945) zinc sulfatebarium hydroxide reagents. Aliquots of the supernatant were then used for the assay of fructose and sorbitol.

a) *Fructose.* Fructose was assayed with the cystein-sulfuric acid method of *Dische & Borenfreund* (1951).

b) *Sorbitol.* Sorbitol was assayed with the periodate-chromotropic acid reaction of *Corcoran & Page* (1947). Glucose gives a weak reaction (only 2 % of that given by an equal amount of sorbitol), which was corrected for.

Statistical evaluations. The increases in blood sugar concentration at each time interval were calculated (Tables II and III). The mean increase

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in the group was calculated for each time interval and for a comparison between Lycasin (R) and sucrose Student's t-test was applied. An Olivetti Programma computer was used for the calculations.

RESULTS

The glucose values obtained by the glucose-oxidase method usually represented about 75 per cent of the values obtained by the *Folin-Wu* method (Table I).

The error of the glucose-oxidase method was determined at 3.8 per cent (variation coefficient).

The control experiments showed that intake of Lycasin caused insignificant changes in the fructose and sorbitol concentrations of the blood. (Tables II, V and VI.) Consumption of sucrose was followed by a very moderate increase in the fructose concentration of the blood, but not in the sorbitol concentration.

Table I.

Determination of the blood glucose concentration according to two different methods

Sucrose	Folin and Wu	Glucose oxidase	Glucose oxidase/Folin-Wu per cent
Fasting value	80	61	77
» »	78	—	
30 minutes	174	127	72
» »	171	—	
90 minutes	80	56	70
» »	80	—	
150 minutes	80	58	74
» »	77	—	

Lycasin®	Folin and Wu	Glucose oxidase	Glucose oxidase/Folin-Wu per cent
Fasting value	87	69	82
» »	87	73	
60 minutes	144	116	81
» »	143	—	
120 minutes	71	56	76
» »	76	56	

Table II.

Changes in blood fructose and sorbitol concentrations (mg %) after consumption of Lycasin®

Pat.	Fructose 0 mg %	30 min mg %	diff.	Sorbitol 0 mg %	30 min mg %	diff.
T.S.	1.41	0.99	—0.42	4.8	4.7	—0.1
L.L.	1.04	0.84	—0.20	5.1	5.2	0.1
K.S.	0.68	1.01	0.33	4.1	5.2	1.1
S.N.	0.22	1.54	1.32	2.3	2.5	0.2
W.Y.	0.63	0.47	—0.16	3.5	3.8	0.3
E.E.	0.88	3.43	2.55	3.2	2.5	—0.7
L.P.	—	—	—	—	—	—
B.L.	0.62	0.92	0.30	4.2	7.7	3.5
E.S.	0.11	0.24	0.13	3.6	5.4	1.8
S.K.	1.13	0.96	—0.17	8.4	6.1	—2.3
$\bar{X}$	0.75	1.16	0.41	4.4	4.8	0.4

Table III.

Changes in blood glucose concentrations (mg %) after consumption of sucrose

	0 mg %	30 mg %	diff.	60 mg %	diff.	90 mg %	diff	120 mg %	diff.
T.S.	57	109	52	62	5	51	— 6	53	—4
L.L.	51	91	40	50	— 1	36	—15	46	—5
K.S.	52	90	38	40	—12	51	— 1	57	—5
S.N.	56	91	35	62	6	46	—10	50	—6
W.Y.	55	83	28	71	16	71	16	48	—7
E.E.	54	96	42	81	27	68	14	58	4
L.P.	57	98	41	67	10	53	— 4	49	—8
B.L.	67	105	38	102	35	64	— 3	62	—5
E.S.	52	100	48	56	4	47	— 5	46	—6
S.K.	55	95	40	68	13	42	—13	51	—4
$\bar{X}$	56	96	40	66	10	53	— 3	52	—4

In Tables III and IV and in Fig. 1 the results of the comparative experiments on blood glucose with Lycasin and sucrose on 10 subjects are given.

The statistical evaluation (Table VII) showed that there were no statistically significant differences between Lycasin and sucrose after 30 and 60 minutes. After 90 and 120 minutes, however, the blood glucose concentration after Lycasin was higher than after sucrose.

Table IV.

Changes in blood glucose concentrations (mg %) after consumption of Lycasin®

	0 mg %	30 mg %	diff.	60 mg %	diff.	90 mg %	diff.	120 mg %	diff.
T.S.	55	115	60	82	27	57	2	62	7
L.L.	50	83	33	52	2	50	0	57	7
K.S.	52	119	67	68	16	57	5	59	7
S.N.	58	90	32	40	—18	67	9	73	15
W.Y.	53	77	24	61	8	66	13	60	7
E.F.	43	113	70	126	83	95	52	70	27
L.P.	52	81	29	56	4	57	5	44	—8
B.L.	58	99	41	71	13	61	3	59	1
E.S.	51	71	20	64	13	54	3	54	3
S.K.	53	92	39	55	2	66	13	51	—2
$\overline{X}$	53	94	41	68	15	63	10	59	6

Table V.

Blood concentration of fructose before and 30 minutes after consumption of Lycasin®

9 subjects	mg %
0 min	0.75
30 »	1.16
Difference	0.41
t-value	1.29
Level of significance	—

Table VI.

Blood concentration of sorbitol before and 30 minutes after consumption of Lycasin®

9 subjects	mg %
0 min	4.4
30 »	4.8
Difference	0.41
t-value	0.80
Level of significance	—

Table VII.

Comparison between the blood glucose concentrations after consumption of sucrose and Lycasin®. Experiments with 10 subjects

	0	30	60	90	120 min
a) Sucrose					
Glucose		0—30	0—60	0—90	0—120 min.
Difference		40,2	10	—3	—4
t-value		19.3213	2.4127	0.8266	2.5569
Level of significance		***	*	—	*
b) Lycasin					
Glucose		0—30	0—60	0—90	0—120 min.
Difference		41.5	15	10	6
t-value		7.3126	1.7823	2.1775	2.1223
Level of significance		***	—	—	—
c) Sucrose — Lycasin					
Sucrose	56	96	66	53	52
Lycasin	53	94	68	63	59
Difference	3	2	—2	—10	—7
t-value	0.8580	0.3478	0.2128	2.8983	2.5776
Level of significance	—	—	—	*	*

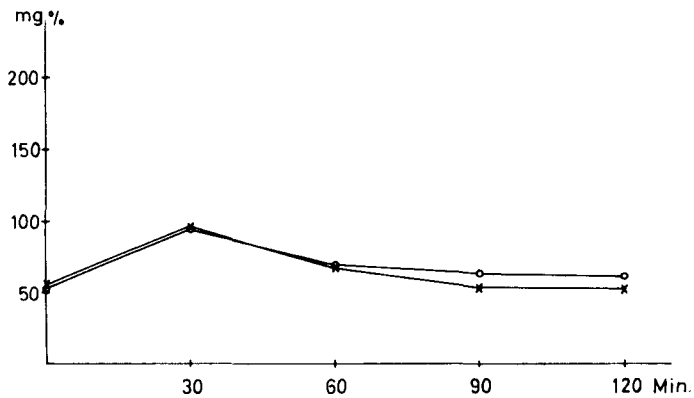

Fig. 1. Changes in blood glucose concentrations after consumption of sucrose (x—x) and Lycasin® (o—o). Means of results with 10 subjects.

DISCUSSION

The glucose oxidase method used in this study is considered to be specific for glucose and thus more representative than the Folin-Wu method. Since a calibration between the two methods was performed previous to the study proper, it is possible to calculate approximately the level of the blood sugar concentrations, which would have been obtained if the older method had been used.

It has been shown that if the precipitation is carried out with zinz sulphate-barium hydroxide instead of perchloric acid, the values will be on an average 14 per cent higher (*Hjelm & de Vordier*, 1963). However, in the present investigation the authors preferred to use the reagents of the standard kit throughout.

The results agree with the concept that sorbitol is absorbed very slowly from the intestine. Neither sorbitol or fructose (which could be formed in the liver by sorbitol dehydrogenase) were found in significant amounts in the serum after Lycasin administration. The increased blood glucose concentration after Lycasin agrees with the previously reported liberation of glucose from Lycasin by the enzymes of the digestive tract (*Dahlqvist & Telenius* 1965).

Also after the administration of sucrose, there was only a very moderate increase in blood fructose concentration. This is probably due to a rapid conversion of fructose to glucose and other metabolites in the liver, since fructose is known to be readily absorbed from the intestine.

Since intake of Lycasin rises the blood glucose concentration in healthy individuals to the same extent as intake of an equal amount of sucrose, it is hard to believe that Lycasin candy should be better tolerated than conventional candy. The present authors have no reasons to believe that the breakdown of Lycasin in the intestine may be different in the diabetics than in the healthy individuals. In a few tests performed on diabetics with Lycasin a rapid increase in blood sugar concentration was found. Thus, the results indicate that also in such patients the intake of Lycasin has approximately the same effect on blood sugar concentration as intake of an equal amount of sucrose.

Since blood concentration experiments were performed only at 30 and 60 minutes after the consumption it is possible that a peak in the blood sugar concentration curves may have been found between 0 and 30 minutes or between 30 and 60 minutes if tests had been made at shorter intervals. Control experiments indicated, however, that the blood sugar was at its maximum between 20 and 40 minutes after consumption. The results are

interpreted so that the differences in blood sugar concentrations after consumption of sucrose and Lycasin are of no practical significance.

SUMMARY

Lycasin®, a hydrogenated starch hydrolysate containing sorbitol and hydrogenated saccharides, has been used as substitute for sucrose candy by diabetics. A few experiments with diabetics and healthy individuals have indicated, that blood glucose concentration increases considerably after Lycasin consumption.

Experiments were carried out with 10 healthy volounteers, who consumed either 1.0 gram of sucrose or Lycasin per kg body weight. The blood sugar concentration was determined at 30, 60, 90 and 120 minutes after the consumption. In some experiments blood fructose and sorbitol concentrations were also determined 30 minutes after consumption of Lycasin or sucrose.

Lycasin and sucrose caused an increase in blood sugar concentration comparable to that obtained after a glucose tolerance test. There were no significant differences between the blood sugar concentrations obtained after Lycasin intake and sucrose intake after 30 and 60 minutes. After 90 and 120 minutes, however, the blood glucose concentration was somewhat higher after Lycasin intake than after sucrose consumption.

The results indicate that intake of Lycasin causes blood sugar changes comparable to those after intake of an equal amount of sucrose.

RÉSUMÉ

EFFETS DE LA CONSOMMATION DE SACCHARIDES HYDROGÉNES ET DE SACCHAROSE SUR LA GLYCÉMIE

Le produit Lycasine, un hydrolysat d'amidon hydrogéné contenant du sorbitol et des saccharides hydrogénés a été utilisé par les diabétiques pour remplacer les confiseries de saccharose. Quelques expériences effectuées avec des sujets diabétiques et des sujets bien portant sont indiqué que la glycémie augmentait considérablement après consommation de Lycasine.

Des expériences ont été pratiquées avec 10 volontaires bien portants qui ont consommé soit le produit Lycasine soit du saccharose, à la dose de 1,0 g/kg de poids. La glycémie a été déterminée au bout de 30, 60, 90 et 120 minutes après l'ingestion. Dans quelques expériences, les teneurs en fructose et en sorbitol ont aussi été déterminées au bout de 30 minutes après ingestion de Lycasine ou de saccharose.

Saccharose et Lycasine causaient une augmentation de la glycémie comparable à celle obtenue après le test de tolérance au glucose. Au bout de 30 minutes et au bout de 60 minutes, il n'existait pas de différence significative entre les glycémies ontenues après ingestion de Lycasine et après ingestion de saccharose. Mais au bout de 90 minutes et au bout de 120 minutes, la glycémie était plus élevée après ingestion de Lycasine qu'après ingestion de saccharose.

Les résultats de cette étude indiquent que la consommation de Lycasine provoque des modifications de la glycémie qui sont comparables à celles provoquées par l'ingestion de la même quantité de saccharose.

ZUSAMMENFASSUNG

EINWIRKUNG VON KONSUMTION VON HYDROGENIERTEN STÄRKEHYDROLYSATEN UND SACCHAROSE AN DER BLUTZUCKERKONZENTRATION

Lycasin®, ein hydrolysiertes Stärkehydrolysat das hydrogenierten Sacchariden und Sorbitol enthält, wird von Diabätikern und gesunde Individuen als Saccharosesubstitut verwendet. Einige orientierende Experimente mit Diabätikern und gesunde Individuen haben erwähnt, dass die Blutglukosekonzentration erheblich gesteigert wird nach Konsumtion von Lycasin.

Experimente wurden mit 10 gesunden Individuen gemacht, die entweder 1.0 Gram von Saccharose oder Lycasin pro Kilogram Körpergewicht konsumierten. Die Blutglukosekonzentration wurde nach 30, 60, 90 und 120 Minuten bestimmt. In einigen Experimente wurden auch Blutfruktose- und Blutsorbitolkonzentrationen 30 Minuten nach Lycasin (R)- oder Saccharosekonsumtion bestimmt.

Lycasin und Saccharose verursachten eine Steigerung der Blutzuckerkonzentration, die mit derjenigen die nach einer Glukosetoleranztest gefunden werden. Keine signifikante Differenzen zwischen Blutzuckerkonzentrationen gefunden nach Konsumtion von Lycasin oder Saccharose wurden beobachtet, aber nach 90 und 120 Minuten war die Blutzuckerkonzentration grösser nach Lycasin (R) konsumtion als nach Saccharosekonsumtion.

Die Resultate zeigen dahin, dass Konsumtion von Lycasin Veränderungen in die Blutzuckerkonzentration verursacht, die mit derjenigen vergleichbar sind, die nach Konsumtion von einer gleichen Menge von Saccharose beobachtet wird.

REFERENCES

Astra: Kliniska laborationsmetoder. Ab. Astra, Södertälje, Sveden.

Corcoran, A. C. & J. H. Page, 1947: Method for the determination of mannitol in plasma and urine. J. Biol. Chem. *170:* 165.

Crowley, M. C., V. Harner, A. S. Bennett, & P. Jay, 1956: Comparative fermentability of sorbitol, glucose and glycerol by common oral microorganisms. J. Am. dent. Ass. *52:* 148.

Dahlqvist, A. & U. Telenius, 1965: The utilization of a presumably low-cariogenic carbohydrate derivative. Acta physiol. scand. *63:* 156.

Dische, Z. & E. Borenfreund, 1951: A new spectrofotometric method for the detection and determination of keto sugars and trioses. J. Biol. Chem. *192:* 583.

Folin, O., 1930: A new blood sugar method. J. Biol. Chem. *77:* 421, 1928; J. Biol. Chem. *81:* 231, 1929; J. Biol. Chem. *86:* 173.

Fosdick, L. S., H. R. Englander, K. C. Hoerman & R. G. Kesel, 1957: A comparison of pH values of in vivo dental plaque after sucrose and sorbitol mouth rinses. J. Am. dent. Ass. *55:* 191.

Frostell, G., 1964: Quantitative determination of the acid production from different carbohydrates in suspensions of dental plaque material. Acta odont. scand. *22:* 457.

Frostell, G., 1965: The shape of the Stephan curve after consumption of some different types of sweets. Part I. Sweets containing sorbitol or Product 6563. Sv. Tandläk.-Förb. Tidn. *57:* 696.

Frostell, G., 1969: Dental plaque pH in relation to intake of carbohydrate products. Acta odont. scand. *27:* 3.

Frostell, G., P. H. Keyes & R. H. Larson, 1967: The effect of various sugars and sugar substitutes on dental caries in hamsters and rats. J. Nutr. *93:* 65.

Grubb, T. C., 1945: Studies on the fermentation of sorbitol by oral microorganisms. J. dent. Res. *24:* 31.

Hjelm & de Verdier, 1963: A methodological study of the enzymatic determination of glucose in blood. Scand. J. Clin. Lab. Invest. *15:* 415.

Huggett, A. St. G. & D. A. Nixon, 1957: Use of glucose oxidase, peroxidase, and o-dianisidine in determination of blood and urine glucose. Lancet *273:* 368.

Klapper, C. E. & J. F. Volker, 1954: The influence of selected sugars on the dental caries susceptibility of desalivated hamsters. J. dent. Res. *33:* 666.

Klapper, C. E. & J. F. Volker, 1955: The effect of powdered whole milk–sorbitol diets on dental caries in desalivated hamsters. J. dent. Res. *34;* 703.

Mühlemann, H. R., 1969: Zuckerfreie, zahnschonende und nicht-kariogene Bonbons und Süssigkeiten. Schweiz. Mschr. Zahnheilk. *79:* 117.

Shaw, J. H. & D. Griffiths, 1960: Partial substitution of hexitols for sucrose and dextrin in caries-producing diets. J. dent. Res. *39:* 377.

Shay, D. E., 1954: The in vivo fermentability of sugars and polyhydric alcohols in carious lesions. J. dent. Res. *33:* 717.

Shockley, T. E., C. I. Randels, & M. C. Dodd, 1956: The fermentation of sorbitol by certain acidogenic oral microorganisms. J. dent. Res. *35:* 233.

Somogyi, M., 1945: Determination of blood sugar. J. Biol. Chem. *160:* 69.

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