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## EFFECTS OF SUCROSE, STARCH AND A HYDROGENATED STARCH DERIVATIVE ON DENTAL CARIES IN THE RAT

by

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### INTRODUCTION

Previous experiments with hamsters and rats (*Frostell, Keyes & Larson, 1967; Frostell, in press*), revealed a great difference in caries scores between groups of animals fed sucrose as compared to those fed a starch or a hydrogenated starch derivative, Product 6563, Lycasin®), diet. The latter product is used for production of candy, and is believed to be of low cariogenicity.

From previous experiments on calculus formation in rats (*Smith et al., 1963*) it was known that animals given different starch diets often developed dental caries. Although starch is generally considered to be only moderately cariogenic, considerable dental destruction by caries was sometimes noted in these experiments.

Unmodified potato starch (raw starch) is known to cause insignificant changes in pH of the dental plaques (*Neff, 1967; Frostell, in press*). It is believed that the reason for this is that the large molecules of starch diffuse only slowly into the dental plaques. It is known that acid production in suspensions of dental plaque material in the presence of raw starch occurs rather fast, to an extent of about 80 per cent of the acid production in the presence of sucrose (*Frostell, 1964*). *Neff* found that cooked starch caused considerably greater pH-decreases in the dental plaques than raw starch, a

finding confirmed by results of an investigation going on at present in this laboratory.

Pregelatinized starch is available as a white powdered product. The pregelatinization process is believed to break up the starch and to straighten out the twisted amylose molecule chains making them more available to amylase enzymes and more easily fermentable and digestible. Neither raw starch nor pregelatinized starch contain low-molecular saccharides as revealed by chromatographic studies in this and other laboratories.

In the present study a comparison was made between the caries promoting capacities of sucrose, unmodified potato starch, pregelatinized potato starch and a hydrogenated potato starch derivative (Product 6563, Lycasin®).

#### MATERIAL AND METHODS

Female weanling Sprague-Dawley rats were used in these experiments. The animals were 25 to 30 days of age when the experiment began. They were housed in wire bottomed cages, one or two per cage, and received distilled drinking water, *ad libitum*. They were weighed once a week. Seven groups of weanling female Sprague-Dawley rats were fed powdered diets containing 32 per cent skim milk, 2 per cent liver powder and 66 per cent test carbohydrate. The following carbohydrates were given to 4 groups for 30 days: sucrose, pregelatinized potato starch, a hydrogenated potato starch derivative supplemented with 0.5 per cent calcium carbonate. Three groups were given the following diets for 60 days: sucrose, unmodified potato starch and pregelatinized potato starch (Table I).

At the end of the experimental period the animals were weighed, killed by ether anesthesia and decapitated. The jaws were defleshed by the use of dermestid beetles (*Hall & Russel*, 1933). They were bleached with 30 per cent  $H_2O_2$  and dried with acetone. Caries was scored according to *Keyes* (1958).

#### RESULTS

Results are given in Table I. All animals kept on the diet containing the hydrogenated starch derivative developed diarrhoea.

Three animals out of 26, which were fed the hydrogenated potato starch derivative for 30 days, developed sulcal caries only.

Table I. *Number of carious enamel areas in the dietary groups*

| Carbohydrate group                               | No. of<br>ani-<br>mals | Days | CT   | Bucco-<br>lingual<br>E | Mor-<br>sal | Sul-<br>cal<br>E | Proxi-<br>mal<br>E | Total<br>no of<br>carious<br>areas | Per<br>cent<br>vs<br>control |
|--------------------------------------------------|------------------------|------|------|------------------------|-------------|------------------|--------------------|------------------------------------|------------------------------|
| Sucrose                                          | 20                     | 30   | 5.2  | 8.6                    | 0.2         | 3.2              | 2.6                | 14.6                               | 100                          |
|                                                  | 19                     | 60   | 10.5 | 34.3                   | 0.6         | 13.7             | 11.9               | 60.6                               | 100                          |
| Pregelatinized potato<br>starch                  | 12                     | 30   | 7.8  | 22.4                   | 2.0         | 8.1              | 1.8                | 34.3                               | 235                          |
|                                                  | 23                     | 60   | 9.5  | 13.2                   | 3.8         | 13.7             | 2.2                | 32.9                               | 54.3                         |
| Unmodified potato<br>starch                      | 22                     | 60   | 6.4  | 6.6                    | 0.2         | 9.6              | 1.2                | 17.6                               | 29                           |
| Hydrogenated saccha-<br>rides                    | 26                     | 30   | 0.2  | —                      | —           | 0.3              | —                  | 0.3                                | 2.1                          |
| Hydrogenated saccha-<br>rides, CaCO <sub>3</sub> | 42                     | 30   | 0.8  | —                      | —           | 1.0              | —                  | 1.0                                | 6.9                          |

CT = carious teeth per animal

E = number of enamel areas

Six animals out of 42, which were given the hydrogenated potato starch diet with a 0.5 per cent calcium carbonate additive for 30 days, developed sulcal caries. The animals, however, were not in good physical condition, and the experiment was not extended beyond 30 days.

Seventeen animals out of 22 receiving the unmodified potato starch diet for 60 days developed caries. All animals had sulcal and bucco-lingual caries and seven animals also had proximal caries.

All animals, which were on the pregelatinized potato starch diet for 30 days (12), developed caries. All had sulcal and bucco-lingual caries. Nine animals also had proximal cavities.

All animals (23) that were on the pregelatinized potato starch diet for 60 days developed caries, which often penetrated into the dentine. All animals, except one, had sulcal and bucco-lingual caries in many teeth. That one animal developed bucco-lingual caries. Sixteen animals also had proximal caries.

All animals given the sucrose diet for either 30 or 60 days developed severe dental caries of all types. Deep lesions penetrating the dentine were found in great numbers in animals which had been on the diet for 60 days.

## DISCUSSION

Previous results with sucrose, unmodified starch, and the hydrogenated starch derivative were confirmed in this study. In spite of the fact that the pregelatinized starch did not contain glucose, maltose or other low-molecular saccharides, it was considerably more caries-inducing than the unmodified starch diet. The results indicate that even a comparatively mild processing of the starch increases its caries-inducing properties.

Only sulcal lesions were found in the animals which were fed the diets containing the hydrogenated starch derivative. These lesions were confined to the enamel and no softening of the underlying dentine was observed. If the animals had been on the diets for periods of longer than 30 days, other lesions would probably have developed.

Since all the diets contained skim milk powder, which contains lactose fermentable by dental plaque material, it cannot be ruled out that this sugar did not to some extent contribute to the development of dental caries in these experiments. The hydrogenated starch derivative diet was not conducive to smooth surface caries but sulcal caries was found in 10 animals out of 58.

Accurate records were not kept of the animals eating patterns and food consumption. However, since some groups of animals gained weight somewhat more slowly than others, the results may to some extent depend on differences in eating habits and food consumption and not only on differences in the caries-inducing properties of the diets. However, the almost complete absence of soft deposits on the teeth and the excellent status of the alveolar bone gave the impression that the diets containing the hydrogenated starch derivative were not conducive to formation of dental plaque.

The addition of calcium carbonate was reported by *Gustafson, Stelling & Brunius* (1964) to reduce dental caries in animals or humans living on an otherwise calcium deficient diet. In these experiments calcium carbonate did not exert such an effect. Since all the diets used in these experiments contained 32 per cent skim milk, they were certainly not deficient in calcium, however.

In the previous rat experiments (*Frostell, Keyes & Larson*, 1967) the animals were infected with fecal flora taken from animals with rampant dental caries. In these experiments the animals were not infected in this way. In spite of this, dental caries developed in approximately the same way and to the same extent as in previous experiments. However, a group on pregelatinized starch for 30 days surprisingly developed much caries which may be due to the presence of an unusual bacterial flora.

## SUMMARY

Seven groups of weanling female Sprague-Dawley rats were given powdered diets containing 32 per cent skim milk, 2 per cent liver powder and 66 per cent test carbohydrate. The following carbohydrates were given to 4 groups for 30 days: sucrose, pregelatinized potato starch, a hydrogenated potato starch derivative and the same derivative supplemented with 0.5 per cent calcium carbonate. Three groups were given the following diets for 60 days: sucrose, unmodified potato starch and pregelatinized potato starch.

At the end of the experimental period the animals were sacrificed and dental caries were scored.

The caries scores of the groups decreased in the following order: sucrose, pregelatinized potato starch, unmodified potato starch, hydrogenated potato starch derivative.

Animals on the sucrose diet developed rampant dental caries on smooth surfaces and in the sulci. Unmodified potato starch and pregelatinized potato starch also induced smooth surface caries and sulcal caries, which penetrated the enamel and softened the dentine, but considerably less than the sucrose diet. The hydrogenated potato starch derivative, which was given for 30 days only, was not conducive to smooth surface caries but sulcal caries confined to the enamel was found in 10 animals out of 58.

It was concluded that both unmodified and pregelatinized starch may be caries-inducing, that pregelatinization increased the cariogenicity of starch, and that hydrogenation of a starch hydrolysate considerably reduced its caries-inducing properties.

## RÉSUMÉ

## ACTION DU SACCHAROSE, DE LA FÉCULE ET D'UN PRODUIT DÉRIVÉ DE LA FÉCULE HYDROGÉNÉ

Des régimes en poudre administrés à 7 groupes de femelles de rats Sprague-Dawley venant d'être sevrées contenaient 32 % de lait écrémé, 2 % de poudre de foie et 66 % d'hydrate de carbone expérimental. Les hydrates de carbone suivants ont été donnés pendant 30 jours à 4 groupes: saccharose, fécula de pomme de terre pré-gélatinisée, un produit dérivé de la fécula de pomme de terre hydrogéné et le même produit additionné de 0,5 % de carbonate de calcium. Trois groupes ont reçu pendant 60 jours les régimes suivants: saccharose, fécula de pomme de terre non modifiée et fécula de pomme de terre pré-gélatinisée.

A la fin de la période expérimentale, les animaux ont été sacrifiés et les caries dentaires ont été enregistrées.

Les taux de carie allaient en diminuant dans l'ordre suivant: saccharose, féculé prégélatinisée, féculé de pomme de terre non modifiée, produit dérivé de la féculé hydrogéné.

Les animaux recevant le régime contenant du saccharose présentaient une polycarie évolutive sur les faces lisses et dans les sillons. La féculé de pomme de terre non modifiée et la féculé prégélatinisée provoquaient aussi l'apparition de caries des faces lisses et des sillons, pénétrant l'émail et ramollissant la dentine, mais nettement moins que le régime au saccharose. Le produit dérivé de la féculé de pomme de terre hydrogéné, administré pendant 30 jours seulement, ne provoquait pas de caries des faces lisses, mais des caries des sillons limitées à l'émail ont été trouvées chez 10 des 58 animaux.

En conclusion, la féculé non modifiée et la féculé prégélatinisée peuvent provoquer la carie; la prégélatinisation augmentait le pouvoir cariogène de la féculé, et l'hydrogénation d'un hydrolysate de féculé diminuait considérablement son pouvoir cariogène.

#### ZUSAMMENFASSUNG

##### EINWIRKUNG VON SACCHAROSE, STÄRKE UND EIN HYDROGENISIERTES STÄRKE- DERIVAT AUF DER KARIESBEFALL IN DER RATTE

Sieben Gruppen, zusammengesetzt aus eben abgewöhnter weiblicher Sprague-Dawley Ratten, wurden verschiedene pulverisierte Diäte gegeben, die 32 Prozent Magermilch, 2 Prozent Leberpulver und 66 Prozent Testkohlenhydrat enthielten.

Während 30 Tagen erhielten 4 Gruppen folgende Kohlenhydrate: Saccharose, pregelatinisierte Kartoffelstärke, ein hydrogenisiertes Kartoffelstärkederivat und dasselbe Derivat mit 0,5 Prozent Kalziumkarbonat supplementiert. Drei Gruppen bekamen 60 Tage lang folgende Diäte: Saccharose, nichtmodifizierte Kartoffelstärke und pregelatinisierte Kartoffelstärke.

Nach abgeschlossener Experimentperiode wurden die Tiere getötet und der Kariesbefall wurde bestimmt.

Der Kariesbefall nahm in folgender Ordnung ab: Saccharose, pregelatinisierte Kartoffelstärke, nichtmodifizierte Kartoffelstärke, hydrogenisiertes Kartoffelstärkederivat.

Tiere, die Saccharosediat erhielten, entwickelten hochaktive Karies an glatten Flächen und in den Sulci. Nichtmodifizierte Stärke und pregelatinisierte Stärke induzierten auch Glatflächenkaries und Karies in den Sulci,

aber sehr viel weniger als die Saccharose. Das hydrogenisierte Kartoffelstärkederivat, welches den Ratten nur während 30 Tagen gegeben wurde, war nicht glattflächenkariesinduzierend, erzeugte aber Emaillekaries bei 10 von insgesamt 58 Tieren in den Sulci.

Folgende Schlussfolgerung wurde gezogen: nichtmodifizierte Stärke und pregelatinisierte Stärke können Karies induzieren, Pregelatinisierung steigert die Kariogenität der Stärke und durch Hydrogenisierung eines Stärkehydrolysates wird die Kariogenität wesentlich reduziert.

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