

Dental Caries in the Cotton Rat IX. Effect of Milk Rations*

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Investigations in this laboratory on the experimental production of dental caries in the cotton rat showed that the molars of this animal were highly susceptible to decay when the rat was fed a dry ration high in fermentable sugar.^{1,2} In contrast to this, animals fed on a diet consisting of liquid whole milk were found to be completely free of caries.³ The consumption of a dry ration approximating milk solids in composition resulted in a low incidence and extent of carious lesions, although protection was not complete, as it was in the case of the liquid milk. The protection afforded by milk is as great as, or greater than, that found with any other ration, and further study of this effect therefore seemed important. Two approaches were made: (1) fermentable sugars known to be highly cariogenic when fed as the carbohydrate portion of dry rations were added to the liquid milk diet; and (2) supplements of milk were given to animals being fed the cariogenic control ration.

Experimental. The cotton rats used in these experiments were raised in our own stock colony and placed on experiment at weaning (20-25 g). Animals from each

litter were distributed as equally as possible among the control and experimental groups, since susceptibility to dental caries has been found to vary among different litters.⁴ The animals were kept on experiment for 14 weeks, during which time their weights were recorded at bi-weekly intervals. At the end of the experimental period, the animals were killed, and the incidence and extent of carious lesions in each animal were evaluated by the method of Shaw and his associates.^{1,5}

The control animals were fed a sucrose ration (802) previously found to be highly cariogenic.[†] The liquid whole milk ration was fortified with minerals (iron, copper and manganese) and with 1:20 liver extract as described by Schweigert and co-workers.³ The carbohydrate (sucrose, glucose or dextri-maltose) was added to the milk at a 5% or 10% level. This, together with liver extract, was homogenized into the milk in a Waring blender. These diets were fed *ad libitum*. In one group milk was fed in addition to the 802 ration. In this case the milk was fed *ad libitum*, but the intake of ration 802 was limited to 63% of that of the controls (802 ration only) in order to induce greater consumption of the milk. The milk consumed constituted roughly one-third of

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¹ Shaw, J. H., Schweigert, B. S., McIntire, J. M., Elvehjem, C. A., and Phillips, P. H., *J. Nutr.*, 1944, **28**, 333.

² Schweigert, B. S., Shaw, J. H., Phillips, P. H., and Elvehjem, C. A., *J. Nutr.*, 1945, **29**, 405.

³ Schweigert, B. S., Shaw, J. H., Zepplin, M., and Elvehjem, C. A., *J. Nutr.*, 1946, **31**, 439.

⁴ Schweigert, B. S., Shaw, J. H., Elvehjem, C. A., and Phillips, P. H., *Proc. Soc. Exp. Biol. and Med.*, 1945, **59**, 44.

⁵ Shaw, J. H., Schweigert, B. S., Elvehjem, C. A., and Phillips, P. H., *J. Dent. Res.*, 1944, **23**, 417.

[†] This ration consisted of 67% sucrose, 24% casein, 5% corn oil and 4% salts IV. Four per cent of 1:20 liver extract was added at the expense of the entire ration. Adequate quantities of the B vitamins⁶ were added to the ration, and each rat received one drop of halibut liver oil per week.

⁶ McIntire, J. M., Schweigert, B. S., and Elvehjem, C. A., *J. Nutr.*, 1944, **27**, 1.

TABLE I.
Effect of Various Milk Rations on Growth Rate and on Incidence and Extent of Carious Lesions in the Cotton Rat.

Ration	No. of pairs	Avg weekly gain		Avg incidence	Avg extent
		6 wks	14 wks		
802* milk	15	10.1 7.3	7.2 5.3	29 0	75+ 0†
802 milk + 5% sucrose	3	8.4 6.6	5.5 4.8	30 0	76+ 0
802* milk + 10% sucrose	11	9.5 7.4	6.5 5.5	32 4	82+ 7+
802 milk + 5% dextrimaltose	3	11.6 10.3	7.8 7.2	34 1	109+ 1+
802 milk + 10% dextrimaltose	7	11.1 8.5	8.0 7.4	24 0	50+ 0
802* milk + 10% glucose	13	9.0 7.3	6.7 5.8	27 6	68+ 10+
802 802 + milk	9	9.5 6.7	7.8 7.7	31 14	78+ 25+

* These groups included one animal which died and was evaluated at 12 weeks instead of at 14 weeks.

† One of these 15 animals had a 1 — 1+ lesion.

the daily caloric intake of the animals in this group.

Results. In Table I the data from the animals on each experimental ration are compared with those from their respective litter-mate controls. The control and experimental animals from each litter were paired so that averages represented equal numbers of animals.

Growth rates were calculated as average weekly gain for the first 6 weeks and for the total 14 weeks on experiment. Since the two sexes have been found to grow at different rates, all figures were calculated as growth of males in order to make them comparable. This was formerly done by increasing the values for the females by 25%;² but analysis of a larger volume of data now at our disposal has shown that more accurate factors are 20% at 6 weeks and 15% for the total 14 weeks. Accordingly, the gains of females were increased by these percentages for the respective periods. From the data it is evident that the animals fed on milk alone grew less than those receiving the control ration (802). Growth was somewhat better when supplemental carbohydrates were added to

the milk, although it was still below that of the control animals. The animals fed ration 802 plus milk grew slowly during the first weeks of the experiment, but the average weekly gain for the total 14 weeks was very nearly the same as that for the controls receiving only the dry ration.

Table I also gives the data on incidence and extent of carious lesions. The comparison of average scores for the experimental animals with those for litter-mate controls receiving the cariogenic ration (802) indicates the degree of protection afforded by each ration. The scores of animals on the milk diets were low in comparison with the high incidence and extent of lesions found in animals fed the control ration. In agreement with previous findings, animals fed only liquid milk were free of caries (except one animal, which developed a small lesion—1+). The caries indices of animals receiving milk with added carbohydrate varied considerably, ranging from zero to less than one-fourth the average for litter-mate controls. In the case of the animals fed milk plus ration 802, the milk appears to have reduced the caries scores by more than 50%, the

averages being 14 and 25+ for the experimental animals as compared with 31 and 78+ for the controls. Thus, the replacement of approximately one-third of the caloric intake by liquid milk resulted in a lowered caries score.

Discussion. From these data it appears that a diet of liquid whole milk is protective against dental caries in the cotton rat. Even in the presence of fairly high levels of fermentable sugars, it exerts a protective action. The protection is less, but evident, when a cariogenic dry ration is fed in addition to the milk. Since it is probable that such protection is the result of a combination of factors, it is difficult to speculate on the mechanism involved.

On a percentage basis the composition of these milk diets, even with the carbohydrate additions, resembles that of a "medium fat" ration used in earlier experiments.^{3,7} In previous work all dry rations with this medium fat level have given partial protection against caries, although scores have not usually been as low as they were on these milk diets.

The kind of carbohydrate may also have been important. The carbohydrate portion of these diets was at least partially lactose, which appears from our preliminary evidence to be somewhat less cariogenic than the more fermentable sugars. The effects of the various fermentable sugars, however, seem to be similar. The caries scores on the milk plus carbohydrate rations showed considerable variation; there appeared to be no consistent trend, and overlapping of individual scores occurred. In dry rations of the medium fat level, these same sugars—sucrose, glucose and dextri-maltose—showed no significant differences in caries production.⁷

The differences in caries scores between the rats fed only a liquid diet and those receiving dry ration in addition suggests that the physical state of the ration may play a considerable role in the protective action. In the liquid diets carbohydrates were consumed

in the dissolved state, and it is possible to attribute the protection exhibited to a lack of mastication or to the fact that the carbohydrates probably remained in the mouth for a comparatively short time. The lower growth rates of the animals on the liquid diets, as compared with their controls, indicate that a difference in caloric intake may also have been a contributing factor.

In this connection it is interesting to note the possible effect of the condition of the fat, which exists in relatively free form in liquid milk. Rosebury and Karshan⁸ found that free oil or fat in the diet was effective in reducing the caries index in white rats. They postulated that lipids may form a mechanical coating on the tooth surface or on the particles of food, thus protecting against bacterial action, an idea also suggested by McCollum.⁹

As yet, inadequate investigation has been made of the effect of milk on the growth and activity of microorganisms associated with dental decay, and an inhibitory effect through this channel might be possible. Other conditions of the oral environment, such as pH, might also play a role. Further studies are in progress.

Summary. Data on growth and caries indices of cotton rats fed various milk rations were secured from these experiments.

The data indicate that milk is protective against dental caries in the cotton rat. Previous findings of zero scores in animals fed only liquid milk were confirmed. Animals receiving milk to which sucrose, glucose or dextri-maltose had been added exhibited low caries scores as compared with controls on a cariogenic dry ration. These sugars will produce caries when fed in dry rations. The caries indices of animals receiving approximately one-third of their caloric intake as liquid milk and the remainder as the cariogenic ration 802 were less by 50% than those of litter-mate controls not receiving milk.

⁸ Rosebury, T., and Karshan, M., *J. Dent. Res.*, 1939, **18**, 189.

⁷ Schweigert, B. S., Potts, E., Shaw, J. H., Zepplin, M., and Phillips, P. H., *J. Nutr.*, 1946, **32**, 405.

⁹ McCollum, E. V., Orent-Keiles, E., and Day, H. G., *The Newer Knowledge of Nutrition*, 5th ed., Macmillan, New York, 1939.