

ENAMEL EROSIIVE PROPERTIES OF FRUITS AND FRUIT JUICES¹

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INTRODUCTION

A number of investigators (McClure, '43; Gortner, Restarski, Bieri and McCay, '45; Bieri, McCay, Restarski and Gortner, '46; and Wynn and Haldi, '48) have shown that acid beverages, natural or synthetic, when fed to rats cause destruction of the lingual enamel of the molar teeth. No one seems to have tested the reaction to acid fruits themselves, nor compared their enamel erosive properties with those of the juices made from them.

We had assumed that acid fruits have an effect similar to that of the juices, but this appears not to be true. The present paper presents data on the enamel erosive properties of 5 fruits and the juices made from them.

PROCEDURE

Animals and their teeth

Young female albino rats from our colony were weaned at three weeks of age, placed in separate cages, and continued on the stock diet until they weighed approximately 155 gm at 7 to 8 weeks of age. (All males were used for vitamin A assay.) Free access to food and water was permitted when the supplements were fed. In a few cases, if the full supplement was not readily taken, the food cup or the water was

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removed from the cage for a part of the day or for overnight.

Insofar as possible, matched litter mates were used for testing the fruits and the juices prepared from them. All supplements were fed for 5 days (Monday to Friday) and on the 6th day the rats were killed. One rat out of 10 was used as a control.

The jaws and teeth were removed, prepared and examined by the method recommended by Restarski, Gortner and McCay ('45) with some modifications. The heads of the rats were placed in individual beakers with the mouth upward and, to stain the teeth, 0.5 ml of 0.125% alizarin red in a 20 to 25% alcoholic solution was placed in each mouth before autoclaving. The stain aids greatly in differentiating the degree of etching. The first evidence of any effect upon the teeth is that the enamel takes the stain, whereas the enamel of the teeth of controls and of those animals given certain supplements show little or no stain.

Only the molars of the mandible were scored because, in comparison, the upper molars were very slightly affected. With a supplementation period of 5 days no rats presented the most severe destruction, which Restarski et al. ('45) rate as 6. As in the report by Wynn and Haldi ('48), high polish of lingual enamel, slight etching, mild destruction, moderate destruction and severe destruction were graded, respectively, 1, 2, 3, 4 and 5.

Since only one person examined the teeth, to obtain completely objective scores an assistant handed the teeth to the author who, without knowing the supplement fed, announced the score, which was recorded by the assistant. The teeth were rechecked on a different day and if there was lack of agreement with the previous scores, they were scored a third time.

Fruits and fruit juices

Preparation. Some fruits and juices were fed in the fresh state, others were cooked. Grapefruit were peeled and the

membranes removed from each section. One-half of each fruit, divided from stem to blossom end, was used for fresh fruit and the other for juice, which was made by squeezing a known weight of fruit through two thicknesses of cheese-cloth.

The outer heavy rind of guavas, here referred to as the "shells," was used both in the raw and cooked states. The guavas were cut in half and the seedy portion removed and treated separately. One-half of each shell was used for the composite raw sample, the other half for juice. The halves used for juice were sliced and weighed, a known weight of water was added and, after being cooked for 15 minutes, they were strained in a jelly bag. After ceasing to drip the bag was squeezed gently to remove the maximum quantity of juice, which was weighed, measured and stored in a refrigerator until used.

For cooked guavas the finely chopped shells were placed in a beaker, covered and heated in a pressure cooker for 5 minutes at 15 lb. pressure.

The seedy portion from each guava was divided into two lots. One composite was put through a strainer to make fresh, uncooked puree; the other was used to prepare the cooked juice in a manner similar to that used in obtaining the "juice" from the shells.

Java plums (*Eugenia cumini*) from the same picking were divided into two equal lots. The flesh was cut from the seeds and fed as fresh fruit. After being weighed the corresponding lot was covered with water, cooked until tender, and strained as were the guavas. Seeds were recovered and weighed so that the amount of juice equivalent to the edible portion could be calculated.

The half-ripe mangoes were peeled and the edible portion fed raw without sugar. The rats ate the half-ripe mango with the same gusto as do children in Hawaii. Green or half-ripe mangoes contain starch and when they are cooked with water they form a thick colloidal mass from which it would be extremely difficult to get any juice. Therefore, a known weight

of half-ripe mangoes was cut in small pieces, water was added and the resulting material mixed for about one minute in a Waring Blendor, strained in a cloth and the resulting "juice" measured.

Only fresh, high quality pineapple of the Smooth Cayenne variety was used. The opposite quarters of each fruit were cut in chunks, weighed and squeezed to produce a measured amount of juice. The remaining two quarters were chopped and fed as fresh fruit.

Ten to 15% of sugar was added to most of the fruits and juices to induce the rats to eat them more readily. The raw half-ripe mangoes were fed without added sugar and the mango juice with 5% sugar. The weight of the fruits and volume of juices given in the table are for the mixture of fruit and sugar as fed. For example, 20 gm guava shells (table 1) means 17 gm of edible guava plus 3 gm of sugar. To the amount of juice calculated to be equivalent to 17 gm of fresh guava, 15% of sugar was added.

Glass drinking tubes having a J shape were used for the fruit juices, and special supplement cups for the fruits.

pH and titratable acidity of fruits and juices. The methods used were essentially those recommended by the A. O. A. C. ('45). The determinations of pH and titratable acidity were made on the products containing sugar as fed.

Fruits. Fifteen grams were weighed in a 250-ml beaker. The pH was read on the industrial model Beckman pH meter. With the exception of pineapple, the mixtures were stirred in a Waring Blendor, distilled water added to make a total volume of 150 ml, and the whole titrated to pH 8.1 with approximately 0.1 N NaOH. The results were converted to exactly 0.1 N NaOH and the amount of 0.1 N acid per 100 gm of fruit was calculated.

Juices. Fifteen milliliters were pipetted into a 250-ml beaker, the pH read and the volume made up to 150 ml with distilled water. The mixture was titrated to pH 8.1 and the milliliters of 0.1 N acid per 100 ml of juice were calculated.

RESULTS AND DISCUSSION

Data pertinent to the experiments are summarized in table 1.

There are practically no differences between the pH values for the fruits themselves and for their juices.

The titratable acidities of the expressed grapefruit and pineapple juices are markedly higher than those of the fruits. The acidity for the pineapple probably would have been somewhat higher if the fruit had been more thoroughly mixed with the distilled water in the Waring Blendor. The Java plum juice has a titratable acidity only slightly higher than that of the fruit, and the cooked guava juice a lower titratable acidity than the raw or cooked fruit.

Through an oversight the pH and titratable acidity of the half-ripe mangoes fed were not determined. Later two other lots of mangoes, one green and one half-ripe, showed the pHs of the fruit and the juice to be similar, but the titratable acidities for the mangoes were greater than were those for the juices. For green mangoes the figures for fruit and juice, respectively, were 124 and 91 and for half-ripe mangoes 97 and 50. As with guavas, the titratable acidity of the fruit is greater than that of the juice.

The pulp from the seedy portion of guavas and the juice made from it always have a greater acidity than the guava shells and their juice. However, the difference is not always as great as might be judged from the figures in table 1. This pulp and its juice were made from guavas obtained later in the season than the shells which were first fed. The pH and titratable acidity were determined for shells and juice of the same guavas which were used for pulp. The pH of both shells and juice was 3.8; the titratable acidities were 243 for shells and 129 for juice.

The scores for the controls given stock diet and water were zero. It may be noted (table 1) that the average molar scores for all the sweetened fruits fed at a level of 20 gm per day for 5 days, except grapefruit, were 0.7 or less. This usually

TABLE 1
In vivo decalcifying effect of acid fruits and fruit juices on lower molar teeth of rats

| FRUIT OR JUICE | PH | TITRATABLE ACIDITY | NO. OF RATS | DAILY SUPPLEMENT | | AVERAGE MOLAR SCORES | |
|---|-----|--------------------|-------------|------------------|-------|----------------------|--------------|
| | | | | Fruit | Juice | Fruit | Fruit juices |
| | | ml | | gm | ml | | |
| Controls (no supplements) | | | 12 | | | 0 | |
| Grapefruit | 3.9 | 197 | 6 | 20 | | 2.0 | |
| Grapefruit Juice ⇄ 20 gm fruit | 3.8 | 228 | 6 | | 13 | | 4.6 |
| Grapefruit Juice ⇄ 10 gm fruit | 3.8 | 250 | 5 | | 6.5 | | 3.5 |
| Guava shells, raw | 4.1 | 167 | 9 | 20 | | 0.7 | |
| Guava shells, cooked | 3.9 | 252 | 5 | 20 | | 0.1 | |
| Guava shells Juice ⇄ 20 gm fruit | 4.2 | 110 | 6 | | 21 | | 4.6 |
| Guava shells Juice ⇄ 10 gm fruit | 4.2 | 118 | 5 | | 10.5 | | 3.9 |
| Guava shells Juice diluted ⇄ 10 gm fruit (10.5 ml guava juice + 9.5 ml water) | 4.2 | 61 | 5 | | 20 | | 4.3 |
| Guava pulp, raw | 3.6 | 309 | 5 | 17 | | 0.6 | |
| Guava pulp Juice ⇄ 8.5 gm pulp | 3.6 | 215 | 5 | | 15 | | 4.0 |
| Java plum | 3.9 | 184 | 5 | 20 | | 0.4 | |
| Java plum Juice ⇄ 13.3 gm fruit | 4.0 | 204 | 5 | | 12.5 | | 4.8 |
| Java plum Juice ⇄ 10 gm fruit | 3.6 | 206 | 5 | | 9.5 | | 4.1 |
| Mango (half ripe), raw | | | 5 | 20 | | 0.2 | |
| Mango Juice ⇄ 20 gm fruit | 4.2 | 146 | 5 | | 20 | | 3.2 |
| Mango sauce, cooked (from green and half-ripe mangoes) | 4.5 | 72 | 5 | 20 | | 0.6 | |
| Pineapple | 4.0 | 96 | 8 | 20 | | 0.09 | |
| Pineapple Juice ⇄ 20 gm fruit | 4.0 | 180 | 6 | | 11 | | 2.7 |

meant that out of 5 rats, two or three showed no etching of the molars and two or three showed some slight effect—often on only one side of the mandible, sometimes on only one or two of the teeth.

It was impossible to prepare grapefruit without a juicy exudate which the rats consumed along with the fruit itself. The consumption of the juice may have accounted for the higher molar score of grapefruit.

Average molar scores of 4.6, 4.6, and 4.8 for the grapefruit juice, guava juice, and Java plum juice, respectively, indicate severe destruction of lingual enamel in comparison with the slight effect of the fruits themselves.

It may also be noted that even when the rats were given juice supplements equivalent to half the quantity of fruit fed, the scores for grapefruit, guava and Java plum juices were 3.5 to 4.1. Even when guava juice equivalent to half the fruit supplement was diluted by half with water, the molar score was high (4.3).

Like the guava shells, the pulp gave a low average molar score (0.6), whereas juice equivalent to half the weight of the pulp gave a high average score (4.0), just as did the juice made from the shells.

The enamel erosive properties of pineapple and pineapple juice appear to be definitely less than those of the other fruits and juices tested. Gortner et al. ('46) have shown that small amounts of oxalate in an acid beverage tend to protect the tooth enamel, but Clark ('39) found the quantity of oxalate in pineapple to be extremely small. It may nevertheless have some protective effect.

As yet we have no satisfactory explanation for some of the results shown in table 1. Muller and Gortner ('49) state that "The degree to which acid solutions attack the teeth is a function of the titratable acidity of the solutions." If that is true, why do 20 ml of diluted guava juice with a pH of 4.2 but a titratable acidity of only 61 have almost as great an enamel erosive effect as an equal amount of undiluted guava juice with the same pH but a titratable acidity of 110?

To determine if some heat labile substance in the fresh fruit might be the protective factor, guava shells prepared as for feeding were heated as described above and then fed. As may be seen in table 1, the cooked guava shells gave an average molar score slightly lower than that obtained with raw ones.

Why fruits and fruit juices affect the molar teeth of rats differently remains to be determined. Some possible explanations may be: (1) the greater buffer action of the fruits themselves; (2) some principle which the fruits contain but the juices do not; (3) some constituent formed in the juice when it is expressed from the fruit; (4) a difference in the physical contact with the teeth when the two are consumed; or (5) some combination of these factors. That a marked difference exists is clearly demonstrated by the data presented.

Preliminary experiments with Boysenberries and juice and with tamarind and juice indicate results similar to those detailed in this paper. It seems safe, therefore, to postulate that acid fruits themselves may have little or no enamel erosive effects, whereas the juices made from them are certain to have this effect in varying degree.

SUMMARY AND CONCLUSIONS

1. Five tropical and semi-tropical fruits — namely grapefruit, guava, Java plum, mango, and pineapple — and juices prepared from them have been fed to standard rats to determine their enamel erosive properties.

2. The pH and titratable acidity were determined for each lot of sweetened fruit and fruit juice used.

3. Quantities of juice equivalent to the daily fruit supplement had three to 10 times the enamel erosive properties of the fruits themselves.

4. No adequate explanation for the different effect of fruit and fruit juice can be offered at the present time, but it appears not to be related to the titratable acidity of the two.

5. Data given for 5 fruits of widely different species and preliminary experiments with two other fruits appear to jus-

tify the postulate that acid fruits generally have a slight enamel erosive effect, in contrast to the marked effect of the juices made from them.

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