Oral digestion of a complex-carbohydrate cereal: effects of stress and relaxation on physiological and salivary measures1-2

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ABSTRACT A comprehensive study was undertaken with 12 dental hygiene students to ascertain whether the time of chewing or the degree of relaxation is more important in the oral digestion of complex carbohydrates. In addition, we studied whether the effects of stress and relaxation on salivary α-amylase activity was corroborated by physiologic measures. The dental hygiene students chewed an oat cereal for either 20 or 60 s while under two different orders of stress and relaxation conditions: 1) stress/20 s, stress/60 s, relax/20 s, relax/60 s; and 2) relax/20 s, relax/60 s, stress/20 s, stress/60 s. Galvanic skin resistance, pulse rate, and blood pressure (systolic and diastolic) were used to physiologically verify the effects of stress and relaxation on amylase activity. Amylase activity was judged by spectrophotometric analysis of maltose produced from a specific dilution of expectorated saliva. Results showed that the physiological measures significantly corroborated the salivary determinations of stress and relaxation and that deep relaxation was significantly more important than thorough chewing in the oral digestion of complex carbohydrates.

KEY WORDS Stress, relaxation, carbohydrate digestion, starch, cereal, oral cavity, saliva, physiological measures

Introduction

We have conducted investigations on the effects of stress and relaxation on saliva, including its volume, viscosity, pH, and protein, glycoprotein, bacteria, and α-amylase content (1-8). Stress was induced by endodontic (root canal) therapy, college examinations, or mental arithmetic. Relaxation was induced by transcendental meditation (TM) or by simple-word meditation (9). During relaxation, contrary to stress, there were statistically significant decreases in salivary protein, glycoprotein, bacteria, and viscosity and increases in salivary volume, pH, and α-amylase activity. The salivary determinations of stress and relaxation were corroborated by questionnaire and physiological measures.

The salivary findings are apparently related to the autonomic nervous system (ANS) innervation of the salivary glands. The sublingual and minor glands are predominantly composed of mucous cells that are activated by the sympathetic division of the ANS to produce large-molecular-weight, glycoprotein-rich, low-volume saliva, which mainly accounts for the increased protein, glycoprotein, and viscosity of the stress-induced saliva. The parotid glands are predominantly composed of serous cells that are activated by the parasympathetic division of the ANS to produce an α-amylase-rich, high-volume, free-flowing, high-bicarbonate saliva that mainly accounts for the increased volume, amylase activity, and pH and the decreased bacteria of relaxation-induced saliva (10-13). The submaxillary glands have an approximately equal mixture of mucous and serous cells. The type of secretion varies depending on the relative conditions of stress and relaxation, among other factors such as food intake.

Salivary α-amylase (primarily produced by the parotid glands) is the principal salivary protein (11). It catalyzes the breakdown of large-molecular-weight complex carbohydrates to produce maltose (principally), maltotriose, α-limit dextrins, and a small amount of D-glucose (12). Parotid saliva (unlike submaxillary, sublingual, and minor-gland secretions) is greatly augmented by physical and chemical stimulation (14). We found significantly higher parotid α-amylase activity under relaxed chewing...
conditions than under relaxation alone (15). In that study, 4 of the 40 subjects were trained in either meditation or hypnosis. Their mean α-amylase activity was significantly greater than the mean α-amylase activity of the 36 other subjects. With this background, we decided to investigate amylase activity during the chewing of complex carbohydrate foods.

The rationale for the recent series of investigations into salivary amylase activity was three-fold. First, there is currently a widespread interest in complex carbohydrates as a major food constituent and energy source for athletic performance, for use in weight-loss diets (16), and as a possible preventive measure for coronary heart disease, diabetes mellitus, some gastrointestinal diseases, and colon cancer (17–19).

Second, there are conflicting reports on the importance of oral digestion of complex carbohydrates. Some authorities contend that food does not remain in the mouth long enough for more than a small percentage of dietary starch to be converted to maltose (20–22). Others maintain that if chewing is thorough, a major part of starch is converted to maltose (23). Unfortunately, evidence is not given for either viewpoint. With evolution salivary α-amylase has remained intact as a component of complex carbohydrate digestion but there is little evidence that fat or protein digestion occurs orally. This appears to emphasize the importance of the first stage (oral) of complex carbohydrate digestion. It has also been emphasized that saliva is not sufficiently alkaline to have much digestive activity because α-amylase works best in an alkaline medium (as is present in the small intestine) (24). However, in three studies we found that saliva is acidic during stress but alkaline during relaxation (2, 6, 7).

The third reason for investigating salivary α-amylase is that the rate of oral digestion of starches was found to be related to the blood glucose response (glycemic index) after ingestion of food (25–27). This is important to diabetics because it is usually thought that foods that increase the blood glucose level the least for a given carbohydrate are most suitable for the diabetic (26).

To help in the resolution of the divergent viewpoints with regard to oral digestion of starches, the first case study was undertaken (28). Two other purposes for that investigation were to evaluate the varying amounts of maltose found in some common complex carbohydrate foods and to determine how much digestion of these foods occurs from the activity of salivary α-amylase.

In this and all subsequent studies, we used in vivo expectoration of a chewed food for α-amylase activity determination rather than analyzing α-amylase activity in vitro by quantitatively collecting saliva. We used in vivo expectoration because we wanted to examine the amylase activity resulting from chewing a variety of complex-carbohydrate foods to find one food that could be used as a model, based on its ability to produce a large mean amount of maltose across conditions. In all of the studies the percentage of available carbohydrate in the various foods that was actually digested orally was not determined. Although it would have been of interest to have determined the actual percentage of digestion of available carbohydrate, we could find no practical way to achieve this.

The subject of the case study (28), a trained meditator, had his salivary α-amylase activity measured as he chewed 15 different starch foods while he was under the conditions of stress and relaxation. The major findings were 1) a statistically significant increase in maltose production with 60-s chewing as opposed to 20-s chewing; 2) a statistically significant increase in maltose production with relaxation as opposed to stress; 3) no order effect; and 4) certain foods such as an oat cereal accounted for the largest mean amount of maltose under all conditions.

To generalize these findings, a comprehensive study with 20 dental hygiene student subjects was undertaken (29). The subjects chewed an oat cereal for the same 20- and 60-s time periods as in the case study (28). Because there was no order effect in the case study, only the first order was used in this study, ie, under stress while chewing for 20 s (stress/20 s), stress while chewing for 60 s (stress/60 s), relaxation while chewing for 20 s (relax/20 s), and relaxation while chewing for 60 s (relax/60 s). As in the previous study (28), stress was induced by the same mental arithmetic exercise and relaxation was induced by the simple-word meditation technique (9, 30). The main findings were a statistically significant increase in maltose production with 60-s chewing as opposed to 20-s chewing and a statistically significant increase in maltose production with relaxation as opposed to stress.

Because no independent measures were used to verify the conditions of stress and relaxation as determined by the changes in saliva in the two previous studies (28, 29), another study was undertaken with 25 female dental hygiene students as subjects (31). The main purpose of this new study was to corroborate the findings concerning salivary α-amylase relative to stress and relaxation and rapid (20-s) and slow (60-s) chewing. To accomplish this only the conditions that previously showed the most diverse findings were evaluated, ie, stress/20 s and relax/60 s. The physiological indices of galvanic skin resistance (GSR), pulse rate, and both systolic and diastolic blood pressure were used as the corroborative measures of stress and relaxation (7, 9, 30, 32). The main findings were a statistically significant greater α-amylase activity under relax/60 s than under stress/20 s, and all the physiological measures corroborated the findings concerning salivary amylase with respect to the determination of stress and relaxation.

This study was undertaken not merely as a reworking or replication of the previous studies but rather, to include all of the previous components in one study and to determine, if possible, which is more important in the oral digestion of complex carbohydrates: time of chewing or degree of relaxation. Because it required > 3 h/subject to do all of the necessary procedures and the pool
of subjects was defined by the dental hygiene curricula requirements, the number of subjects had to be limited.

Subjects and methods

Subjects

The subjects were 12 female dental hygiene students with a mean age of 20.8 y (range 18–32 y). All subjects were in good health, were not taking any drugs, and had fully functioning salivary glands. None of the subjects were pregnant (a condition in which salivary rate usually increases [33]) and none were evaluated while in the premenstrual or menstrual state (a condition in which salivary rate usually decreases [34]). To control for other variables that could affect salivary secretion, such as hunger (salivary rate increases with meal anticipation and sight and odor of food [35]) and circadian rhythm (salivary rate usually increases early in the morning [36]), all of the subjects were seen on the same day (Thursday) and at the same time (morning). All subjects gave their informed consent by signing a form approved by the Human Research Study Review Board at the Temple University Health Sciences Center. This organization approved of the experiments performed in this study.

Measurements and procedures

Each subject sat partially inclined in a comfortable chair. The room was isolated, with moderate temperature and humidity. No external distractions were present. The same mental arithmetic exercise (with subject verification of its stressful nature), simple-word meditation technique, and 5-g portion of oat cereal (Cheerios®, General Mills, Inc, Minneapolis, MN) was used as in the previous studies (28, 29, 31). The same physiological indices were used as in the previous study with dental hygiene students (31), ie, GSR, pulse rate, and systolic and diastolic blood pressure. As in the case study (28), two condition orders were used, ie, stress/20 s, stress/60 s, relax/20 s, relax/60 s; and relax/20 s, relax/60 s, stress/20 s, stress/60 s.

The same measurement procedures and techniques were used as in the previous study with dental hygiene students (31). However, because some of these methods may not be well known, a brief description of them is now given.

The portion of oat cereal was placed in a sterile, plastic weighing boat immediately before use. The subjects were told to start chewing immediately on receiving the first portion of cereal. The subjects kept their eyes open during the stress conditions. In previous studies, it was shown that merely closing the eyes can increase the frequency of a brain wave patterns on the electroencephalogram, but other indices of relaxation (eg, GSR, pulse rate) do not necessarily change [30, 32].

For 5 min while under stress conditions, the subjects performed the mental arithmetic exercise. The mental arithmetic was continued during the actual chewing periods. The subjects kept their eyes closed during the relaxation conditions. For 5 min while under these conditions, the subjects performed the simple-word meditation technique. The eyes were kept closed and the meditation was continued during the actual chewing periods.

Before each subject performed the mental arithmetic exercise and the simple-word meditation technique, the GSR 2® (Thought Technology Ltd, Montreal, Canada) device was attached to the index and middle finger of the left hand and the blood pressure cuff (Digiprint 2000 Digital Blood Pressure and Pulse Rate Monitor®, Labtron Scientific Corp, Hauppauge, NY) was attached to the right arm. Two readings were taken for each measure during each condition order and the mean was entered as the value. The first readings were taken immediately before the subjects began to chew the food. The second readings were taken immediately after the subjects expectedly rated the food. The GSR readings were taken and entered by an individual who was not involved in the study. The blood pressure and pulse rate readings were automatically recorded and printed; they were then placed in the subjects' records. Because the subjects were not permitted to move their arms because of the attached devices, the food was fed to them during the allocated time periods.

Immediately after each chewing, each subject completely expectorated the paste into a homogenizer cup. Distilled water was then added until it reached a premarked level within the homogenizer cup. The cup and its contents were then thoroughly mixed in a liqueur blender (Oster Division, Sunbeam Corp, Milwaukee, WI) for exactly 1 min. The material was then transferred into two centrifuge tubes and centrifuged (model HN-S, International Equipment Co, Needham Heights, MA) for exactly 5 min at 2000 rpm. One milliliter of the supernatant from one of the two tubes was then added to 19 mL distilled water to make a 1:20 dilution. (The second tube was kept as a back-up in case of spillage.) The diluted solution was subsequently thoroughly mixed for 1 min. Then 1 ml of the solution was added to 1 mL maltose reagent (1 g 3,5-dinitrosalicylic acid in 20 mL sodium hydroxide (NaOH, 2 mol/L)(NaOH) and 30 g NaK-tartrate and enough water to make 100 mL) in another test tube. This tube was then placed in a boiling water bath for exactly 5 min. It was subsequently withdrawn and run under cold tap water for 1 min. Ten milliliters of distilled water was then added to the test tube. The tube was subsequently placed in the reading tube of the spectrophotometer (Spectronic 20®, Bausch and Lomb, Rochester, NY). The absorbency was read at 530 nm. Milligrams of maltose per originally expectorated sample were calculated with the following formula:

\[ \text{Milligrams of maltose per mL} = \left(\frac{A_{u}}{A_{S}}\right) \times mg \text{ of maltose of standard} \times (1/V) \]

where \( U \) = unknown, \( S \) = standard, and \( V \) = volume of the supernatant. The standard was prepared from 1 mL maltose standard (1 mg/mL) that was placed in the reading tube and the absorbency was read at 530 nm. In this study \( S = 46.0 \text{ mg/mL} \) and \( V = 0.05 \text{ mL} \) in all cases.

For each of the four conditions, milligrams maltose per milliliter per sample was obtained in both condition orders. Then the two readings per order in each condition were totaled and a mean per condition was obtained. For example, with stress/20 s, if the reading was 25 mg/mL in order 1 and 23 mg/mL in
order, the readings were combined and a mean of 24 mg/mL was obtained and entered as the reading for stress/20 s for that subject.

In addition to the two experimental conditions there was a control, which was a measurement of the milligrams of maltose per milliliter of the oat cereal before it was chewed and digested by α-amylase. A 5-g sample of the cereal was homogenized with distilled water to the same predetermined level in the homogenizer cup. It was then analyzed for maltose content in the same way as under the experimental conditions.

Statistical analysis

The t test was used to determine if there was any significant difference between the milligrams per milliliter maltose readings for the two orders per each condition. A two-factor analysis of variance (ANOVA) with repeated measures was employed to analyze the results with respect to mean values of maltose (mg/mL) produced from the oat cereal under the four conditions (stress/20 s, stress/60 s, relax/20 s, relax/60 s) (37). A Newman-Keuls procedure was used to determine which of the conditions contributed to the overall statistical significance. An a posteriori test was employed to analyze the results for the differences with each of the five measures (maltose, GSR, pulse rate, systolic blood pressure, diastolic blood pressure) between the stress/20-s and relax/20-s conditions and the stress/60-s and relax/60-s conditions. Cochran’s relatively simple test (37) was used to test for homogeneity of variance. The level for significance for all statistics was set at 0.05.

Results

Maltose findings

A comparison between the two orders of the mean values of maltose under the four experimental conditions is presented in Table 1. Note that there is no significant difference between the values for the two orders. A summary of the ANOVA with repeated measures for the 12 subjects under 4 experimental conditions with respect to oat cereal in terms of mean values of maltose is presented in Table 2. As a reference point it can be noted that the mean value of maltose for oat cereal homogenized with distilled water is 4.3 mg/mL.

As shown in Table 2 the main effects between subjects for all conditions is statistically significant (F = 3.23, df = 11, p < 0.01), which suggests that individual differences are important. More importantly, however, the main effects of the four conditions is statistically significant (F = 23.32, df = 3, p < 0.01). Further analysis with the Newman-Keuls procedure to determine which of the conditions contribute to the overall statistical significance is presented in Table 3. The conditions are significantly different from each other (p < 0.05) and the ordered conditions (means) from the least to the greatest are as follows: stress/20 s (37.6 mg/mL), stress/60 s (47.0 mg/mL), relax/20 s (57.0 mg/mL), and relax/60 s (80.4 mg/mL) (Fig 1).

From the data in Table 1, the mean value of 20-s chewing is calculated as 47.3 mg maltose/mL whereas the mean value of 60-s chewing is 63.7 mg/mL. The mean difference between these averages is 16.4 mg/mL which is statistically significant (p < 0.01). The mean value of relax is 68.7 mg maltose/mL whereas the mean value of stress is 42.3 mg/mL. The mean difference between these averages is 26.4 mg/mL, which is also statistically significant (p < 0.01). The difference in maltose production between relaxation and stress is greater than the difference between 20- and 60-s chewing (Fig 1).

Corroborative measures

The results of the correlated t test for the five measures under stress/20 s and relax/20 s are shown in Table 4. The results of the correlated t test for the five measures under stress/60 s and relax/60 s are shown in Table 5. In relax/20 s as opposed to stress/20 s the increased mean...
TABLE 3
Summary of Newman-Keuls procedure for differences between mean values of maltose in mg/mL under four conditions

<table>
<thead>
<tr>
<th>Condition (Ordered)</th>
<th>Stress/20 s (37.6 mg/mL)</th>
<th>Stress/60 s (47.0 mg/mL)</th>
<th>Relax/20 s (57.0 mg/mL)</th>
<th>Relax/60 s (80.4 mg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress/20 s</td>
<td></td>
<td>9.4*</td>
<td>19.4†</td>
<td>42.8†</td>
</tr>
<tr>
<td>Stress/60 s</td>
<td></td>
<td></td>
<td>10.0</td>
<td>33.4†</td>
</tr>
<tr>
<td>Relax/20 s</td>
<td></td>
<td></td>
<td></td>
<td>23.4†</td>
</tr>
<tr>
<td>Relax/60 s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05.
† p < 0.01.

maltose is highly statistically significant (corr- \( t = 5.98, p < 0.01 \)); the increased GSR (lower values in the arbitrary scale used) is also highly statistically significant (corr- \( t = -5.26, p < 0.01 \)); the decreased pulse rate is in the indicated direction but it was not statistically significant (corr- \( t = -1.70, p > 0.05 \)); the decreased systolic blood pressure is highly statistically significant (corr- \( t = -4.68, p < 0.01 \)); and the decreased diastolic blood pressure is highly statistically significant (corr- \( t = -4.85, p < 0.01 \)). In relax/60 s as opposed to stress/60 s the increased mean maltose is highly statistically significant (corr- \( t = 6.31, p < 0.01 \)); the increased GSR (lower values in the arbitrary scale used) is highly statistically significant (corr- \( t = -2.87, p < 0.01 \)); and the decreased diastolic blood pressure is highly statistically significant (corr- \( t = -4.58, p < 0.01 \)). Hence, the four physiological measures corroborate the \( \alpha \)-amylase activity measure as a determinant of stress and relaxation.

Discussion

In a previous study of dental hygiene students (31), correlated \( t \) analysis of the physiological measures of GSR, pulse rate, and systolic and diastolic blood pressure, along with the salivary \( \alpha \)-amylase-produced maltose, showed that there were statistically significant differences between the conditions. In the present study, correlated \( t \) analysis of the same measures showed that there were statistically significant differences among all four conditions, ie, stress/20 s, relax/20 s, and stress/60 s, and relax/60 s. Hence, it appears that the conditions that were labeled as stress and relaxation in the previous three studies of salivary digestion (28, 29, 31) and the present study were appropriately designated.

In this study the finding that the differences between individuals was statistically significant (Table 2) was not of major interest to us. In expectation of this result, we used a repeated-measures design to control for individual differences. In fact, the differences between individuals tended to mask the differences of interest, which were those between stress and relaxation and between rapid and slow chewing. Differences between rapid and slow chewing are shown in the post hoc test (Table 3).

The variance for the stress conditions was generally lower than the variance for the relaxation conditions (114.92 and 101.00 vs 312.23 and 595.85, respectively; Table 1). It appears that the subjects of this study (and probably individuals in general) are more alike in how they react to stress than in how they react to relaxation. Employing Cochran's relatively simple test, homogeneity of variance is rejected at the 0.05 level but not at the 0.01 level (\( C = 0.53, C_{0.95} = 0.48, C_{0.99} = 0.55 \)). On the basis of this result, one may question the tenability of the hypothesis of homogeneity of variance with respect to the stress and relaxation conditions. Recognizing that there is a difference between these conditions, we interpret the findings of the mean differences for the stress and relaxation conditions with reasonable caution.

It also appears from the findings of this and the previous studies of dental hygiene students (29, 31) that, of those used, the best measures for determining the conditions of stress and relaxation are salivary \( \alpha \)-amylase-produced maltose and GSR. In a previous study (31) and in the present one, every one of the subjects (25 + 12 = 37) produced a change in the indicated direction with the maltose measure. With GSR, only one subject showed an unexpected response. With the other three measures.
TABLE 4
Summary of mean values of five measures under the stress/20-s and relax/20-s conditions for 12 subjects

<table>
<thead>
<tr>
<th>Measure</th>
<th>Stress/20 s*</th>
<th>Relax/20 s*</th>
<th>Mean difference</th>
<th>Corr-t†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maltose (mg/mL)</td>
<td>37.6 ± 10.72</td>
<td>57.0 ± 17.67</td>
<td>+19.4</td>
<td>+5.98‡</td>
</tr>
<tr>
<td>Galvanic skin response (arbitrary units)</td>
<td>3.3 ± 0.24</td>
<td>2.0 ± 0.92</td>
<td>−1.3</td>
<td>−5.26‡</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>81.3 ± 9.36</td>
<td>78.9 ± 8.82</td>
<td>−2.4</td>
<td>−1.70</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>106.5 ± 6.90</td>
<td>101.0 ± 5.62</td>
<td>−5.5</td>
<td>−4.68‡</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>73.9 ± 10.03</td>
<td>67.5 ± 8.06</td>
<td>−6.4</td>
<td>−4.85‡</td>
</tr>
</tbody>
</table>

* x ± SD.
† Corr-t=1.80.
‡ Corr-t=2.72.

(pulse rate and systolic and diastolic blood pressure), most but not all of the readings were in the indicated directions.

In the two previous studies of dental hygiene students (29, 31) the oat cereal had a small amount of maltose (x = 7.0 mg/mL) before digestion and it was readily digestible by salivary α-amylase to yield substantial amounts of maltose (mean stress = 61.3 mg/mL; mean relax = 78.5 mg/mL). In the present study similar results were found. Oat cereal yielded 4.3 mg/mL before digestion, and after digestion a mean of 42.3 mg/mL was produced under stress and 68.7 mg/mL was produced under relax. In the case study with a trained meditator (28), both stress and relax conditions yielded a substantially greater amount of maltose from oat cereal (mean stress = 107.8 mg/mL; mean relax = 150.5 mg/mL). Although this was a report involving only a single individual, it appears that a trained meditator has less stress manifestations (at least as determined by a salivary measure) and a greater ability to digest complex carbohydrates orally. The combined results of the four studies (28, 29, 31, and this one) show that oat cereal is a complex-carbohydrate cereal containing a small amount of maltose that can be readily digested by salivary α-amylase to yield substantial amounts of maltose. Hence, under the proper chewing conditions foods such as oat cereal would be a readily available source of energy because the maltose produced orally would require only one additional cleavage to yield two molecules of glucose. Although it is true that maltose could also be produced in the small intestine by the action of pancreatic amylases, it would appear that it is more efficient if a substantial amount of maltose production is done earlier in the chain of events (ie, in the oral cavity rather than the small intestine).

The other major disaccharide, sucrose, is much more cariogenic and is therefore less advantageous than maltose (8). In a study on the influence of various dietary carbohydrates in caries activity in hamsters (38), the following carbohydrates were analyzed: starch, dextrin, sucrose, maltose, lactose, fructose, and glucose. The results showed that starch and dextrin did not support caries activity. Sucrose and fructose supported the highest caries activity, glucose and lactose were the next highest, and maltose was the lowest. With rats, the results were not as clear-cut but generally maltose was significantly less cariogenic than was sucrose (38). Even though maltose may produce acid that is potentially conductive to initiation of dental caries, the results of our stress-relaxation studies on saliva (2, 6, 7) showed that the saliva becomes alkaline under deep relaxation. Hence, this could counteract the maltose-induced acid production. In addition, in our four studies of salivary α-amylase digestion (28, 29, 31, and this one), the maltose present in the chewed-up bolus of food did not appear to adhere to tooth sur-

TABLE 5
Summary of mean values of five measures under the stress/60-s and relax/60-s conditions for 12 subjects

<table>
<thead>
<tr>
<th>Measure</th>
<th>Stress/60 s*</th>
<th>Relax/60 s*</th>
<th>Mean difference</th>
<th>Corr-t†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maltose (mg/mL)</td>
<td>47.0 ± 10.05</td>
<td>80.4 ± 24.41</td>
<td>+33.4</td>
<td>+6.31‡</td>
</tr>
<tr>
<td>Galvanic skin response (arbitrary units)</td>
<td>3.3 ± 0.28</td>
<td>1.5 ± 0.91</td>
<td>−1.8</td>
<td>−7.42‡</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>83.0 ± 7.35</td>
<td>78.4 ± 8.10</td>
<td>−4.6</td>
<td>−3.33‡</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>105.8 ± 8.32</td>
<td>99.8 ± 4.96</td>
<td>−6.0</td>
<td>−4.58‡</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>71.0 ± 7.68</td>
<td>68.2 ± 7.82</td>
<td>−2.8</td>
<td>−2.87‡</td>
</tr>
</tbody>
</table>

* x ± SD.
† Corr-t=1.80.
‡ Corr-t=2.72.
faces (an important requisite for initiation of dental caries). This was evaluated by physical examination; biochemical analysis was not done. Therefore, from currently available information we believe that the maltose that is formed from cereals such as oat cereal is not cariogenic.

As the result of the findings from this study and from the previous three studies on salivary digestion (28, 29, 31), two apparently important chewing variables were determined. These variables are involved in the oral digestion of complex carbohydrates. The first variable is the amount of time spent chewing. In the case study with a trained meditator (28), the mean value of 20-s chewing was 72.8 mg maltose/mL whereas the mean value of 60-s chewing was 185.6 mg/mL. In the first dental hygiene student study (29), the mean value of 20-s chewing was 62.8 mg/mL whereas the mean value of 60-s chewing was 99.9 mg/mL. In the second dental hygiene student study (31), the mean value of 20-s chewing was 51.3 mg/mL whereas the mean value of 60-s chewing was 65.5 mg/mL. In the present study, the mean value of 20-s chewing was 47.3 mg/mL whereas the mean value of 60-s chewing was 63.7 mg/mL. The mean differences (112.8 mg/mL in the case study, 37.1 mg/mL in the first dental hygiene student study, 14.2 mg/mL in the second dental hygiene student study, and 16.4 mg/mL in this study) are statistically significant \( p < 0.01 \). Hence, it appears that with the longer time period there is more salivary \( \alpha \)-amylase present to digest complex carbohydrates, which would then result in the production of a larger amount of maltose. The amount of maltose produced by the subject of the case report (28) under the two time conditions was substantially greater than the mean of values from the dental hygiene student subjects of the other three studies (29, 31, and this one). In fact, not a single dental hygiene student subject in any of those studies was close to producing as much maltose as did the case study subject. The probable reason is that the case study subject is a male who is well-developed (a former weight-lifting champion) who exerted excessive force while he was chewing. In contrast, the subjects of the three dental hygiene student studies are all young females, none of whom are involved in weight training or any type of heavy exercise. Nevertheless it is realized that this rationale is hypothetical because there is no direct evidence that physical strength is related to biting pressure. Furthermore, even if such evidence exists, biting pressure was not measured in these studies.

Eighty percent of salivary \( \alpha \)-amylase is produced by the parotid glands (11, 13). During chewing, contraction of the buccinator muscles occurs and this activity results in massage of the Stensen (parotid) ducts. This allows for more forceful expulsion of parotid saliva (14, 39). Therefore, the 60-s chewing should result in the expulsion of more amylase than the 20-s chewing. However, because salivary \( \alpha \)-amylase levels were not measured, it cannot be definitely stated that longer chewing time results in greater \( \alpha \)-amylase secretion. The rate-limiting step in maltose production is not known; it could be either \( \alpha \)-amylase or starch levels or, possibly, pH. We did find in previous studies (2, 6, 7) that saliva has an acidic pH during stress and an alkaline pH during relaxation. However, that was not related to time of chewing. It may even be that the higher maltose level in 60-s saliva reflects an improved efficacy of \( \alpha \)-amylase digestion instead of higher levels of amylase.

Our findings apparently contradict the opinion of Seckurt's text (22) in which it is stated, "The extent to which food is chewed has no effect on the processes of digestion and absorption; it is not necessary as proposed by some faddists to chew each mouthful of food for prolonged periods of time." Our results, in contrast, tend to support the old adage about the benefits of thorough chewing.

The second important variable in the oral digestion of complex carbohydrates is the degree of relaxation. In the case study with the trained meditator (28), the mean value of relax was 150.5 mg maltose/mL whereas the mean value of stress was 107.8 mg/mL. In the first dental hygiene student study (29), the mean value of relax was 91.4 mg/mL whereas the mean value of stress was 71.2 mg/mL. In the second dental hygiene student study (31), the mean value of relax was 65.5 mg/mL whereas the mean value of stress was 51.3 mg/mL. In the present study, the mean value of relax was 68.7 mg/mL whereas the mean value of stress was 42.3 mg/mL. The mean differences (42.7 mg/mL in the case study, 20.2 mg/mL in the first dental hygiene student study, 14.2 mg/mL in the second dental hygiene student study, and 26.4 mg/mL in this study) are statistically significant \( p < 0.01 \). Hence, it appears that with deep relaxation there is more salivary \( \alpha \)-amylase present in the mouth to digest complex carbohydrates, which then yields a higher amount of maltose. A summary of mean maltose in milligrams per milliliter for the four studies is given in Table 6.

With deep relaxation, as with meditation, the parasympathetic division of the ANS is activated (40). Studies showed that parasympathetic stimulation yields a rapid flow of watery saliva that is rich in \( \alpha \)-amylase (20, 33, 41). This is apparently what occurred during the relax conditions.

With respect to which factor is more important in oral digestion of complex carbohydrates, an examination of the mean results from the present study shows that of all four conditions (stress, relax, 20-s chewing, 60-s chewing), relax produced the largest amount of maltose (Fig 1). Therefore, from the results of this study, the most important factor in oral digestion of complex carbohydrates appears to be deep relaxation. However, the best results occur when deep relaxation is coupled with thorough chewing (Fig 1).

It is understood that people generally do not eat under the extreme conditions of stress and relaxation as used in these studies. Nevertheless, it would appear that eating in a relaxed atmosphere and chewing food thoroughly would help in subsequent digestion and absorption.
The great playwright Oscar Wilde was aware of the benefits of relaxation during eating. In his 1895 play, "The Importance of Being Earnest (42)," there is a section in act 2 during which two friends are angry with each other because of premarital problems. The following is an excerpt:

"Jack: How can you sit there, calmly eating muffins when we are in this horrible trouble. I can't make it out. You seem to me to be perfectly heartless. Algernon: Well, I can't eat muffins in an agitated manner. The butter would probably get on my cuffs. One should always eat muffins quite calmly. It is the only way to eat them."

**References**


