

The Value of Maltitol Containing Cookie as a Food for the Elderly

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Running title: Maltitol-containing Cookies for Eldery People

## **Abstract**

### **Purpose**

There is a need for food products that can assure the quality of life (QoOL) of elderly people who are at risk of tooth decay (particularly those who require long-term care and are unable to ensure adequate oral hygiene). Here, we focused on maltitol, a leading alternative sweetener.

### **Methods**

We made maltitol-containing cookies and investigated their effect on calcification on the enamel surface layer of teeth, as well as carrying out a questionnaire survey regarding the test cookies. Enamel blocks for use as test materials were made from healthy premolars extracted for orthodontic reasons. Saliva (450 mL) was collected from volunteer participants. Test samples were created containing saliva only as well as saliva with addition of 5% maltitol, 5% sucrose, flour, unsalted butter, egg yolk, baking powder, cookie dough made with maltitol, or cookie dough made with sucrose. Enamel blocks were immersed in saliva solutions for 1 week in an incubator at 37°C. Before and after immersion, their pH was measured, the surface was observed by scanning electron microscopy and contact microradiography (CMR), and calcification levels were analyzed. Double-blind taste tests were also carried out by 102 healthy adults who responded to a questionnaire.

## **Results**

There was almost no evidence of decalcification after immersion in saliva alone as well as in saliva containing 5% maltitol, flour, egg yolk, unsalted butter or baking powder. Considerable decalcification occurred after immersion in saliva containing 5% sucrose or cookie dough made with sucrose, but almost no decalcification after immersion in saliva containing cookie dough made with maltitol. Questionnaire results revealed that, though some respondents felt that maltitol-containing cookies were insufficiently sweet, they were highly satisfied with how easy they were to masticate and swallow, and a large number said they would be willing to purchase them.

## **Conclusion**

Our results suggest that maltitol-containing cookies may be valuable foods for preventing tooth decay (a major problem in elderly subjects).

Keywords: Alternative sweeteners, maltitol, decalcification

## Introduction

As of 2015, 26% of the Japanese population is aged  $\geq 65$  years<sup>1)</sup>. Diet is an important factor in enabling elderly people to continue to live healthy and fulfilled lives, maintaining/improving their state of health, and ensuring that they have a high quality of life (QoL).

The Japanese Ministry of Agriculture, Forestry and Fisheries has been commissioning its Food and Marketing Bureau to carry out projects on new ingredients since 1984. In that year, they published the Project to Establish and Disseminate Techniques for the Appropriate Use of New Ingredients for Snacks. They continued with the Project to Disseminate Techniques for the Effective Use of Functional Ingredients in Foods and Beverages from 1989, the Project to Promote the Appropriate Dissemination of New Ingredients for Food Products from 1994, and the Project to Test New Ingredients, etc., for Snacks and Food Products from 2010.

The number of frail, elderly subjects (those who are more vulnerable to various health problems due to an age-related decline in a range of functions) is increasing, as is the number of individuals with sarcopenia (age-related decline in muscle strength or reduction in muscle mass), and nutritional issues are a matter of great urgency<sup>2)</sup>. Some studies have found that a lower intake of energy and protein contributes to these

issues<sup>3)</sup>. Oral ingestion of food is regarded to be highly effective for the prevention of frailty and sarcopenia.

Attempts are underway to develop foods preferred by elderly people. “Universally designed foods”, commercially available foods that span different levels of the “dysphagia diet pyramid”,<sup>4)</sup> and soft foods for the elderly<sup>5)</sup> are among available foods that are “tailored” to be easy to eat in accordance with individual eating abilities. Atrophy of the taste buds<sup>6)</sup>, reduced secretion of saliva<sup>7,8)</sup>, and the effects of medication are among can result in an increased taste threshold and blunted oral sensations<sup>9)</sup>. Studies have also demonstrated that, though age-related changes in taste cause the thresholds for perception of saltiness and bitterness to rise significantly, there is less of an increase in the threshold for sweetness. Thus, in comparison with younger generations, elderly people tend to prefer sweeter foods<sup>10)</sup>. However, the sweetener sucrose is a risk factor for dental caries. Sucrose is used in various foods, and limiting its intake helps to prevent caries. There is an unmet need for non-sucrose sweeteners that inhibit dental caries.

Reduced maltose (“maltitol”) is one such “alternative sweetener”. It is non-cariogenic because it does not act as a substrate that produces acids, and so does not result in the synthesis of insoluble glucans<sup>11)</sup>. The sweetness of maltitol is  $\approx 80\%$  that of sugar, and its taste is the closest to sucrose of any sugar alcohol. It is highly

heat-resistant and, if added to foods, it is not susceptible to fermentation by microorganisms such as molds, yeasts or bacteria. Its safety has been confirmed in four types of toxicity testing (mutagenicity; acute, subacute and chronic toxicity). Unlike sucrose, maltitol does not result in the synthesis of insoluble glucans, so its plaque-forming ability is negligible. Therefore, maltitol may be of use in the production of foods that assure/enable QoL in elderly people who require long-term care and who cannot ensure adequate oral hygiene and who are, therefore, at high risk of developing dental caries.

Here, we focused on subsurface decalcification of the enamel layer, which is a known cause of dental caries. We carried out a comparative investigation of the effects of sucrose-containing cookies (a popular type of confectionery) and maltitol, as well as the other ingredients used in preparation of these cookies, on salivary pH and the severity of decalcification of the enamel layer. We also gave two types of cookies to healthy adults to eat, and evaluated their opinions by means of a questionnaire.

## **Materials and Methods**

### **1. Preparation of Test Samples**

The recipe for maltitol cookies comprised 240 g of flour (Nisshin flour®; Nisshin Seifun Group Inc., Tokyo, Japan), 120 g of unsalted Yukujirushi butter (Hokkaido butter®; Megmilk Snow Brand Co., Ltd., Tokyo, Japan), 40 g of egg yolk (commercially available hen eggs), 3 g of baking powder (Meidi-ya baking powder®; Meidi-ya Food Co., Kanagawa, Japan), and 100 g of maltitol (Marvie®; H+B Life Science Co., Ltd., Tokyo, Japan). In sucrose cookies, the same weight of sucrose (Jyohakuto®; Mitsui Sugar Co., Ltd., Tokyo, Japan) was substituted for maltitol. By mixing the flour, baking powder, and maltitol or sucrose, and then adding the unsalted butter and mixing, a smooth dough was created. This smooth dough was shaped into cookies of size 2 cm ~ 3 cm and baked for 20 min in an oven (170°C). Two types of cookies were baked that contained maltitol or sucrose.

### **2. Immersion Experiments**

The study protocol was approved by the Ethics Committee of Osaka Dental University (approval number, 110825; Osaka, Japan). We used healthy premolars extracted for orthodontic reasons after obtaining written informed consent from patients. Occlusal surfaces of premolars were ground with #1000 waterproof abrasive paper. Circular

blocks (depth from the occlusal surface,  $\approx 0.5$  mm; diameter, 0.3 mm) were cut and embedded in sticky wax to leave only the enamel surface exposed. Samples of whole saliva (450 mL) were collected from a female volunteer (29 years) after she had chewed a gum base, and the pH of the saliva was measured. Saliva samples were divided between nine measuring cylinders, and different ingredients were added to produce solutions containing: (i) saliva alone; (ii) saliva and 5% maltitol; (iii) saliva and 5% sucrose; (iv) flour; (v) unsalted butter; (vi) egg yolk; (vii) baking powder; (viii) maltitol cookies; (ix) sucrose cookies. The enamel blocks described above were added to each saliva solution, and immersed for 1 week in an incubator at 37°C. After immersion, the pH of each saliva solution was measured. Test samples were washed in distilled water and their surface dried. Then, they were immersed in xylene to remove wax.

### **3. Observation Methods**

Test samples were embedded in resin made of methyl methacrylate. Their surfaces were exposed by using a precision cutter (IsoMet 1000; Buehler, Lake Bluff, IL, USA). Then, an MG-400CS microgrinding machine (Exakt; Norderstedt, Germany) was used for mirror polishing. Carbon deposition was carried out on this surface, which was then observed by a scanning electron microscope (SU8010; Hitachi Technologies, Tokyo,



Japan). Surface images were imported into a computer, and ImageJ ver 1.45 (National Institutes of Health, Bethesda, MD, USA) used to obtain a graphical representation of the level of calcification. Areas of enamel were analyzed as “100% calcified”, and areas of resin alone as “0% calcified”. Some samples were cut into blocks using the precision cutter (IsoMet 1000; Buehler). Then, they were ground to a thickness of 90–100  $\mu$  m using a grinder (Speed Lap ML-521D; Maruto International, Tokyo, Japan) and ground by hand to prepare slices for contact microradiography (CMR; Hitachi) with a X-ray device (SRO-M50; Sofron, Kanagawa, Japan).

#### **4. Questionnaire Evaluation**

Maltitol cookies and sucrose cookies prepared by the method described above were evaluated by means of a questionnaire. Subjects were 102 healthy adults (mean age,  $29 \pm 13$  years) with no difficulties in mastication or swallowing. They carried out a double-blind taste test of prepared cookies, and responded to questions concerning ease of mastication, ease of swallowing, and the sensation of sweetness after eating each type of cookie.

## **Results**

### **1. Measurements of Salivary pH**

At the time it was sampled, the pH of saliva alone was 7.5. After immersion for 1 week, the pH of: saliva alone was 8.18; with added egg yolk was 6.98; with added baking powder was 7.99; with added butter was 7.02. Hence, no changes in pH were observed. However, the pH of the solution with added flour was 3.35, that with added maltitol-containing cookies was 3.38, and that with added sucrose-containing cookies was 3.52. Hence, a decrease in pH was noted. With the addition of maltitol, the pH was 4.80, which constituted a moderate decrease (Fig. 1).

### **2. Results of Scanning Electron Microscopy (SEM), CMR, and Image Analyses**

Analyses of SEM and CMR data revealed that the surfaces of test samples immersed in saliva alone and saliva with egg yolk, baking powder, unsalted butter, or maltitol were almost flat, with almost no signs of decalcification or other changes (Fig. 2, 3). Image analyses also showed that the level of calcification was 100% from layers close to the surface. For maltitol, though the level of calcification of the surface layer was low, there was no sign of a decrease in calcification. For flour, image analyses suggested that the level of calcification was almost 100%, though there was a drop in the level of calcification at a depth of 200  $\mu\text{m}$  (Fig. 4). Results were similar for SEM and CMR.

For sucrose and sucrose cookies, however, SEM and CMR revealed severe decalcification and CMR showed that, though there was no dramatic difference in the severity of subsurface decalcification, the greater the depth, the lower was the level of calcification.

### **3. Questionnaire Evaluation**

Questionnaire results revealed that subjects perceived the two types of cookies as differing in sweetness. More than twice as many respondents felt that sucrose cookies were “sweeter” than maltitol cookies. However, there was almost no difference between the two types in terms of ease of mastication or ease of swallowing (Fig. 5). Having eaten both types of cookie, 83% of subjects answered “Yes” to the question “Would you buy cookies containing maltitol as an alternative sweetener if they were available for purchase?” When asked to give their reasons, their answers included “To prevent dental caries”, “I’d like to recommend them to family and friends”, and “They tasted delicious” (Fig. 6).

## Discussion

We used maltitol (a leading alternative sweetener to sugar) as an ingredient in cookies with the aim of producing a new anti-cariogenic food that might improve the QoL of elderly people. We carried out a comparative investigation of the effects of the bacteria in saliva on tooth enamel using test samples containing maltitol, sucrose and other cookie ingredients, as well as asking subjects to eat baked cookies and evaluate them by means of a questionnaire.

We found that neither maltitol nor the other cookie ingredients incurred subsurface decalcification of enamel, whereas sucrose caused severe decalcification.

Questionnaire results showed that, though maltitol cookies were less sweet than standard cookies, they were very similar in terms of ease of mastication and ease of swallowing. More than 80% of subjects said that they would like to purchase them, suggesting that maltitol-containing cookies may be valuable foods for the prevention of tooth decay. This type of cookie would be expected to be valuable food for elderly subjects because their teeth carry high risks for caries.

In general, the capacity for food to induce caries is evaluated in terms of its action as a substrate for oral function, and is assessed according to its ability to form plaque and generate acids<sup>12,13</sup>). Foods that contain no sucrose (such as those made with alternative sweeteners) do not result in the synthesis of insoluble glucans, so there is no need to

evaluate their plaque-forming capacity<sup>14</sup>). Therefore, we analyzed decalcification of the enamel subsurface as a result of acid production. Several studies that have investigated the effect of bacteria on enamel have focused on specific types of bacteria. However, the present study concerned food, so we used whole saliva because this approximated the oral environment most closely.

In immersion experiments, pH measurements revealed no change resulting from saliva alone or saliva with cookie ingredients other than sucrose and maltitol. However, there was a slight decrease in saliva pH with maltitol or maltitol-containing cookies, and a large decrease in saliva pH with sucrose or sucrose-containing cookies. In general, dental caries occur if organic acids are produced as the metabolic products of oral bacteria, causing teeth decalcification. *Streptococcus mutans* in saliva is known to be a strong generator of acids; it synthesizes exopolysaccharides from sucrose and contributed to colonization of the tooth surface<sup>15,16</sup>). The drop in pH due to sucrose and sucrose-containing cookies seen in the present study may have been due to *S. mutans* using sucrose and producing acids. Maltitol is an alternative sweetener that is non-cariogenic because it is not metabolized by *S. mutans*<sup>17</sup>), as shown by a smaller drop in pH compared with sucrose. The reason that it decreased pH more than saliva alone (or the other ingredients required for making cookies) may have been resident microbiota that utilize xylitol and other alternative sweeteners<sup>18</sup>). This observation

suggests that the saliva of subjects may have contained bacteria sensitive to alternative sweeteners.

We used SEM, CMR and image analyses to assess the effects on enamel caused by bacteria in saliva with various test substances. Sucrose and sucrose-containing cookies caused severe decalcification, whereas there was almost no evidence of decalcification due to maltitol, maltitol-containing cookies, or the other ingredients required for making cookies. Maltitol is a disaccharide alcohol composed of glucose and sorbitol. Studies have found that it is not decomposed into these components in the human body, and, therefore, is not absorbed<sup>19)</sup>. According to Izumiya et al., because maltitol is not fermented or decomposed by any of the major strains of *Streptococcus* in plaque or saliva, it cannot produce acids. Würsch and Koellreutter also found that maltitol and maltotriitol inhibit acid production by blocking the hydrolysis of reduced dextrin<sup>20,21)</sup>. These reasons also explain why maltitol and maltitol-containing cookies caused almost no decalcification of the enamel surface in our experiments. In contrast to maltitol, sucrose is a disaccharide composed of glucose and fructose. Sucrose is taken up by bacteria such as *S. mutans*, where it is decomposed and produces organic acids. The organic acids generated induce enamel decalcification<sup>14, 22)</sup>, leading to the results seen in our study. Flour is a polysaccharide that is believed to produce plaque, but its ability to produce acids and induce caries is only one-third to one-quarter that of sucrose<sup>23–25)</sup>,

and our results are in accordance with such data. The slight decalcification caused by maltitol-containing cookies may have stemmed from the same cause. There was no correlation, however, between the small drop in pH due to maltitol and maltitol-containing cookies described above and decalcification. It is likely that, though bacteria in saliva were sensitive to alternative sweeteners and produced some acids, the amount was small and they acted on enamel for only a very short time. One of the characteristics of elderly subjects is the likelihood of dental caries. In addition, food residue collects readily because of reductions in function in the oral cavity. A caregiver of an elderly individual usually has a heavy workload, and ensuring sufficient time for oral hygiene can be very difficult. Therefore, sucrose included in the food residues in the mouths of elderly subjects is transmitted by Streptococcus and forms a plaque as a nourishment source. However, plaque formation will not occur with maltitol-containing foods because the synthesis of insoluble glucans does not occur. And also, critical pH of the exposed root surfaces of the elderly is said to be similar to the baby teeth high, it is said that the cause root caries is higher in the elderly. Maltitol does not occur reduction in the severity of pH for not be bacteria-mediated. Thus, maltitol could be used in foods given to elderly individuals. Questionnaire results showed that the two types of cookie differed in terms of sweetness. Maltitol is the closest alternative sweetener to sucrose in terms of

sweetness. Maltitol is perceived immediately to have a clean flavor with no aftertaste, and provides a crisp, sweet taste. The fact that its sweetness is  $\approx 80\%$  that of sucrose is consistent with the answers concerning sweetness in our questionnaire<sup>26, 27</sup>).

Sucrose containing cookies were rated slightly higher with respect to ease of mastication and ease of swallowing, but this difference was not significant. If maltitol is used in cookies, it causes horizontal spreading in the same way as sucrose does when the dough is first heated such that, after baking, the cookies “spread out” on the baking sheet. Then, the dough rises vertically, but this occurs later than horizontal expansion on heating, making the finished cookies thicker. Okita et al. found that, if maltitol was used in cookie dough, the tensile strength of the dough increased, and the high physical properties of wet gluten meant that hard gluten was formed, which was reflected in the hardness and breaking properties of the cookie dough<sup>27</sup>). Those findings suggest that maltitol provides cookies with just the right degree of hardness and “crumbliness”.

Maltitol as an ingredient has been reported in several studies to be the sweetest of the various alternative sweeteners, so we hypothesized that it would be the best confectionery ingredient for making cookies. The fact that maltitol-containing cookies were so easy to masticate and swallow will also make them extremely useful for elderly people with suboptimal swallowing function.



When asked “Would you buy cookies containing maltitol as an alternative sweetener if they were available for purchase?”, 83% of subjects answered “Yes”. Their reasons for this positive response were “To prevent dental caries”, “I’d like to recommend them to family and friends” and “They tasted delicious”.

In recent years, the birthrate in Japan has been declining and the population is aging rapidly, resulting in a change in policy away from prioritizing treatment to emphasizing prevention in light of the “8020 Campaign” (for individuals to retain  $\geq 20$  of their own teeth up to the age of 80 years). Achievement of this goal will require lifestyle habits to become established by the time children attend school. Studies have shown high levels of awareness regarding the need for dental care among family members and staff at long-term care facilities. Our finding that subjects were aware of the need to prevent dental caries is in accordance with those results<sup>28-31</sup>.

Maltitol-containing cookies could be valuable food for elderly people due to their anti-cariogenic effects and because they meet their taste preferences. Consideration of their effects on health, however, must also take into account that use of flour caused a moderate drop in pH, and that such cookies contain fat. It may be necessary to improve their value for elderly people further by measures such as using soy pulp as a flour substitute or including functional oils. We intend to investigate such possibilities in future studies.

## **Conclusion**

Our results suggest that maltitol-containing cookies may be valuable foods for preventing tooth decay (a major problem in elderly subjects).

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Fig. 1 Measurements of salivary pH before and after immersion (a): a = egg yolk; b =



flour; c = baking powder; d = unsalted butter; e = whole saliva; (b): a = maltitol; b = sucrose; c = maltitol cookies; d = sucrose cookies)

Fig. 2 SEM analyses (bar = 200  $\mu\text{m}$ ; a = egg yolk; b = flour; c = baking powder; d = unsalted butter; e = whole saliva; f = maltitol; g = sucrose; h = maltitol cookies; I = sucrose cookies)

Fig. 3 CMR analyses (bar = 100  $\mu\text{m}$ ; a = egg yolk; b = flour; c = baking powder; d = unsalted butter; e = whole saliva; f = maltitol; g = sucrose; h = maltitol cookies; I = sucrose cookies)

Fig. 4 Image analyses (a = egg yolk; b = flour; c = baking powder; d = unsalted butter; e = whole saliva; f = maltitol; g = sucrose; h = maltitol cookies; I = sucrose cookies)

Fig. 5 Questionnaire results: Comparison of sweetness, as well as ease of mastication and ease of swallowing

Fig. 6 Willingness and reasons to purchase cookies containing an alternative sweetener (a = to prevent dental caries; b = would like to recommend them to others; c = they were delicious; d = other)

高齢者向け食品としてのマルチトール含有クッキーの有用性

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## 抄録

目的：

口腔清掃が十分に行えない要介護者などをはじめとする齲蝕感受性の高い高齢者にとって QOL を保証, 提供できる食品製作が期待される. そこで本研究では, 主要な代用甘味料の一つであるマルチトールに着目し, マルチトール含有クッキーを作製し, エナメル質表層の石灰化程度に及ぼす影響と試作したクッキーについてアンケート調査を行った.

材料と方法：

矯正的理由に抜去された健全な小臼歯からエナメル質ブロックを作製し, 試験試料とした. 任意の被験者より 450ml の唾液を採取し, 唾液のみ, 唾液に 5% マルチトール, 5% スクロース, 小麦粉, バター, 卵黄, ベーキングパウダー, マルチトール含有クッキー生地, スクロース含有クッキー生地をそれぞれ添加した物を作製し, それらにエナメル質ブロックを入れ, 37°C の恒温器内で 1 週間浸漬した. 浸漬前後の pH を測定するとともに SEM, CMR による表面観察, 石灰化程度の解析を行った. また, 健常成人 102 人に二重盲検法にて摂食させアンケートに回答させた.

結果：

唾液のみ，5%マルチトール，小麦粉，卵黄，バター，ベーキングパウダーではほぼ脱灰像を認めなかった．5%スクロース，スクロース含有クッキー生地では著しい脱灰を認めたもののマルチトール含有クッキー生地ではほぼ脱灰を認めなかった．また，アンケート結果ではマルチトール含有クッキーは甘みが足りないという意見があったもの咀嚼しやすさや嚥下しやすさには満足度が高く，多くの方が購入したいと答えた．

結論：

以上の結果から，マルチトール含有クッキーが高齢者の QOL を向上させる可能性のある食品として有用であることが明らかとなった．

**Keyword：** 砂糖代用甘味料，マルチトール，脱灰

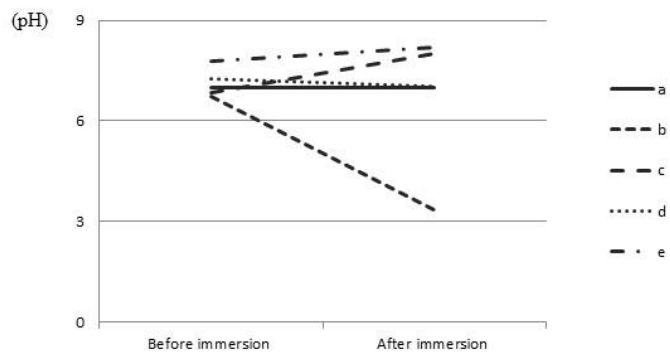


Fig. 1

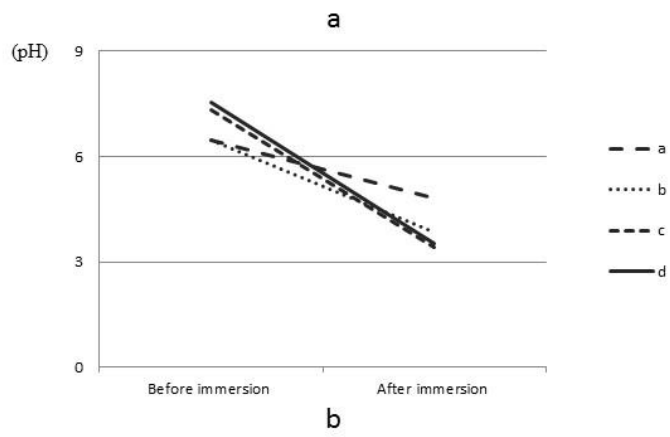


Fig. 2

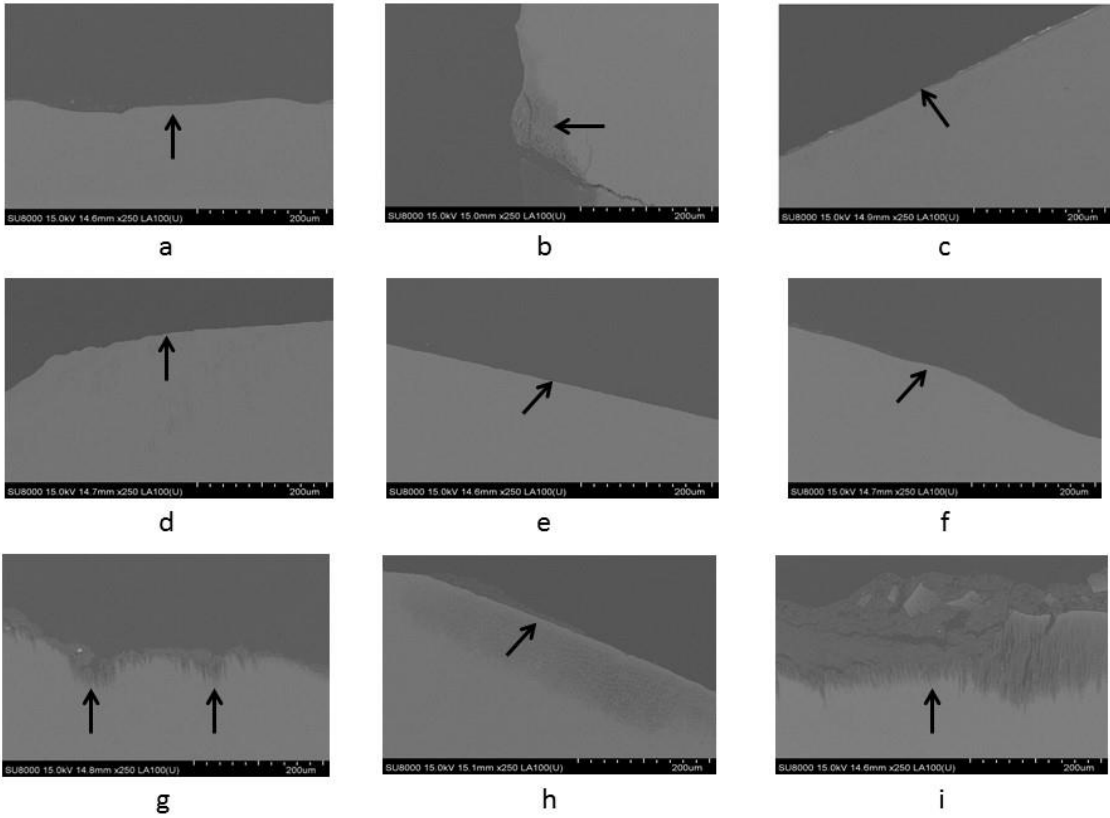
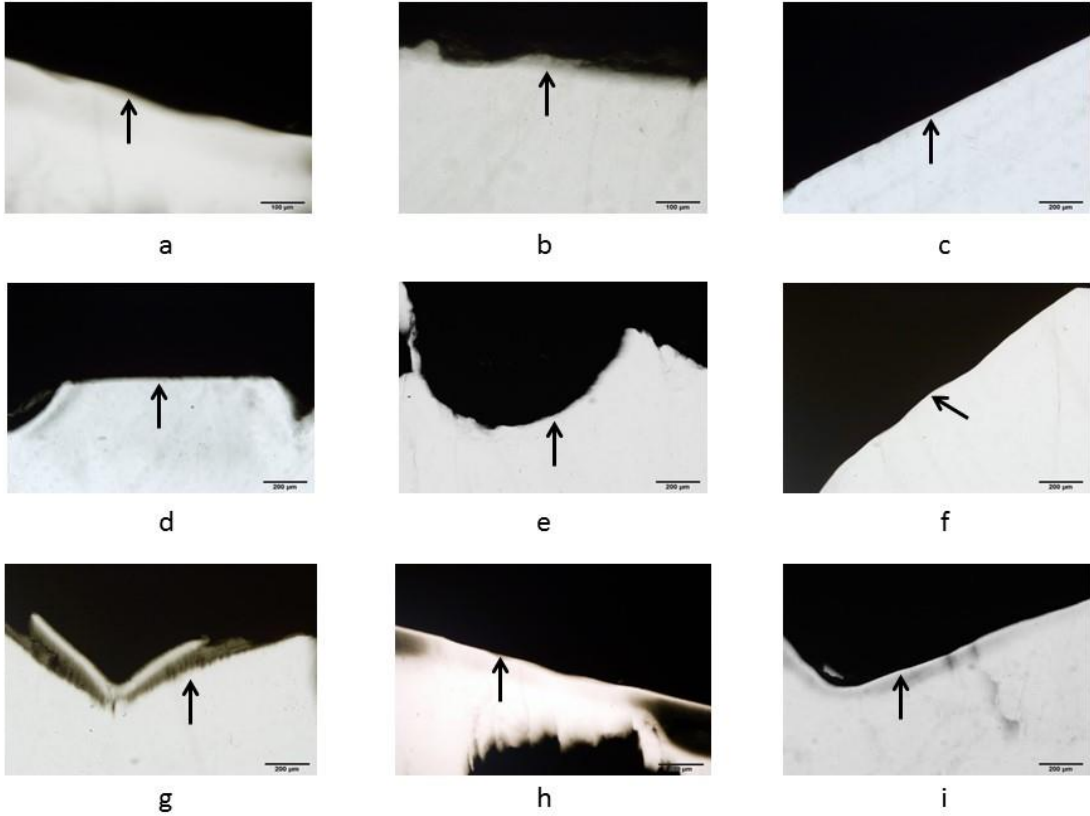


Fig. 3



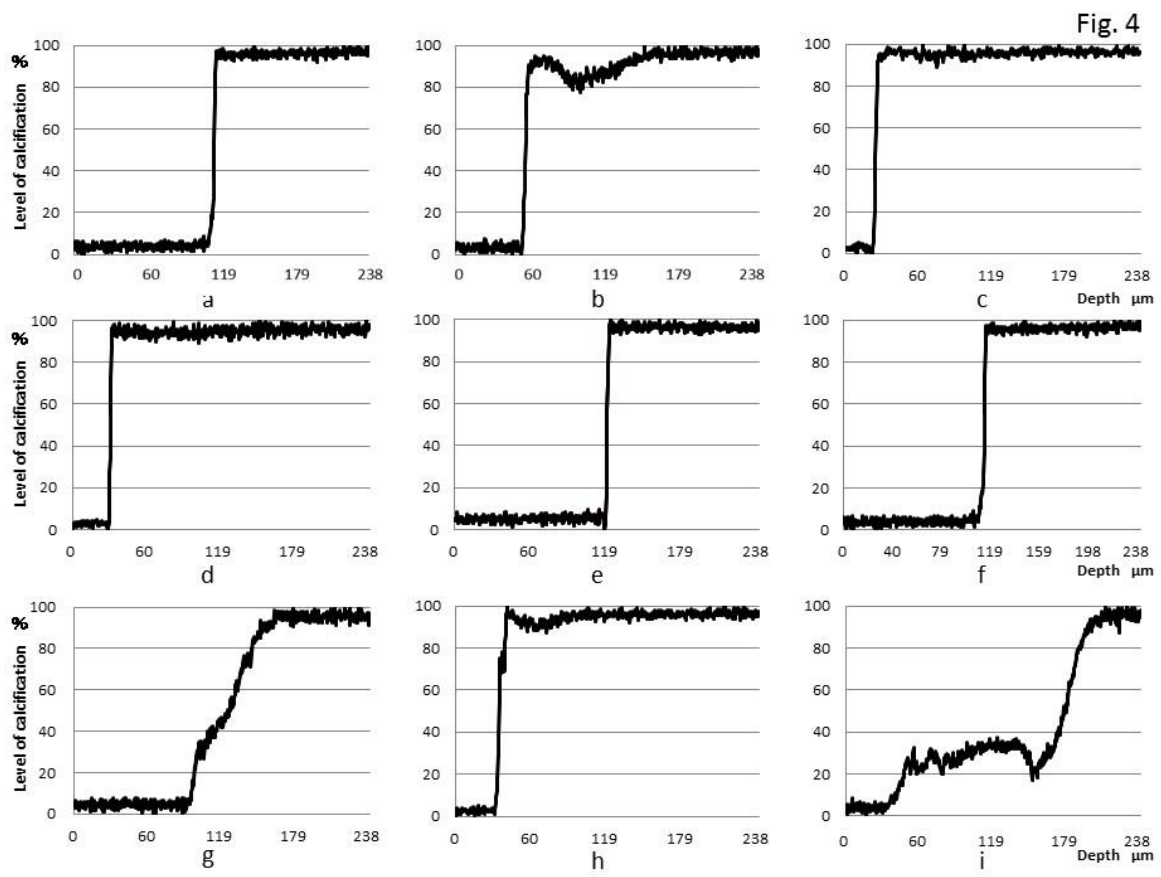




Fig. 5

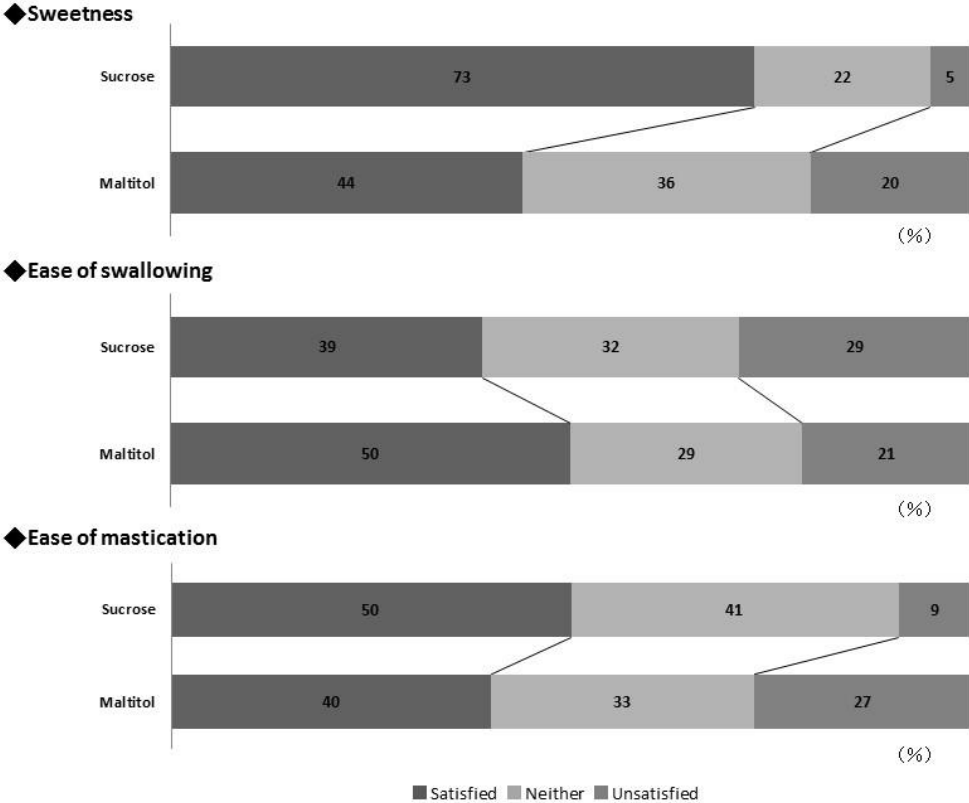
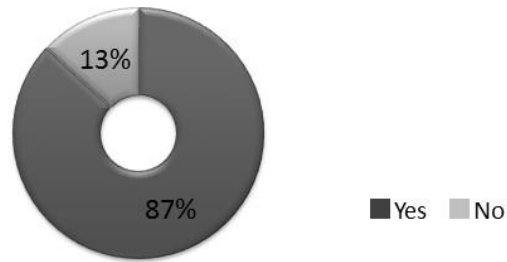


Fig. 6

**"Would you buy cookies containing maltitol as an alternative sweetener if they were available for purchase?"**



**Question : Please put a circle to the appropriate choice .**

