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The Difference of Plaque Acidity between Chewing Sucrose Dark Chocolate and Xylitol Dark Chocolate in Children aged 10-12 Years

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Abstract

Purpose: This study aims to determine the difference of plaque acidity between chewing sucrose dark chocolate and xylitol dark chocolate in children aged 10-12 years.
Methodology: Quantitative research using by a quasi-experimental with a non-equivalent control group design. Twenty-one children had their plaque acidity measured before and after chewing sucrose dark chocolate and xylitol dark chocolate. Measurement of the plaque acidity before chewing sucrose and xylitol dark chocolate was carried out by taking plaque samples using an excavator on the buccal, palatal, or lingual, and proximal surfaces of the first permanent molars, then dissolving them in a test beaker containing 2.5 ml of deionized water. Measurement of the degree of plaque pH is carried out using a pH meter which is measured three times and the final result is obtained from the average. The same procedure was carried out to measure the degree of plaque acidity after 20 minutes of chewing sucrose and xylitol dark chocolate. The measurement results were analyzed using the independent t-test.
Results: Data analysis was carried out using an independent t-test and tabulated using SPSS 22. There was a significant difference in plaque acidity between subjects who chewed sucrose dark chocolate ($\bar{x}$ = 6.2794 ± 0.11425) and xylitol dark chocolate ($\bar{x}$ = 6.4079 ± 0.10269).
Applications/Originality/Value: The difference between this study and previous research is this study measured differences in the degree of plaque acidity in subjects who chewed sucrose dark chocolate and xylitol dark chocolate the measurement time was used as a variable.

Introduction Section

Elementary school-age children, which is 6-12 years, are very susceptible to dental caries. According to Riskesdas 2018, shows the results that the largest prevalence of dental disease cases in Indonesia is cavities (45.3%). Children aged 10-14 years have a prevalence of cavities of 73.4% (Husen, *et al.,* 2022). This can be influenced by children's eating habits who like to eat sweet and sticky foods. Generally, at this age, children still pay little attention to their dental health (Pariati, 2021).

School-aged children need to receive more intensive care regarding dental health. Between the age of 6 and 12 years old, children will gradually lose their primary teeth and the first permanent teeth begin to erupt (6-8 years). The newly erupted teeth are not yet mature so they are susceptible to damage (Idaryati, *et al*., 2021).

The most popular sweet food is chocolate. There are many types of processed chocolate products, one of which is dark chocolate. Dark chocolate is made from pure cocoa beans which have additional ingredients such as lecithin, cocoa butter, and sweeteners. Pure cocoa beans have good benefits for teeth because they contain theobromine (Durhan, *et al.,* 2021). Research conducted on hamsters showed that pure cocoa powder containing theobromine can inhibit the development of dental caries. Theobromine compound can improve the quality of enamel crystals by binding capabilities calcium and phosphate to increase remineralization ability tooth enamel (Durhan, *et al.,* 2021). The amount of theobromine content in cocoa powder depends on the quality and type of cocoa pod, usually between 1.2% - 2.4%. Theobromine concentration was found to be higher in processed dark chocolate than in chocolate mixed with milk (Sudharsana, *et al.,* 2014).

There are various forms of consuming chocolate, for example by chewing and sucking. Chewing is the process of mechanical destruction of food that occurs in the mouth which involves the strength of the mastication muscles, teeth, and biting pressure which provides a self-cleansing effect (Yusro, *et al*., 2021). Chewing food well on both sides. If chewing is done only on one side, the other side that is not used can accumulate the plaque (Yusro, *et al*., 2021).

The high incidence of tooth decay in school children is because children like snacks that contain sugar, such as chocolate, candy, bread, lollipops, cotton candy, and crackers. Many people associate chocolate with the process of dental

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caries because it contains the sweetener sucrose as a cariogenic substance which can cause the process of demineralization of hard tissue (Garrido, *et al*., 2016). The frequency of exposure to cariogenic substances affects the duration of caries because after consuming snacks, bacteria in the mouth convert sugar into acid products, thereby reducing the acidity of plaque. Over the time, the degree of plaque acidity returns to normal values due to the salivary buffering capacity and the presence of dissolved mineral content from the tooth surface (Listrianah, 2017).

Bacteria in the oral cavity that accumulate in plaque have an important role in the process of demineralization of hard tooth tissue. Plaque is a soft, colorless deposit which is a collection of bacteria dominated by Streptococcus mutans which then forms a biofilm layer. The location of plaque is usually tightly attached to the tooth surface (Karyadi, et al., 2021. These bacteria will decompose the substrate and cause a decrease in plaque acidity. This condition will cause enamel demineralization and forms white spot lesions which indicate the start of the caries process (Subekti, *et al*., 2019).

A prolonged decrease in acidity will accelerate the demineralization of hard tooth tissue. The critical value that occurs is below 5.5. The degree of plaque acidity is closely related to the development of caries, namely the hard tissue demineralization when the degree of environmental acidity falls below 5.5. The value of the local acidity degree of caries is around 4.5 – 5.5, while in physiological conditions, the acidity degree of saliva ranges from 6.2 – 7.6 (Wang, *et al*., 2023).

An alternative non-cariogenic natural sweetener that can be used as an ingredient in making dark chocolate is xylitol. Xylitol is a sugar alcohol that comes from fibrous materials such as fruits and vegetables (Mansour, 2018). A food preparation with the addition of xylitol that is well known to the public is xylitol chewing gum. Xylitol cannot be broken down into acid by microorganisms in the oral cavity so that levels of *Streptococcus mutans* in plaque and saliva will decrease (Nuraini, et al., 2021; Janakiram, 2017).

Therefore, the author aims to examine the differences in the plaque acidity between chewing sucrose dark chocolate and xylitol dark chocolate in children aged 10-12 years. Children aged 10-12 years were chosen because at that age they are psychologically more cooperative when given instructions so it will make the research easier, and also at that age children is in the mixed dentition period so their teeth are prone to damage. The author hopes that this research can provide readers with a reference regarding sweeteners that have a good effect on teeth and can prevent teeth from enamel damage (caries).

METHODS

Research design

This quantitative research uses a quasi-experimental type (quasi experiment), which has a control group, but its role cannot fully control other factors that influence the research (Millera, et al., 2020). The research design used was nonequivalent control group design. This design was carried out in two stages, namely before and after treatment was given.

Time and place of research

This research was carried out in October - November 2023. The chocolate used for the research was made at the Bodag Chocolate Production House, Madiun, East Java. The consideration for choosing a chocolate production house is based on the fact that Madiun Regency is one of the cocoa bean producing centers and there is guidance carried out for Small and Medium Enterprises (SMEs) in the plantation sector which is in accordance with the objectives of the research object. Treatment of research subjects who consumed sucrose chocolate and xylitol chocolate was carried out on students at Muhammadiyah 1 Ketelan Elementary School, Surakarta.

Sample/Subject/Object

Samples were taken using a purposive sampling technique. The subjects were children aged 10-12 years at Muhammadiyah Ketelan Elementary School, Surakarta. The same treatment was given to subjects who consumed sucrose chocolate and xylitol chocolate. Subjects are controlled by categorizing them according to inclusion criteria.

The inclusion criteria are:

1. Children aged 10-12 years
2. Have at least 25 teeth with erupted permanent posterior teeth
3. Teeth do not have caries
4. Do not have allergies to chocolate
5. Do not have systemic disease
6. Not currently undergoing orthodontic or prosthetic treatment
7. Willing to follow research procedures with parental permission
8. Cooperative

The objects in this research were dark chocolate sweetened with 30% sucrose and dark chocolate sweetened with 30% xylitol, each weighing 3 grams. The addition of 30% sucrose sweetener in this research was obtained from the results of a survey regarding the concentration of dark chocolate with sucrose sweetener which is most popular and whose taste is acceptable to the public was conducted at the Bodag (Madiun), Ndalem (Yogyakarta), and Monggo (Yogyakarta)

Chocolate Production Houses. The use of 30% xylitol sweetener in this research is based on previous research that a concentration of 30% have a desired effect (Kaswindiarti, *et al*., 2017).

Research Preparation

The research proposal was submitted to the Health Research Ethics Committee of Dr. Moewardi General Hospital, Surakarta to obtain approval for ethical clearance. Requests for research permission were submitted to the Dean of the Faculty of Dentistry, Muhammadiyah University of Surakarta, and the Principal of Muhammadiyah Ketelan Elementary School, Surakarta. After obtaining an ethical clearance letter from the Health Research Ethics Committee of Dr. Moewardi General Hospital and permission from the school, screening was carried out on students who met the research inclusion criteria. A total of 21 subjects who met the inclusion criteria were then given informed consent in the form of letters of permission to participate in research subjects to their parents. Informed consent contains an explanation of the aims and objectives of the research, procedures, benefits, and risks that may occur during the conduct of the research. This informed consent is given in written form.

The research used dark chocolate sweetened with 30% sucrose and dark chocolate sweetened with 30% xylitol with a weight of 3 grams each. Chocolate is made at the Bodag Chocolate Production House, Madiun, East Java. The composition used is cocoa beans, cocoa butter, lecithin, sucrose, and xylitol which are formulated in the following table.

Table 1. Dark chocolate composition formulations

Material	Function	Formulation (in %)	
		Glucose	Xylitol
Chocolate paste	The main ingredient	59,65	59,65
Sugar	Sweetener	30	30
Lecithin	Emulsifier	0,35	0,35
Cocoa butter	Chocolate consistency and creates a better taste	10	10
	Total	**100**	**100**

Research implementation stage

On the first day of the research, preparations were made for the research subjects. If the children have calculus, then the oral cavity is cleaned to create the same condition of the subject's oral cavity (OHI=0) by scaling carried out by the dental profession (co-assistent) at Muhammadiyah University of Surakarta. Subjects were also instructed not consume anything except water for 30 minutes before the study.

The first stage of the research was to measure the degree of plaque acidity (pH) before chewing sucrose chocolate, which was done by taking plaque samples using an excavator on the buccal, palatal or lingual, and proximal surfaces of the first permanent molars, then dissolving them in a test beaker containing 2.5 ml of deionized water. Measurement of the degree of plaque acidity using a pH meter which has previously been calibrated by buffer solution of pH 4 and 7. The pH number will appear directly after a few moments from the pH meter-monitor. The degree of plaque acidity was measured three times and the results obtained were the average of the measurement results (Sofrullah, *et al*., 2021).

The next stage was to distribute sucrose chocolate weighing 3 grams to the subject by chewing on both sides for 60 seconds until finished. Furthermore, to obtain a significant reduction in the degree of plaque acidity at 20 minutes, the subject was instructed to sit quietly in a chair. Activities that the subject may do are light activities, such as reading a book. Subjects were prohibited from doing activities that could stimulate saliva, such as running around or watching videos, because this could affect the research results. Twenty minutes later, the plaque was taken which was dissolved in 2.5 mL deionized water and then the plaque acidity (pH) was measured using a pH meter. Measurement of the plaque acidity using a pH meter which has previously been calibrated by buffer solution of pH 4 and 7. The pH number will appear directly after a few moments from the pH meter monitor reading. The degree of plaque acidity was measured three times and the results obtained were the average of the measurement results (Sofrullah, *et al*., 2021).

The next day, we measured the plaque acidity when chewing xylitol dark chocolate. The research began with subject preparation on the first day and continued with measuring the degree of plaque acidity before chewing xylitol dark chocolate using the same procedure. In the next stage, subjects were given treatment to chew 3 grams of xylitol dark chocolate using both sides for 60 seconds, and the same plaque sampling and measurement procedures were carried out as on the first day.

RESULTS

The results of research regarding the degree of plaque acidity between chewing sucrose dark chocolate and xylitol dark chocolate in children aged 10-12 years showed that there was a significant difference. There was a greater reduction in the degree of plaque acidity in subjects who consumed sucrose dark chocolate compared to those who consumed xylitol dark chocolate. Data analysis to assess the difference in the degree of plaque acidity between chewing sucrose dark chocolate and xylitol dark chocolate used the parametric independent T-test because the data was normally distributed

(p>0.05). The average degree of plaque acidity before chewing sucrose dark chocolate was 6.6222 ± 0.13137 and after chewing chocolate was 6.2794 ± 0.11425 and the difference between before and after chewing sucrose chocolate was 0.3429 ± 0.08508 (Table 2). The average degree of plaque acidity before chewing xylitol dark chocolate was 6.6643 ± 0.10359 and after chewing xylitol chocolate was 6.4079 ± 0.10269 and the difference between before and after chewing xylitol chocolate was 0.2563 ± 0.07197 (Table 2). The results showed that there was a significant difference in the degree of plaque acidity between chewing sucrose dark chocolate (0.3429 ± 0.08508) and chewing xylitol dark chocolate (0.2563 ± 0.07197) with a significance of $p \leq 0.05$ (Table 2).

Table 2. Mean and Standard Deviation and Independent T-test Difference in Degree of Plaque Acidity between Chewing Sucrose Dark Chocolate and Xylitol Dark Chocolate in Children Aged 10-12 Years

Treatment group	Variable (unit)	N	Average before ($\bar{x} \pm SD$)	Average after ($\bar{x} \pm SD$)	Difference ($\bar{x} \pm SD$)	Sig.
Sucrose Chocolate	Degree of Plaque Acidity	21	6,6222 ± 0,13137	6,2794 ± 0,11425	0,3429 ± 0,08508	0,001
Xylitol Chocolate		21	6,6643 ± 0,10359	6,4079 ± 0,10269	0,2563 ± 0,07197	

DISCUSSION

Based on the research results, there was a greater reduction in the degree of plaque acidity in subjects who chewed sucrose dark chocolate than in subjects who chewed xylitol dark chocolate, and there was a significant difference in the two groups (p-value = 0.001). Chewing dark chocolate which contains the sweeteners sucrose and xylitol can reduce the acidity of dental plaque, this is because chewing chocolate, which is sticky in nature, can stick to the surface of the teeth so it can affect the acidity of dental plaque. However, subjects who chewed dark chocolate containing xylitol had a smaller decrease in the degree of dental plaque acidity than subjects who chewed sucrose dark chocolate. This is because xylitol cannot be fermented by plaque bacteria and is supported by saliva flow which is stimulated by double-sided chewing which can increase saliva buffers which can neutralize the acidity of dental plaque.

The results of this research show compatibility with research that has been conducted previously, research on chewing gum containing xylitol on the acidity of dental plaque, which is the xylitol gum cannot be fermented by bacteria, so the reduction in plaque acidity that occurs is not that great (Wu, *et al*. (2021). The addition of 30% xylitol sweetener composition in this study was able to have an effect on inhibiting the formation of bacteria which caused a decrease in the degree of dental plaque acidity (Kaswindiarti, *et al*., 2017).

The mechanism of action of xylitol in tooth defense is to disrupt the growth of *Streptococcus mutans* in plaque and saliva by interfering the bacterial metabolism in the formation of polysaccharides so it can stop the decrease of the plaque acidity (Xin, *et al*., 2016). Mansour (2018) stated that xylitol sweetener also helps repair enamel damage by stimulating saliva production through the cooling effect of xylitol which plays a role in self-cleaning. Saliva will play a role in providing protection to the tooth enamel layer. Another advantage of xylitol is that it is very suitable for consumption by diabetes sufferers and people with obesity (Mansour, 2018).

Sucrose is the most cariogenic type of carbohydrate because it can quickly cause the greatest biochemical and physiological changes in the formation of dental biofilm. Fermentable food products cause microorganisms in the teeth to produce acid which causes a decrease in the plaque acidity (Vasanthakumar, *et al*., 2016). Potentially acidogenic and aciduric bacteria can be found naturally in dental plaque. However, at neutral acidity levels, these organisms have weak competitive power so acid production by bacteria is not significant and the demineralization and remineralization processes are in balance. If the frequency of fermentable carbohydrate intake increases, it the oral cavity environment will be below critical acidity for longer (Fejerskov, *et al*., 2008).

The process of demineralization of enamel tissue leading to the development of dental caries occurs when the degree of plaque acidity decreases for a long time, to below 5.5. The degree of acidity (pH) is closely related to the development of caries, which is the demineralization of hard tissue when the pH is below 5.5 (Wang, et al, 2023). The degree of resting plaque acidity occurs 2 to 2.5 hours after the last carbohydrate intake and is in the range of 6 to 7. Bacteria that ferment carbohydrates cause the plaque acidity to decrease rapidly during the first 5 minutes and reach a minimum value after 5 to 20 minutes. The degree of plaque acidity will slowly return to the initial level within 30 to 60 minutes (Xin, *et al*., 2016).

The composition of dark chocolate combined with the sweetener xylitol produces a good effect on dental health. Dark chocolate is a processed food made from cocoa beans that does not use additional milk in its composition. The composition of dark chocolate consists of cocoa beans, cocoa butter, lecithin, and sweeteners (Nurhayati, *et al*., 2018). Cocoa beans, which are the main ingredient in dark chocolate, contain theobromine compound which has good benefits for teeth.

Theobromine (3,7-dimethylxanthine) is one of the main elements in cocoa beans and is found in high concentrations in processed dark chocolate (Lakshmi, *et al*., 2019). This compound can improve the quality of enamel hydroxyapatite crystals by binding calcium and phosphate to remineralize tooth enamel (Durhan, *et al*., 2021). Increasing the size of hydroxyapatite crystals produces tooth enamel that has high hardness, thereby increasing the enamel's resistance to acids, which prevents the demineralization process (Irmaleny, *et al*., 2017).

Research conducted by Bhat (2016) stated that dark chocolate containing more cocoa paste would have greater antimicrobial activity against Streptococcus mutans (Bhat *et al.*, 2016). The composition formulation in making dark chocolate in this research is based on previous research which showed that a chocolate paste concentration of 59.65% is considered to provide a good antioxidant effect on body health, including teeth (Nurhayati, *et al*., 2018). Dark chocolate also has lower acidogenicity which is probably due to the content of dark chocolate which can increase antioxidant levels and also has a higher concentration of unsaturated fatty acids such as oleic acid, fatty acids, palmitic acid, and stearic acid (Vasanthakumar, *et al.,* 2016).

This research showed that the choice of sweeteners in the food consumed by children is important for selection. Additional of xylitol as a sweetener alternate for sucrose has also been recommended by the US Food and Drug Administration (FDA) and the American Academy of Pediatric Dentistry (Nuraini, *et al*., 2021). If children's teeth are exposed to cariogenic substances too often and not balanced with good dental health habits, then the risk of dental caries in children may occur. Caries that do not receive treatment will progress to the dentin and even the pulp and can cause abscesses, which can cause a lot of pain and suffering. Treatment to relieve this pain is time-consuming and expensive, which may require students to take time off from school. This can create an imbalance in achievement and affect children's educational abilities (Shahzad, *et al*., 2020).

Therefore, based on the results of research that has been carried out on the differences in the degree of plaque acidity between chewing sucrose dark chocolate and xylitol dark chocolate in children aged 10-12 years, it is recommended that there be counseling or education for school children regarding xylitol dark chocolate for dental health that is carried out by health workers in coordination with teachers at school and begins to replace the habit of consuming sweet foods containing regular sucrose with sweet foods containing xylitol.

CONCLUSION

Based on the results of research regarding the difference in the degree of plaque acidity between chewing sucrose dark chocolate and xylitol dark chocolate in children aged 10-12 years at Muhammadiyah 1 Ketelan Elementary School, Surakarta, it can be concluded that there is a meaningful difference between the plaque acidity in subjects before and after chewing dark chocolate sucrose and dark chocolate xylitol. Subjects who consumed dark chocolate sweetened with sucrose showed a greater reduction in plaque acidity than subjects who consumed dark chocolate sweetened with xylitol.

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