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Natural Amelioration of Chocolate-Induced Acidity: The Role of Pineapple in Maintaining Oral pH Balance

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A B S T R A C T

The consumption of chocolate, especially varieties high in sugar, can disrupt the delicate pH balance in the oral cavity, increasing the risk of dental caries. Pineapple, with its rich enzymatic and organic acid profile, presents a potential natural solution to counteract this acidic challenge. This study investigates the efficacy of pineapple consumption in mitigating the pH-lowering effects of chocolate and its impact on saliva volume, a crucial factor in maintaining oral health. A quasi-experimental design with a pre-test and post-test control group approach was employed. Participants included children aged 6-9 years (n=40), divided into two groups: a control group (chocolate consumption only) and an intervention group (chocolate consumption followed by pineapple consumption). Saliva volume and pH were measured before and after treatment, and the data were analyzed using paired t-tests. Pineapple consumption significantly increased saliva volume in the intervention group (from 2.01±1.29 mL to 5.3±0.88 mL, $p<0.05$), exceeding the volume observed in the control group. Furthermore, the decrease in saliva pH in the intervention group (from 7.45±0.13 to 6.25±0.37) was more controlled compared to the control group (from 7.30±0.09 to 5.28±0.25). In conclusion, the consumption of pineapple after chocolate effectively stimulates saliva production and helps maintain a balanced oral pH, mitigating the acidic effects of chocolate and potentially reducing the risk of dental caries. These findings suggest the potential of pineapple as a natural, dietary approach to support oral health.

1. Introduction

Oral health, a cornerstone of overall well-being, is intricately linked to the maintenance of a balanced pH environment within the oral cavity. The delicate interplay between saliva, a dynamic biofluid with multifaceted protective functions, and dietary factors, particularly those with acidic potential, plays a pivotal role in preserving the integrity of teeth and the surrounding soft tissues. Disruptions in this balance, often triggered by the consumption of acidic foods and beverages, can initiate a cascade of events that compromise oral health, increasing the risk of dental caries and erosion. Saliva, a complex mixture of water, electrolytes, enzymes, and antimicrobial agents, acts as the first line of defense against acidic challenges. Its buffering capacity, primarily attributed to bicarbonate ions, helps neutralize acids produced by the metabolic activity of oral bacteria, preventing a sustained drop in pH that can lead to demineralization and the loss of mineral content from tooth enamel. Saliva also facilitates remineralization, the restoration of minerals to demineralized enamel, promoting the repair and maintenance of tooth structure.[1-3]

Chocolate, a widely consumed confection, presents a significant acidic challenge to the oral environment. Its high sugar content, particularly in varieties with

added sugars, fuels the metabolic activity of acidogenic bacteria, such as Streptococcus mutans and Lactobacillus species. These bacteria ferment sugars into organic acids, primarily lactic acid, lowering the pH of saliva and creating an acidic milieu that favors demineralization. The acidic environment can also promote the growth of acid-tolerant bacteria, further exacerbating the risk of caries development. Pineapple, a tropical fruit revered for its nutritional value and distinctive flavor, emerges as a potential natural modulator of saliva volume and pH. Its rich enzymatic profile, particularly the presence of bromelain, a proteolytic enzyme, suggests a potential role in stimulating salivary secretion. Bromelain has been shown to enhance exocrine gland function, promoting the production and flow of saliva, which contributes to the clearance of food debris and bacteria, dilution of acids, and support of remineralization processes.[4-6]

In addition to its enzymatic activity, pineapple contains organic acids, such as citric acid and malic acid, which may contribute to its buffering capacity. These acids, while contributing to the fruit's characteristic tartness, can also act as natural buffers, counteracting the acidity produced by the fermentation of sugars by oral bacteria. The buffering action of these acids helps maintain a more neutral oral pH, reducing the risk of enamel demineralization and caries development. The potential of pineapple to mitigate the acidic challenge posed by chocolate and promote a balanced oral environment has significant implications for oral health. By stimulating saliva secretion and controlling pH reduction, pineapple consumption may offer a natural, dietary approach to support oral health and caries prevention. This approach is particularly relevant for children, who are often more susceptible to caries development due to their higher intake of sugary foods and beverages.[7-10] This study aims to evaluate the effects of pineapple consumption on saliva volume and pH after chocolate consumption, exploring its potential as a natural strategy to maintain oral health. By elucidating the interplay between chocolate, pineapple, and salivary parameters, this research contributes to the development of dietary recommendations for caries prevention and promotes a holistic approach to oral health management.

2. Methods

This study employed a quasi-experimental design with a pre-test and post-test control group approach to rigorously evaluate the impact of pineapple consumption on saliva volume and pH following chocolate consumption. This design allowed for a direct comparison between a control group, exposed only to the acidic challenge of chocolate, and an intervention group, provided with pineapple as a potential mitigating agent. The study adhered to ethical guidelines, obtaining informed consent from parents and ensuring the comfort and cooperation of the participating children throughout the procedures.

The study was conducted among children aged 6-9 years, a demographic group particularly susceptible to dental caries due to their dietary habits and developing oral health behaviors. This age range was chosen to ensure comprehension of the procedures and cooperation with sample collection. Participants were recruited from a local elementary school, providing a representative sample of children within this age group. A total of 40 children were enrolled in the study, divided equally into two groups; Control Group (n=20): This group served as the baseline for comparison, consuming only chocolate to assess its impact on saliva volume and pH without any intervention; Intervention Group (n=20): This group consumed chocolate followed by pineapple, allowing for the evaluation of pineapple's potential to mitigate the acidic effects of chocolate and stimulate saliva production.

To ensure the validity and reliability of the study findings, specific inclusion and exclusion criteria were implemented; Inclusion criteria: Children were strictly within the age range of 6-9 years to maintain homogeneity within the sample and minimize variability due to developmental differences. Informed consent was obtained from parents or legal guardians of all participating children, ensuring ethical conduct

and transparency. Children were assessed for their ability to understand and comply with the study procedures, ensuring accurate and reliable data collection. Children were either caries-free or had a maximum of two caries to minimize the influence of pre-existing oral health conditions on the study outcomes; Exclusion criteria: Children absent during any of the sample collection sessions were excluded to maintain the integrity of the data and prevent missing values. Children using systemic medications were excluded to avoid potential confounding effects of medications on salivary parameters. Children with digestive disorders were excluded to prevent any influence of underlying health conditions on saliva production or composition. Children with allergies to pineapple or chocolate were excluded to prevent adverse reactions and ensure participant safety. Children with mouth sores were excluded to prevent discomfort during sample collection and ensure accurate pH measurements.

The study protocol was designed to minimize variability and ensure standardized conditions for both groups; Standardized Diet: Participants were instructed to refrain from eating or drinking anything except water for one hour prior to the study sessions to minimize the influence of prior food consumption on salivary parameters; Chocolate Consumption: Both groups consumed a standardized amount of 13.5 grams of milk chocolate, a commonly consumed type with moderate sugar content, to induce a controlled acidic challenge; Pineapple Consumption: The intervention group consumed 100 grams of fresh pineapple, a portion size considered sufficient to provide a noticeable enzymatic and buffering effect, five minutes after chocolate consumption; Time Intervals: Saliva samples were collected at specific time intervals: before chocolate consumption (baseline), five minutes after chocolate consumption, and, in the intervention group, five minutes after pineapple consumption. This timing allowed for the assessment of immediate changes in salivary parameters in response to the interventions.

Saliva samples were collected using standardized techniques to ensure accuracy and minimize variability; Stimulated Saliva Collection: Saliva production was stimulated by asking participants to chew on a piece of paraffin wax for one minute. This method promotes consistent saliva flow and ensures adequate sample volume for analysis; Sample Collection: Saliva was expectorated into graduated disposable beakers, allowing for direct measurement of volume; Volume Measurement: Saliva volume was measured in milliliters (mL) using the graduated markings on the beakers, providing a quantitative assessment of saliva production; pH Measurement: Saliva pH was measured using a calibrated digital pH meter. The pH meter electrode was carefully rinsed with distilled water and dried between measurements to prevent cross-contamination and ensure accurate readings.

The collected data were analyzed using SPSS software, a comprehensive statistical package widely used in health research. The following statistical tests were employed; Paired t-tests: These tests were used to compare saliva volume and pH within each group before and after treatment. This allowed for the assessment of changes in salivary parameters within each group in response to the interventions; Independent sample t-tests: These tests were used to compare the changes in saliva volume and pH between the control and intervention groups. This allowed for the evaluation of the differential effects of pineapple consumption on salivary parameters. The results of these statistical analyses provided a comprehensive understanding of the impact of pineapple consumption on saliva volume and pH following chocolate consumption, contributing to the evaluation of pineapple's potential as a natural strategy to support oral health.

3. Results and Discussion

Table 1 presents the baseline characteristics of the participants in the study, divided into the control group and the intervention group. The table aims to demonstrate the comparability of the two groups at the outset, ensuring that any observed differences in outcomes can be attributed to the intervention

(pineapple consumption) rather than pre-existing differences between the groups. Both groups had similar average ages (7.2 ± 0.8 years in the control group and 7.4 ± 0.7 years in the intervention group), and the difference was not statistically significant (p=0.63). This indicates that the groups were comparable in terms of age. The gender distribution was almost identical between the two groups, with a nearly even split between males and females. The Chi-square test confirmed no statistically significant difference (p=0.91). The average BMI was also similar between the groups (15.4 ± 2.1 in the control group and 15.1 ± 1.8 in the intervention group), with no statistically significant difference (p=0.52). This suggests that the groups were comparable in terms of nutritional status. The DMFT (Decayed, Missing, Filled Teeth) index, a measure of dental caries experience, was low and comparable in both groups (0.8 ± 0.5 in the control group and 0.9 ± 0.6 in the intervention group), with no statistically significant difference (p=0.75). This indicates that the groups had similar baseline oral health status. The table also shows the distribution of ethnicity, parental education level, and household income. While not all categories have exactly equal numbers, the Chi-square tests indicate no statistically significant differences between the groups in these characteristics (p=0.89, p=0.93, and p=0.85, respectively). This suggests that the groups were broadly comparable in terms of socioeconomic and cultural background.

Table 1. Participant characteristics.

Characteristic	**Control Group (n=20)**	**Intervention Group (n=20)**	**p-value**
Age (years)	7.2 ± 0.8	7.4 ± 0.7	0.63*
Gender (Male/Female)	11/9	10/10	0.91**
BMI (kg/m²)	15.4 ± 2.1	15.1 ± 1.8	0.52*
Caries status (DMFT)	0.8 ± 0.5	0.9 ± 0.6	0.75*
Ethnicity	- Malay: 1 - Minangkabau: 6 - Javanese: 2	- Malay: 10 - Minangkabau: 8 - Javanese: 2	0.89**
Parental education level	- High School: 8 - Bachelor's: 7 - Master's: 5	- High School: 7 - Bachelor's: 8 - Master's: 5	0.93**
Household income (IDR per month)	- < 5 million: 5 - 5-10 million: 9 - > 10 million: 6	- < 5 million: 6 - 5-10 million: 8 - > 10 million: 6	0.85**

DMFT = Decayed, Missing, Filled Teeth Index; *Independent T-test; **Chi-square test.

Table 2 presents the changes in saliva volume after chocolate consumption and, in the intervention group, after subsequent pineapple consumption. The table highlights the significant impact of pineapple on stimulating saliva production; Control Group: The control group showed a slight increase in saliva volume after chocolate consumption (from 1.92 ± 1.01 mL to 2.4 ± 0.7 mL). This change, while positive, was not statistically significant (p=0.02), suggesting that chocolate itself did not have a major impact on saliva flow; Intervention Group: The intervention group, which consumed pineapple after chocolate, demonstrated a substantial increase in saliva volume (from 2.01 ± 1.29 mL to 5.3 ± 0.88 mL). This change was statistically significant (p=0.00), indicating a clear effect of pineapple on saliva production; Comparison Between Groups: The difference in saliva volume change between the control and intervention groups was also statistically significant (p=0.00). This confirms that the increase in saliva volume observed in the intervention group was significantly greater than that in the control group, highlighting the specific effect of pineapple.

Table 2. Saliva volume.

Group	Pre-Test (mL)	Post-Test (mL)	Change (mL)	p-value (Pre vs. Post)*	p-value (Control vs. Intervention)**
Control	1.92 ± 1.01	2.4 ± 0.7	+0.48 ± 0.31	0.02	0.00
Intervention	2.01 ± 1.29	5.3 ± 0.88	+3.29 ± 0.41	0.00	-

*Dependent t-test; **Independent t-test.

Table 3 presents the changes in saliva pH after chocolate consumption and, in the intervention group, after subsequent pineapple consumption. The table illustrates the protective effect of pineapple in mitigating the pH drop caused by chocolate; Control Group: The control group experienced a substantial decrease in saliva pH after consuming chocolate (from 7.30 ± 0.09 to 5.28 ± 0.25). This drop was statistically significant (p=0.00), indicating that chocolate consumption created a more acidic environment in the mouth. This acidic shift is expected due to the fermentation of sugars in chocolate by oral bacteria, producing acids that lower the pH; Intervention Group: The intervention group also showed a decrease in saliva pH after chocolate consumption, but the decrease was less pronounced (from 7.45 ± 0.13 to 6.25 ± 0.37). This change was still statistically significant (p=0.00), indicating that chocolate had an acidic effect even with pineapple consumption. However, the magnitude of the pH drop was smaller than in the control group; Comparison Between Groups: The difference in pH change between the control and intervention groups was statistically significant (p=0.00). This indicates that the intervention group, which consumed pineapple, experienced a significantly smaller drop in pH compared to the control group. This suggests that pineapple effectively buffered the acidity produced by chocolate, helping to maintain a more neutral pH in the oral cavity.

Table 3. Saliva pH.

Group	Pre-Test	Post-Test	Change	p-value (Pre vs. Post)*	p-value (Control vs. Intervention)**
Control	7.30 ± 0.09	5.28 ± 0.25	-2.02 ± 0.16	0.00	0.00
Intervention	7.45 ± 0.13	6.25 ± 0.37	-1.20 ± 0.24	0.00	-

*Dependent t-test; **Independent t-test.

The human oral cavity, a dynamic ecosystem teeming with microbial life and influenced by dietary habits, is in a constant state of flux. Maintaining equilibrium within this environment, particularly the delicate balance of pH and the intricate interplay of enzymes and proteins, is crucial for preserving oral health. Pineapple, a tropical fruit celebrated for its vibrant flavor and nutritional richness, emerges as a surprising ally in this endeavor, wielding a secret weapon in its arsenal bromelain. Bromelain, a proteolytic enzyme abundant in pineapple, is often celebrated for its anti-inflammatory and digestive benefits. However, this remarkable enzyme possesses a hidden talent, the ability to stimulate exocrine gland function, including the salivary glands. This stimulation translates into a heightened production and flow of saliva, a critical component of the oral cavity's intricate ecosystem. The mechanism by which bromelain triggers this salivary response is a captivating tale of multifaceted enzymatic action, a symphony of molecular interactions that culminate in a surge of saliva, a protective wave that safeguards the oral environment. Bromelain is believed to increase the permeability of cell membranes, acting as a key that

unlocks the gates for the transport of water and electrolytes, the fundamental building blocks of saliva, into the salivary glands. This enhanced permeability facilitates a greater influx of these essential components, leading to a more abundant production of saliva within the glands. Bromelain's proteolytic activity, its ability to break down proteins, adds another layer to its saliva-stimulating effect. By cleaving specific proteins, bromelain may enhance the release of certain signaling molecules that trigger saliva secretion. These signaling molecules, acting as messengers, communicate with the salivary glands, prompting them to increase their production and release of saliva. Bromelain may also influence intracellular signaling pathways involved in saliva secretion. These pathways, intricate networks of molecular interactions, regulate the production and release of saliva in response to various stimuli. Bromelain's ability to modulate these pathways could further contribute to its saliva-stimulating effect. Bromelain's renowned anti-inflammatory properties may also play a role in its salivary influence. By reducing inflammation in the salivary glands, bromelain could optimize their function, allowing for a more efficient production and flow of saliva. This increase in saliva volume triggered by pineapple consumption initiates a cascade of protective mechanisms that contribute to a more robust oral defense system. The surge in saliva flow acts as a natural rinse, effectively washing away food debris and bacteria that cling to the tooth surfaces and gums. This mechanical clearance reduces the availability of substrates for acid-producing bacteria, mitigating the risk of plaque formation and subsequent acid attacks on enamel. Saliva, with its inherent buffering capacity, acts as a natural neutralizer of acids in the oral cavity. The increased saliva volume further enhances this buffering action, diluting the acids produced by bacterial fermentation of sugars and preventing a sustained drop in pH that can lead to enamel demineralization. This pH-stabilizing effect is crucial in maintaining the integrity of tooth enamel and preventing the initiation of caries lesions. Saliva is not merely a cleansing and neutralizing agent, it also plays a vital role in the remineralization process. Saliva carries essential minerals, such as calcium and phosphate, to the tooth surface, where they can be incorporated into demineralized enamel, strengthening and repairing weakened areas. The increased saliva flow induced by pineapple consumption ensures a continuous supply of these minerals, promoting the remineralization process and fortifying tooth enamel against future acid challenges. Saliva also contains a variety of antimicrobial agents, such as lysozyme and immunoglobulins, which help to control the growth and activity of harmful bacteria in the oral cavity. The increased saliva flow triggered by pineapple consumption enhances the delivery of these antimicrobial agents, further bolstering the oral defense system against bacterial threats. The saliva-stimulating effect of bromelain extends beyond its potential in promoting oral health. It also holds promise in addressing conditions associated with dry mouth, or xerostomia, a common side effect of certain medications and medical conditions. By promoting saliva production, bromelain could alleviate the discomfort and complications associated with dry mouth, improving quality of life for those affected. Furthermore, bromelain's influence on saliva production could have implications for wound healing in the oral cavity. Saliva contains growth factors that promote tissue repair, and the increased saliva flow induced by bromelain could accelerate the healing process of oral wounds and ulcers. The human oral cavity, a dynamic ecosystem teeming with microbial life and constantly challenged by dietary and environmental factors, possesses a remarkable defense system orchestrated by saliva. This complex biofluid, a dynamic blend of water, electrolytes, enzymes, and antimicrobial agents, acts as a vigilant guardian, diligently working to maintain oral health and prevent disease. Pineapple, a tropical fruit celebrated for its refreshing taste and nutritional value, emerges as a surprising ally in this endeavor, triggering a surge in saliva production that initiates a cascade of protective mechanisms, fortifying the oral

cavity's natural defenses. The surge in saliva flow induced by pineapple consumption acts as a natural rinse cycle, effectively washing away food debris and bacteria that adhere to the tooth surfaces and gums. This mechanical clearance, akin to a gentle tide, removes these potential troublemakers, preventing them from wreaking havoc on the oral environment. This cleansing action is particularly crucial after consuming sugary or acidic foods, which provide a feast for acid-producing bacteria. By swiftly removing these food remnants, the increased saliva flow reduces the availability of substrates for these bacteria, mitigating the risk of plaque formation and subsequent acid attacks on enamel. The mechanical clearance also extends to the gingival crevices, the spaces between the teeth and gums, where bacteria tend to accumulate. The enhanced saliva flow flushes out these hidden corners, reducing the risk of gingival inflammation and periodontal disease. Saliva, with its inherent buffering capacity, acts as a natural neutralizer of acids in the oral cavity. This buffering capacity, primarily attributed to bicarbonate ions and phosphate ions, helps to maintain a neutral pH, preventing the acidic environment that can lead to enamel demineralization. The increased saliva volume triggered by pineapple consumption further enhances this buffering action. The greater volume of saliva dilutes the acids produced by bacterial fermentation of sugars, preventing a sustained drop in pH that can compromise enamel integrity. This dilution effect is crucial in maintaining the delicate balance of the oral environment. This pH-stabilizing effect is crucial in maintaining the delicate balance of the oral environment. A neutral pH not only protects enamel from demineralization but also creates an unfavorable environment for acid-loving bacteria, reducing their ability to thrive and cause harm. Saliva is not merely a cleansing and neutralizing agent, it also plays a vital role in the remineralization process, the natural repair mechanism for tooth enamel. Saliva carries essential minerals, such as calcium and phosphate, to the tooth surface, where they can be incorporated into demineralized enamel, strengthening and repairing weakened areas. The increased saliva flow induced by pineapple consumption ensures a continuous supply of these minerals, promoting the remineralization process and fortifying tooth enamel against future acid challenges. This continuous replenishment of minerals helps to maintain the integrity of enamel, preventing the progression of early caries lesions and promoting the restoration of tooth structure. The oral cavity is a bustling metropolis of microorganisms, a diverse community of bacteria that coexist in a delicate balance. While some bacteria are beneficial, contributing to oral health, others are opportunistic pathogens, capable of causing harm when the conditions are favorable. Saliva plays a crucial role in maintaining this microbial balance, acting as a vigilant police force that keeps harmful bacteria in check. It contains a variety of antimicrobial agents, such as lysozyme, lactoferrin, and immunoglobulins, which help to control the growth and activity of these bacterial troublemakers. Lysozyme, an enzyme found in saliva, breaks down the cell walls of bacteria, effectively killing them. Lactoferrin, an iron-binding protein, deprives bacteria of the iron they need to grow and multiply. Immunoglobulins, antibodies produced by the immune system, bind to bacteria and neutralize their harmful effects. The increased saliva flow triggered by pineapple consumption enhances the delivery of these antimicrobial agents, further bolstering the oral defense system against bacterial threats. This enhanced antimicrobial action helps to prevent the overgrowth of harmful bacteria, reducing the risk of plaque formation, gingival inflammation, and dental caries. The findings of this study, demonstrating the remarkable impact of pineapple consumption on saliva production and oral pH balance, resonate with a growing body of research highlighting the critical role of saliva in maintaining oral health. Saliva, often overlooked in its importance, acts as a dynamic and multifaceted protector of the oral environment, a silent guardian diligently working to preserve the integrity of teeth and gums. Saliva, a complex biofluid composed of water, electrolytes, enzymes, proteins, and antimicrobial agents, is often

taken for granted. Yet, this seemingly simple fluid plays a pivotal role in maintaining oral health, acting as a natural buffer, a lubricant, a cleansing agent, and a carrier of antimicrobial agents. Saliva's inherent buffering capacity, primarily attributed to bicarbonate and phosphate ions, helps to neutralize acids produced by bacteria in the oral cavity, preventing a sustained drop in pH that can lead to enamel demineralization and caries formation. Saliva acts as a natural lubricant, coating the oral tissues and facilitating chewing, swallowing, and speech. This lubricating action also helps to protect the delicate oral mucosa from abrasion and irritation. Saliva's continuous flow helps to wash away food debris and bacteria, reducing the accumulation of plaque and the risk of caries and periodontal disease. This cleansing action also helps to remove toxins and other harmful substances from the oral cavity. Saliva contains a variety of antimicrobial agents, such as lysozyme, lactoferrin, and immunoglobulins, which help to control the growth and activity of harmful bacteria in the oral cavity. These antimicrobial agents contribute to maintaining a healthy oral microbiome and preventing infections. The stimulating effect of pineapple on saliva production adds another dimension to its potential benefits, suggesting that it can contribute to a more robust oral defense system. By enhancing saliva flow, pineapple consumption can amplify the natural protective mechanisms of the oral cavity, further bolstering its defenses against disease. The increased saliva flow induced by pineapple consumption helps to dilute and neutralize acids produced by bacteria, reducing the risk of enamel demineralization and caries formation. Saliva carries essential minerals, such as calcium and phosphate, to the tooth surface, where they can be incorporated into demineralized enamel, strengthening and repairing weakened areas. The increased saliva flow ensures a continuous supply of these minerals, promoting the remineralization process and fortifying tooth enamel against future acid challenges. Saliva plays a crucial role in maintaining a healthy balance of bacteria in the oral cavity. The increased saliva flow helps to distribute beneficial bacteria and antimicrobial agents throughout the mouth, preventing the overgrowth of harmful bacteria and reducing the risk of infections. The findings of this study align with a growing body of research highlighting the critical role of saliva in maintaining oral health. Numerous studies have demonstrated the protective effects of saliva against caries, periodontal disease, and other oral health issues. Saliva's buffering capacity, cleansing action, and remineralization support contribute significantly to caries prevention. Studies have shown that individuals with low saliva flow rates are at increased risk of caries development. Saliva also plays a role in preventing periodontal disease, an inflammatory condition that affects the gums and supporting structures of the teeth. Saliva's cleansing action helps to remove plaque and bacteria from the gingival crevices, reducing the risk of inflammation and infection. Saliva also contributes to wound healing in the oral cavity, taste perception, and speech articulation. Its lubricating action helps to protect the delicate oral mucosa from abrasion and irritation. The importance of saliva in maintaining oral health underscores the need for a holistic approach to oral care. This approach includes not only regular brushing and flossing but also dietary considerations that promote saliva production and a balanced oral microbiome. Pineapple, with its saliva-stimulating properties, emerges as a valuable dietary addition for promoting oral health. Incorporating pineapple into the diet, particularly after consuming acidic foods, can help to enhance saliva flow, amplify the natural protective mechanisms of the oral cavity, and contribute to a lifetime of healthy smiles.[11-14]

The human mouth is a dynamic environment, a bustling hub of microbial activity and dietary influences. Maintaining a balanced pH within this oral ecosystem is crucial for preserving the integrity of tooth enamel and preventing the onset of dental caries. Chocolate, a beloved indulgence, often presents a formidable acidic challenge to this delicate balance. However, pineapple, a tropical fruit celebrated for its vibrant flavor and nutritional richness, emerges as a

natural protector, a shield against the erosive forces unleashed by chocolate consumption. The pH scale, a measure of acidity or alkalinity, ranges from 0 to 14, with 7 being neutral. The oral cavity, ideally, maintains a slightly alkaline pH, typically between 6.5 and 7.5. This slightly alkaline environment favors the mineralization of tooth enamel, the deposition of minerals that strengthen and protect the teeth. However, the consumption of acidic foods and beverages, such as chocolate, can disrupt this delicate balance, tipping the scales towards acidity. When the pH of the oral cavity drops below 5.5, a critical threshold known as the "critical pH," enamel demineralization begins. This process involves the leaching of minerals from the tooth enamel, weakening its structure and making it more susceptible to erosion and caries formation. Chocolate, particularly varieties with high sugar content, poses a significant acidic challenge to the oral environment. The sugars in chocolate serve as a feast for acid-producing bacteria, such as Streptococcus mutans and Lactobacillus species, which reside in the oral cavity. These bacteria ferment the sugars, producing organic acids, primarily lactic acid, as byproducts of their metabolic processes. This surge of lactic acid lowers the pH of saliva, creating an acidic environment that can initiate the demineralization process. The extent of this pH drop depends on several factors, including the type of chocolate consumed, the frequency of consumption, and the individual's oral hygiene habits. Pineapple, with its rich content of organic acids, primarily citric acid and malic acid, acts as a natural buffer against the acidic onslaught of chocolate consumption. These organic acids, while contributing to the fruit's characteristic tangy taste, also possess the remarkable ability to neutralize acids, preventing a drastic drop in pH that can compromise enamel integrity. These organic acids function as weak acids, meaning they do not completely dissociate in solution. This property allows them to act as buffers, resisting changes in pH when acids or bases are added. When the pH of the oral cavity decreases due to the production of acids by bacteria, these organic acids step in, releasing hydrogen ions (H^+) to counteract the acidity and maintain a more neutral pH. This buffering action helps to create a less hospitable environment for acid-loving bacteria, reducing their ability to thrive and cause harm. It also helps to protect tooth enamel from demineralization, reducing the risk of caries development. The study demonstrated the efficacy of pineapple in mitigating the pH-lowering effects of chocolate. While chocolate consumption led to a significant decrease in saliva pH in both groups, the decrease was less pronounced in the intervention group, highlighting the protective effect of pineapple. This finding suggests that the organic acids in pineapple effectively neutralized the acids produced by the oral bacteria, preventing a drastic shift towards an acidic environment that can compromise enamel integrity. The buffering action of pineapple helped to maintain a more balanced pH, reducing the risk of enamel demineralization and caries development. The protective effect of pineapple extends beyond its buffering capacity. The fruit's unique composition and synergistic actions create a multifaceted shield against chocolate's acidity. The increased saliva flow induced by pineapple consumption, coupled with the buffering action of organic acids, enhances the clearance of food debris and bacteria, reducing the availability of substrates for acid production. This mechanical cleansing action further contributes to maintaining a balanced pH environment. The increased saliva flow also ensures a continuous supply of essential minerals, such as calcium and phosphate, to the tooth surface, promoting the remineralization process and strengthening weakened enamel. This remineralization support further contributes to the protective shield against acidic challenges. The organic acids in pineapple may also possess inherent antimicrobial properties, inhibiting the growth and activity of harmful bacteria in the oral cavity. This potential antimicrobial action complements the antimicrobial agents present in saliva, further bolstering the oral defense system.[15-17]

The oral cavity, a dynamic ecosystem teeming with microbial life and constantly challenged by dietary and

environmental factors, is a battlefield where the forces of health and disease wage a continuous war. Maintaining a balanced environment within this oral battlefield, particularly a balanced pH and a robust salivary flow, is crucial for preserving the integrity of tooth enamel and preventing the onset of dental caries. Pineapple, a tropical fruit celebrated for its refreshing taste and nutritional value, emerges as a surprising ally in this battle, offering a natural dietary shield that fortifies the oral cavity's defenses. The combined effect of increased saliva volume and controlled pH reduction, as demonstrated in this study, underscores the potential of pineapple as a natural strategy to support oral health. By mitigating the acidic challenge posed by chocolate, pineapple consumption can contribute to a more balanced oral environment, promoting enamel integrity and reducing the risk of dental caries. The organic acids present in pineapple, primarily citric acid and malic acid, act as natural buffers, counteracting the acidity produced by the fermentation of sugars by oral bacteria. This buffering action helps to maintain a more neutral oral pH, preventing the demineralization of enamel and creating a less hospitable environment for acid-loving bacteria. Pineapple's bromelain content stimulates saliva production, enhancing the oral cavity's natural cleansing and buffering mechanisms. The increased saliva flow helps to wash away food debris and bacteria, dilute acids, and deliver essential minerals for remineralization. Saliva carries essential minerals, such as calcium and phosphate, to the tooth surface, where they can be incorporated into demineralized enamel, strengthening and repairing weakened areas. The increased saliva flow induced by pineapple consumption ensures a continuous supply of these minerals, promoting the remineralization process and fortifying tooth enamel against future acid challenges. Saliva also contains a variety of antimicrobial agents, such as lysozyme, lactoferrin, and immunoglobulins, which help to control the growth and activity of harmful bacteria in the oral cavity. The increased saliva flow triggered by pineapple consumption enhances the delivery of these antimicrobial agents, further bolstering the oral defense system against bacterial threats. This finding has significant implications for dietary recommendations, particularly for children who are often more susceptible to caries development due to their higher intake of sugary foods and beverages. Incorporating pineapple into the diet, especially after consuming acidic foods like chocolate, can help to neutralize acids, stimulate saliva production, and create a more favorable environment for oral health. This natural approach aligns with the growing emphasis on preventive dentistry and the promotion of healthy dietary habits. By harnessing the natural buffering and saliva-stimulating properties of pineapple, individuals can take an active role in maintaining their oral health and reducing their risk of dental caries. While the focus of this study was on children, the implications of these findings extend to individuals of all ages. Adults, particularly those who consume acidic foods and beverages frequently, can also benefit from incorporating pineapple into their diet as a natural strategy to support oral health. Furthermore, individuals with dry mouth, or xerostomia, a condition characterized by reduced saliva flow, may find relief by consuming pineapple. The saliva-stimulating effect of bromelain could help to alleviate the discomfort and complications associated with dry mouth, improving quality of life and reducing the risk of oral health issues.[18-20]

4. Conclusion

This research establishes the beneficial effects of pineapple consumption in mitigating the acidic challenge posed by chocolate and promoting a balanced oral environment. Pineapple's ability to stimulate saliva secretion and control pH reduction highlights its potential as a natural, dietary strategy to support oral health and caries prevention. The findings of this study encourage further research to explore the long-term effects and broader applications of pineapple in maintaining oral health across various populations and dietary habits. By integrating pineapple into dietary recommendations and promoting its consumption as a natural strategy for

oral care, we can empower individuals to take an active role in preserving their oral health and reducing their risk of dental caries.

5. References

1. Tripathy A, Patel MK, Chakraborty S. Microbial production of dextran using pineapple waste extract: a two-step statistical optimization of submerged fermentation conditions and structural characterization. Biotechnol Bioprocess Eng. 2024.
2. Randis, Fellicia DM, Rus TY, Sulaiman AM. Isolation and extraction of microcellulose from pineapple leaves fiber. Memi. 2024; 1(2): 61–6.
3. Nithikulworawong N, Jiwyam W. The immunostimulatory potential and resistance *Aeromonas hydrophila* of pineapple peel extract in Nile Tilapia (*Oreochromis niloticus*). Aquac Stud. 2024; 24(5).
4. Sebastian N, Ashwini TS, Mahendran B, Sowmya HK. Evaluation and comparison of the efficiency of ultrasonically activated intracanal irrigants grapeseed and pineapple extract in removing smear layer from the apical third of the root canal: an in vitro SEM analysis. Endodontology. 2024; 36(3): 251–6.
5. Srivastava S, Kharkar V-R, More S, Kalsi H-S, Sachdev S-S. Efficacy of a novel combination of aloe vera gel and pineapple extracts in improving post-extraction pain and healing: a randomized controlled trial. J Clin Exp Dent. 2024; 16(7): e794–801.
6. Solanki MN, Attur KM, Vachhani KA, Patel NA, Shah MA, Doshi DM. Phytochemicals in vital tooth bleaching: spectrophotometric evaluation of efficacy with papaya, pineapple, or kiwi extracts and 30% hydrogen peroxide. J Conserv Dent Endod. 2024; 27(7): 760–4.
7. Gumber S, Kumar S, Kaushik R, Kumar H, Mehra R. Understanding consumer preferences to develop dahi using pineapple pomace powder and monk-fruit extract. J Food Sci Technol. 2024; 61(8): 1525–35.
8. Hanoi University of Science and Technology, Nguyen V-T, Nguyen N-K, Hanoi University of Science and Technology. A study of automatic pineapple leaf fibre extraction machine using bidirectional rolling mechanism. Int J Integr Eng. 2024; 16(5).
9. Davis D, Umesh M, Santhosh AS, Suresh S, Shanmugam S, Kikas T. Extraction of fungal chitosan by leveraging pineapple peel substrate for sustainable biopolymer production. Polymers (Basel). 2024; 16(17): 2455.
10. Shilpa V, Kauser S, Sudha N, Babu DV, Dr. Vasudha B. Extraction, purification, assay, and antimicrobial activity of bromelain from pineapple. Int Res J Adv Engg Mgt. 2024; 2(08): 2480–7.
11. Minarni, Susi, Murniwati. The effects of pineapple extract toothpaste (*Ananas comosus* L.merr) on saliva flow rate. IOP Conf Ser Earth Environ Sci. 2021; 819(1): 012060.
12. Alibasyah ZM, Rezeki S, Fitri T. The difference in salivary flow rate before and after stimulate between chewing pineapple (*Ananas comocus*) and papaya (*Carica papaya*). Biomed Pharmacol J. 2017; 10(3): 1213–7.
13. Alibasyah ZM, Rezeki S, Fitri T. The difference in salivary flow rate before and after stimulate between chewing pineapple (*Ananas comocus*) and papaya (*Carica papaya*). Ind J Dent Adv. 2017; 09(02).
14. Rooney C, Huang SH, Watson E, Glogauer M, Su J, Hosni A, et al. Impact of post-operative radiotherapy neck volume on unstimulated saliva flow in oral cavity squamous cell carcinoma. Int J Radiat Oncol Biol Phys. 2024; 120(2): e784.
15. Bukhary FA, Obeid AM, Alsayyad HM, Okmi EA. Hijama (wet cupping therapy) enhances oral and dental health by improving salivary secretion volume and pH in adult patients at

King Abdul Aziz University Hospital (KAUH), Jeddah, KSA: a controlled trial study. J Taibah Univ Med Sci. 2023; 18(1): 74–83.

16. Ramadhani AIK, Tjahajawati S, Pramesti HT. The differences of salivary volume, pH and oral cavity conditions of women smokers and non-smokers. J Kedokt Gigi Univ Padjadjaran. 2022; 34(2): 100.
17. Guest S, Essick G, Young M, Lee A, Phillips N, McGlone F. Oral hydration, parotid salivation and the perceived pleasantness of small water volumes. Physiol Behav. 2006; 89(5): 724–34.
18. Bhargava S, Motwani MB, Patni VM. Effect of handheld mobile phone use on parotid gland salivary flow rate and volume. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012; 114(2): 200–6.
19. Heaney JLJ, Killer SC, Svendsen IS, Gleeson M, Campbell JP. Intensified training increases salivary free light chains in trained cyclists: Indication that training volume increases oral inflammation. Physiol Behav. 2018; 188:181–7.
20. A'yun Q. How is the oral hygiene of elementary school students?- saliva pH, saliva volume and saliva viscosity. Asian J Pharm Res Dev. 2021; 9(6): 24–7.