

The preferable taste between glucose and fructose during mouth rinsing

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Abstract:

Numerous studies have demonstrated that mouth rinsing with glucose enhance exercise; however, research on fructose is comparatively limited. Owing to unexpected taste preferences, fructose is rarely used in carbohydrate mouth rinsing studies. Therefore, the objective of this study is to compare perceived taste between glucose and fructose solutions. Ninety-six participants were assigned perform a set of mouth rinse trials with three different solutions in double blind-manner. Participants were instructed to rinse 25 mL of 6% glucose, 5.3% fructose, and 21.2% fructose for 10 seconds. Prior to using the second and third solutions for rinsing, participants were instructed to cleanse their mouth by rinsing with warm water. Following the warm water mouth rinse, participants were asked to assess the visual analog scale and taste test questionnaire before proceeding to rinse with the subsequent solution. The research revealed that the mean score of 21.2% for fructose was significantly higher ($p < 0.05$) in terms of preferred, sweetness and intensity compared to glucose at 6% and fructose at 5.3%. However, for taste, fructose 5.3% has greater mean than others. In general, fructose was predominantly favoured as preferred choice, likely due to its appealing sweetness and intensity. The findings recommend considering higher caloric intake of fructose during mouth rinsing to enhance brain activation and exercise performance, as fructose appears to be a more favoured option compared to glucose. This insight could guide future studies in this direction.

Key Words: - Mouth rinse, Mouth wash, Fructose, Glucose, Taste

Introduction

Specialized sensors known as "taste buds" are located on the top of the tongue, responsible for detecting sugar and other components in foods (Schling, 2021). Upon contact with any form of sugar, these taste buds transmit a signal to the brain. Over time, a growing body of evidence has reinforced the advantageous ergogenic influence of carbohydrate (CHO) mouth rinses on endurance athletes' performance (Carter et al., 2004; Chambers et al., 2009; Che Muhamed et al., 2014; Fraga et al., 2015; Kamaruddin et al., 2019; Kamaruddin & Muhamed, 2022; Lane et al., 2013; Noor et al., 2023). In exploring the notion of enhanced brain activation with mouth rinse, Chamber et al., (2009) examined the level of brain activation from the effects of CHO mouth rinse containing glucose, maltodextrin and a placebo solution containing saccharin. Their study reported that the mouth rinse containing glucose (sweet), and maltodextrin (non-sweet) improved the performance compared to placebos. It is also reported that glucose and maltodextrin activate the anterior cingulate cortex (ACC), an area related to ratings of perceived exertion (RPE).

According to Chambers et al., (2009), five important brain regions that showed up during CHO mouth rinsing were insula/frontal operculum, dorsolateral prefrontal cortex (DLPC), orbitofrontal cortex, striatum and anterior cingulate cortex. In addition, a study on sucrose on human taste pathways also revealed the same brain regions except orbitofrontal cortex (Frank et al., 2008). The neuroimaging literature provides insights into the involvement of motivation and reward in the activation of the insula/frontal operculum, as suggested by Haase, Cerf-Ducastel, and Murphy (2009). According to Rowe and colleagues (2000), the DLPC is implicated in the preparation and selection of cognitive responses. Concerning the orbitofrontal cortex, its activation is believed to be associated with motivation, incentive processing, goal selection (Boorman et al., 2021), and the evaluation of pleasantness (Haase et al., 2009).

The striatum, on the other hand, is thought to play a role in predicting future rewards, as posited by O'Doherty (2004), and in processing immediate rewards, as indicated by Tanaka and colleagues (2016). Finally, the anterior cingulate cortex (ACC) is believed to contribute to motivational states and the mediation of cognitive influences on emotion, as suggested by Haase et al. (2009). Previously, several studies (Noor et al., 2023; Pomportes & Brisswalter, 2020) have been conducted that demonstrated a positive impact on exercise performance through glucose mouth rinsing. However, limited research has explored the use of fructose as a rinsing agent to investigate its effects on exercise performance. Fructose holds the potential to elicit a stronger brain activation during CHO mouth rinsing, possibly due to its pleasant taste. In a prior investigation by Abu

Bakar et al. (2017), it was observed that rinsing with a sweeter fructose solution led to a more pronounced activation of the insula/frontal operculum region of the brain. Furthermore, numerous fruits naturally contain fructose, and this CHO is commonly present in a variety of beverages, often serving as an added sweetening agent (Lowette et al., 2015). However, the utilization of fructose in CHO mouth rinsing studies remains limited, primarily due to the unpredictably preferred taste it offers. Consequently, this study aims to compare the preferable glucose and fructose taste during mouth rinsing.

Material & methods

Participants

Ninety-six (96) participants were randomly and double-blindly assigned to perform a single mouth rinse trial using three distinct solutions. All participants were physically active and aged between 18 and 30 years. Exclusions from the study encompassed individuals who smoked, vaped, or had consumed any caffeinated beverages prior to the experimental trial. The data collection was conducted at Fitness Lifestyles Gymnasium, Perak, Malaysia. The sample for this study was selected using an approach of purposive sampling. There were 100 participants recognized in total in Fitness Lifestyle members. A sample of 79 participants were selected to be involved in the study (Bukhari, 2020). Considering a 20% dropout rate, 96 participants were recruited for this research.

Procedure

All participants in this study took part voluntarily. Detailed explanations of the testing procedures and measurements for each test were provided to the participants during the initial session. The study was conducted with randomized allocation and a single-blind design. Each participant was instructed to rinse with three sets of CHO solutions for a duration of 10 seconds each. Participants were required to rinse with 25 mL of glucose and fructose solution. To ensure oral cleansing and prevent desensitization, participants rinsed with warm water before using the second and third solutions. Subsequently, participants were asked to evaluate and rate the solutions based on their preference, sweetness, intensity, and taste using a Visual Analog Scale (Aitken, 1969). All research procedures concerning human subjects were accepted by the UiTM Research Ethic Committee with reference number REC/192/2022.

Visual Analog Scale

The visual analogue scale (VAS) is a psychometric tool used in questionnaires to measure subjective traits or attitudes that are not directly quantifiable (Aitken, 1969). When answering a VAS item, participants indicate their level of agreement with a statement by marking a position on a continuous line between two endpoints. Each participant's perceived preference, sweetness, intensity, and taste was recorded after rinsing each test solutions using a straight line 10-centimetre VAS on which the anchor point was labelled "dislike extremely" at the 0-centimetre mark and "like extremely" at the 10-centimetre mark.

Mouth rinse solution

The mouth rinse solutions are sourced from Sim Company located in Penang, Malaysia. Participants was provided with 25 mL of both glucose and fructose solutions, as outlined in Table 1. In Cup A, a control solution consisting of glucose with a concentration of 6% with 19.674 kcal/g of caloric content. The reason for choosing 6% glucose is it commonly employed in previous mouth rinse studies (Kamaruddin et al., 2019; Rollo et al., 2008; Shirai et al., 2022). Cup B will contain a fructose solution with a concentration of 5.3%, matching the caloric content of glucose at 19.674 kcal/g. Cup C will be filled with a fructose solution with a concentration of 21.2% with a caloric content of 78.694 kcal/g. This decision is informed by the finding that a 21.2% fructose concentration led to increased brain activity in a previous study (Abu Bakar et al., 2017).

Table 1 Mouth rinse solutions and the concentration of the solutions

Carbohydrates	Cup	Concentration
Glucose	A	6%
	B	5.3%
Fructose	C	21.2%

Data analysis

All data collected in this study undergo analysis using IBM SPSS version 26 statistical software. The data will be reported as mean $\pm$ standard deviation (mean $\pm$ SD). A significance level of $p < 0.05$ will be applied. To assess the differences in preferred taste between the solutions, a One-way ANOVA test was conducted on the independent variables of glucose and fructose.

Results

Table 2 presents descriptive data comparing the preferred taste between glucose and fructose during mouth rinsing. Fructose 21.2% exhibits the highest mean in terms of preferable, sweetness and intensity (mean value of 6.38 ± 3.06 , 8.07 ± 1.50 and 6.44 ± 2.40 , respectively). In terms of taste preferences, fructose 5.3% have higher mean values than glucose and fructose 21.1%, respectively.

Table 2 The values for mean and standard deviation pertaining to the preferable taste of solutions containing fructose and glucose

		Mean	Standard Deviation
Preferable	Glucose 6%	5.20	2.61
	Fructose 5.3%	6.24	2.20
	Fructose 21.2%	6.38	3.06
Sweetness	Glucose 6%	3.07	2.23
	Fructose 5.3%	5.41	2.77
	Fructose 21.2%	8.07	1.50
Intensity	Glucose 6%	3.22	2.00
	Fructose 5.3%	4.59	2.37
	Fructose 21.2%	6.44	2.40
Taste	Glucose 6%	3.38	0.82
	Fructose 5.3%	3.70	0.71
	Fructose 21.2%	3.56	0.82

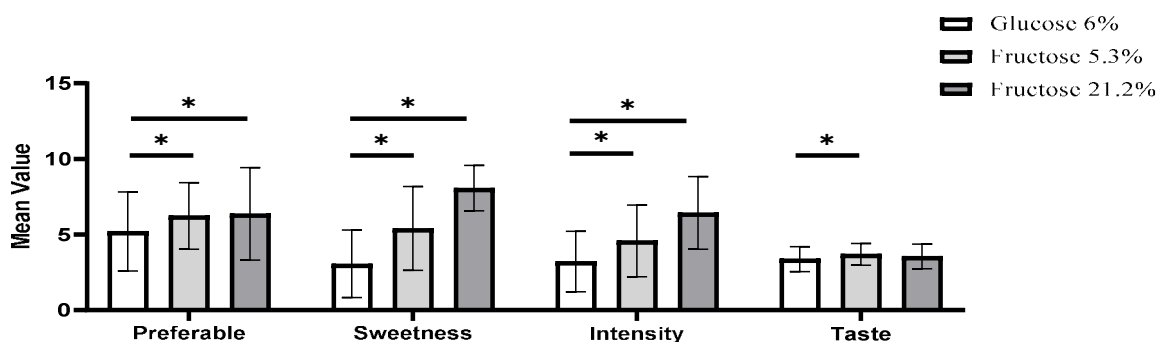


Figure 1 Bar graph for mean and standard deviation pertaining to the preferable taste of solutions containing fructose and glucose

Significant differences were observed between preferable group ($F(2,285) = 5.629$, $p = 0.004$). Similarly, between sweetness group, significant distinctions were noted ($F(2,285) = 120.582$, $p = 0.01$). In the intensity domain, the significance of differences was also evidenced ($F(2,285) = 48.471$, $p = 0.01$). Regarding taste, a significant differences were also observed between the group ($F(2,285) = 3.806$, $p = 0.01$). A Bonferroni post hoc test revealed a significant difference between glucose and fructose in mouth rinsing. In the preference group, both fructose 5.3% and fructose 21.2% showed significantly greater effects compared to glucose 6% ($p < 0.05$). Similarly, in the sweetness and intensity group, fructose 5.3% and fructose 21.2% also demonstrated significantly greater effects compared to glucose 6% ($p < 0.05$). For the taste group, a significant difference was found between fructose 5.3% and glucose 6% ($p < 0.05$), while no significant difference was observed between fructose 21.2% and glucose 6%.

Discussion

This study investigated the preferable of glucose and fructose taste during mouth rinsing. The main finding found that 21.2% of fructose solution appears to be a more favoured option compared to 5.3% of fructose and 6% of glucose. Sugars elicit a unique sensory experience, commonly recognized as "sweetness" in humans, and are generally favoured (McCaughy, 2008). A receptor responsible for binding sweeteners has been discovered, triggering G-protein-mediated signalling in taste receptor cells. This activation subsequently induces alterations in neural firing rates within the brain, contributing to the generation of perceptions related to taste quality, intensity, and palatability (McCaughy, 2008). The findings pertaining to preference, sweetness, intensity, and taste were initially analysed and condensed into significant values.

In terms of preference, a noteworthy difference in mean values was observed for fructose solutions at 5.3% and 21.2% compared to the control. Both fructose solutions exhibited higher mean values than the glucose solution, suggesting a greater preference for fructose over glucose. According to a study by Gibson (2006), sweet tastes, including those from fructose, can provide emotional comfort and relief from stress. This is due to the activation of brain regions associated with reward and pleasure. This might explain why there is a greater preference for fructose.

Regarding sweetness, a significant difference in mean values was also evident for fructose solutions at 5.3% and 21.2% when compared to the control. Fructose is perceived as sweeter than glucose when compared to sucrose, which is considered equal to one in sweetness. According to consensus agreement, the sweetness of glucose is 0.75, while fructose is rated at 1.7 (Grembecka, 2015). Literature supports the sweeter nature of fructose compared to glucose, contributing to the understanding that individuals may favour fructose due to its

heightened sweetness. Moreover, the orbitofrontal cortex (OFC), responsible for evaluating the pleasantness of sensory experiences, shows increased activity when exposed to sweet tastes, including fructose. This enhanced activity correlates with the subjective experience of sweetness and pleasure (Small et al., 2007).

Likewise, in terms of intensity, a notable difference emerged when comparing the mean values of 5.3% and 21.2% fructose solutions with the control solution. The 21.2% fructose solution exhibited a higher mean intensity, likely attributed to its elevated concentration. High-intensity sweetness triggers substantial dopamine release in the brain, especially in the nucleus accumbens (De Araujo, 2011). This dopamine surge is a primary driver of the pleasurable sensations associated with sweet tastes (Volkow et al., 2010).

In terms of taste, a significant difference was observed with fructose at 5.3%, but not at 21.2%, when compared to the control solution. The higher mean taste value was evident specifically with the 5.3% fructose concentration. While no significant difference in taste was found between 21.2% fructose and 6% glucose, the mean value for fructose remained higher compared to glucose. Based on the current result, we believe that the gustatory cortex, which processes taste information, becomes more active with the introduction of a sweet solution like fructose. This increased activity heightens the perception of sweetness and contributes to the overall sensory experience (Rolls et al., 2010).

Conclusions

In general, sweeteners are more favoured than water, yet the degree of this preference may fluctuate over time or differ among individuals. Increased preferences for sugars are frequently linked to more pronounced taste-evoked responses (McCaughey, 2008). Based on the current result, there is a clear preference for fructose over glucose solutions. The findings strongly advocate for the use of fructose as a mouth-rinsing agent in studies on exercise performance. This preference for fructose is underscored by a study conducted by Abu Bakar et al. (2017), which noted that rinsing with a sweeter fructose solution resulted in a more distinct activation of the insula/frontal operculum region of the brain. Certain factors also need to be considered when utilizing fructose as a mouth rinse, it is important to acknowledge that individuals with sweet and sensitive tooth may find the sweetness uncomfortable.

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Conflicts of interest - There are no any conflicts of interest to declare.

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