Healthier Baking Alternatives: Evaluating Stevia and Erythritol in Whole Wheat Bread Production

Proposer: Zeyu Zhang

Instructor: Kai, Huang, Tivadar Pongo, Jin Miao

Programme: Integrated science 205

Duke Kunshan University

May 7, 2024

Abstract

The rising prevalence of non-communicable diseases such as obesity and diabetes has driven consumer demand for healthier baked goods instead of high sugar products. This proposal investigates the effects of stevia and erythritol, individually and in combination, as low calorie and healthy sugar substitutes in whole wheat bread production. The study will utilize an experimental quantitative design to assess the impact of these substitutes on dough rheology, bread quality, and sensory acceptance. Four groups of bread formulations will be examined: a control (sucrose), stevia (50%, 75%, and 100% substitution), erythritol (50%, 75%, and 100% substitution), and a stevia-erythritol blend (50%, 75%, and 100% substitution).

Dough rheology will be measured using an Anton Paar Rheometer, and bread quality will be assessed via a laser profilometry, compression test and LCMS measurement. A sensory panel will evaluate sweetness, texture, and overall acceptance. The study aims to provide insights into both individual and synergistic effects of stevia-erythritol and their impact on whole wheat bread quality, meeting the growing demand for healthier, reduced-sugar bakery products.

The broader impact of this research extends beyond scientific knowledge to contribute positively to public health, industry practices, and consumer behavior. By evaluating sugar substitutes in whole wheat bread production, this study will establish comprehensive data for sugar reduction strategies. Additionally, exploring the synergistic effects of stevia and erythritol blends will offer a framework for choosing the right proportion of adding different sugar substitutes. Furthermore, it will guide the food industry in meeting the growing demand for reduced-sugar bakery products while maintaining quality and acceptance. For people who are concerned with sugar related health issues or young generations who have appearance

anxious, this proposal will serve as the evidence to help them choose sugar alternatives bread in order to avoid these issues.

Introduction

In recent years, increasing attention has been drawn to the detrimental health effects of excessive sugar consumption. High take of sugar is linked to a higher likelihood of developing non-communicable diseases such as obesity, cardiometabolic diseases and dental diseases ((Prada et al., 2022). What's more, high sugar consumption is associated with a decrease in the average life expectancy and many other health issues (Greenberg, 2013; World Health Organization, 2015) Moreover, it is important to know that high sugar consumption can accelerate skin aging leading to wrinkles, loss of skin elasticity, and contribute to severe acnes(Danby,2010), which are a great concern for young generations. Therefore, to use sugar substitutes that have less calories and less negative healthy implications would have great outlook to be chosen as the alternatives in cooking, especially in the bread that we often eat for breakfast and snacks.

In this proposal, the whole wheat bread is chosen as the subject to explore. This is because whole wheat breads are known for their health benefits due to high fibre content and essential nutrients. And this research focuses on the two kinds of sugar substitutes: stevia and erythritol. Stevia, derived from the leaves of the Stevia rebaudiana plant, is a natural, zero-calorie sweetener (Margaret, 2015). What's more, stevia can lower the sugar level, decreases the oxidative stress and thus reduce the risk of diabetes while also be used to treat diabetes (Jan et al., 2021) Therefore, the choice of stevia as sugar substitutes is great as the bread made out of stevia might have a higher nutritional value and a positive healthy impact, which would be examined by this research. The second chosen sugar substititue, erythritol is a sugar alcohol that is low in calories and found in vegetables and plants (Singh,2020). Notably, it is

produced via a natural fermentation process involving yeast (Rzechonek ,2017). And it has been found to reduce the risk of caries in several trials (Kawanabe et al., 1992). Both sugar substitutes are appropriate in diabetes patients, and for individuals who wish or need to regulate their blood sugar levels because of prediabetes or compromised carbohydrate metabolism.

While stevia and erythritol offer potential as healthier baking alternatives, their incorporation into whole wheat bread is not well understood. Research on the effects of these sweeteners on the taste, texture, and consumer acceptance of whole wheat baked bread is limited. Additionally, existing studies do not comprehensively compare stevia and erythritol in terms of their impact on whole wheat baking quality and consumer preferences.

This project investigates the efficacy of non-sugar sweeteners: stevia and erythritol - in yeast-leavened whole wheat bread and also explores the blending effect of the two sugar substitutes. Focusing on substitutes' impact on the fermentation process, texture, and taste, the research employs controlled baking experiments with each sweetener and a comparative analysis against traditional sugar. Preliminary results have suggested varied influence of each substitute on dough rise and sensory attributes, with some mimicking sugar's effectiveness more closely than others. The study aims to offer insights into healthier baking alternatives, aligning with contemporary dietary trends while preserving product quality while also introducing consumers’ preferences with sensory tests.

The findings of this study will be beneficial for food manufacturers who are interested in creating sugar-reduced whole wheat products that maintain taste and quality. Additionally, consumers will gain valuable information about healthier baking alternatives, enabling them to make more informed dietary choices. Moreover, this research will contribute to public health strategies that focus on reducing sugar consumption and addressing diet-related health concerns. By addressing the current knowledge gap on sugar alternatives in whole wheat

baking, this study has the potential to not only improve individual health outcomes but also influence the approach of the broader food industry towards developing healthier products.

Literature review

Scientists have conducted lots of research on using sugar substitutes in baking. Rutkowska et al. (2023) have found that when using xylitol, a low glycaemic index with low calories similar to erythritol to cook cookies, results show that xylitol had better properties than sucrose, positively affecting the shelf life. And the xylitol improved the stability of the pH, water activity of cookies and sensory attributes such as buttery aroma and texture characteristics(Rutkowska et al.,2023). What's more, scientists researched that a total sugar replacement in a sponge cake by the combination of sugar substitutes such as fructose, polydextrose and acesulfame-K showed higher consumer acceptance (Attia et al., 1993). On the contrary, however, Pong et al. (1991) showed that this combination leads to higher density in cakes, due to the less absorbance of air when mixing, which is connected to the increased chewiness. As to the nutritional value, literature is less, but Quitral et al. (2019) finds that the sugar-substituted bread tends to have a higher protein value, a higher lipid value but less sugar and energy (Quitral et al., Quitral 2019). This shows the feasibility of using sugar substitutes to replace the role of sugar to suggest a better choice for people with health concerns.

It is clear that replacing sugar with sugar substitutes can significantly influence the properties of the breads, including the doughs. The addition of both sweeteners, stevia and erythritol, reduces the consistency of the dough and the water absorption (Stefan, 2019). Similar to Marzec et al.'s findings (2021) that conclude dough with erythritol was characterized by the lowest consistency index, also the least viscous. What's more, the

substitutions of the commonly used sucrose with erythritol and trehalose can prepare a porus structure for the bakery products compared with using sugar (Marzec et al., 2021). The different properties of doughs can thus influence the textures, flavors of the bread in a complicated way. It is pertinent to consider that the yeast is known to increase specific volume in a bread system (Corsetti et al., 2008). However, the addition of sugar, or sucrose can weaken the dough structure as sugar itself inhibits the gluten network development (Sahin et al., 2017). Karp et al. (2016) found that the 25 percent of addition of stevia in bakery products was the most appropriate modification of the basic formula in a way that the resulting muffins gained sensory attractiveness and health-promoting qualities. However, Karp et al.(2017) suggest that the reduction of sucrose in excess of 50 percent had a negative impact on the quality of muffins and their sensory profiles.

As to the sugar substitutes that I choose, scientists have found that the increased erythritol addition could improve mechanical properties and shelf life, producing a smoothing effect on the macaron surfaces, a French dessert (Nastaj et al., 2023). Ruiz (2015) examined stevia's influence on bread shelf-life and found that stevia improved antioxidant activity, potentially increasing the bread's shelf-life. Using stevia in bakery might lead to a bitter taste while using erythritol and stevia together can help to mask any aftertaste or bitterness that might be present when either sweetener is used alone (Mora, 2021).

However, few studies have analyzed how these sugar substitutes impact the nutrient profile of whole wheat bread nor have examined specifically the impact of stevia and erythritol in making whole wheat bread. Therefore, my project will offer insight into specifically how the two sugar substitutes affect the fermentation, texture and flavour of whole wheat bread and based on the results suggest a refined method to make whole wheat bread using the sugar substitutes without compromising the taste.

Project description

1. Recipe

   It is important to know that there are hundreds of recipes to make whole wheat bread. And the recipe should always be changed based on the data of this projects in order to better refine the product. In this project, the recipe is as followed(changeable).

Base Recipe (Applies to All Groups):

Ingredients :

- 400g whole wheat flour(Sam's Club)
- 7g dry yeast (approx. 2¼ tsp) (High/low sugar tolerant yeast: ANQI yeast brand)
- 1 tsp salt (xuetian brand salt)
- 2 tbsp olive oil (Chugu brand)
- 300ml warm water

The recipe is inspired by Belkina et al. (2022)

Notably, in Chinese market, there are basically two types of yeast. One is know as high-sugar tolerant yeast and the other one is low-sugar tolerant yeast. The difference lies in the capabilities of fermenting with different concentration of sugar. Another thing that this project explores is how effective it is to use the two types of yeasts. As I look into literature, a lot of researchers do not distinguish this two types of yeasts and as a result some of their conclusions often contradict and differ significantly with each other. Therefore, it is of inspiration to delve into the different efficacy as to fermentation with the two types of yeasts.

Note: 1 table spoon is close to 30 milliliter.

1. **Control (Sucrose):**

- 30g, 100% sugar (sucrose) as the sweetener

2. **Stevia Group:**
    - 50% stevia substitution: 15g sugar + ½ tbsp stevia
    - 75% stevia substitution: 7.5g sugar + ¾ tbsp stevia
    - 100% stevia substitution: 1 tbsp stevia
3. **Erythritol Group:**
    - 50% erythritol substitution: 15g sugar + 15g erythritol
    - 75% erythritol substitution: 7.5g sugar + 22.5g erythritol
    - 100% erythritol substitution: 30g erythritol
4. **Stevia-Erythritol Blend Group:**
    - 50% substitution: 15g sugar + ¼ tbsp stevia + 7.5g erythritol
    - 75% substitution: 7.5g sugar + ⅜ tbsp stevia + 11.25g erythritol
    - 100% substitution: ½ tbsp stevia + 15g erythritol

Quantitative methods:

Dough measurements:

Instrument: Anton Paar Rheometer (MCR 302)

Measurements: Viscosity, storage modulus (G'), and loss modulus (G").

Laser profilometry:

Instrument: Zygo NewView 9000 3D Optical Profiler.

Measurement: surface roughness, thickness (before and after fermentation), and reflectivity.

Bread measurements (after bakery)

Texture analysis

Instrument: TA-XT2i texture analyzer

The samples were compressed at a 1 mm s^{-1} crosshead speed and 50% deformation(Nastaj et al.,2023).

Compression test

Instrument: Instron 5943 Universal Testing System (compression test machine)

Measurements: Bread softness via compression test.

Water activity analysis (doughs and breads)

The water activity of the obtained doughs and breads will be determined by means of a water activity-meter LabMaster-aw (Novasina AG, Lachen, Switzerland) (Nastaj et al., 2023)

Nutritional value measurement

Instrument: Agilent 1290 Infinity II LC system coupled with Agilent 6470 Triple Quadrupole LC/MS.

To measure the proteins content of different breads

Statistical analysis

ANOVA and Tukey's post hoc test will be used to identify significant differences between groups (McHugh, 2011).

Sensory test (inspired by article "*Texture profile and correlation between sensory and instrumental analyses on extruded snacks*"(Paula & Conti-Silva, 2014).

Attribute	Intensity Scale (1-9)	Comments
Texture	1 (Soft) - 9 (Firm)	
Sweetness	1 (Low) - 9 (High)	
Bitterness	1 (Low) - 9 (High)	
Acidity	1 (Low) - 9 (High)	
Flavor	1 (Weak) - 9 (Strong)	
Aroma	1 (Weak) - 9 (Strong)	
Overall Liking	1 (Dislike) - 9 (Like)	

Budget:

The budget should include the cost of buying enough ingredients such as whole wheat flour, sugar, salt, two types of yeast. (32kg whole wheat flour, 10 packets of sugar, salt, stevia, erythritol, 5 bottles of olive oil) ~approximately 83*4+ 10*11+10*3+10*6+ 10*13+30*5=812yuan

Also, the cost of using different machines such as Anton Paar Rheometer (MCR 302), Zygo NewView 9000 3D Optical Profiler should be included. If using machines at campus, it might be free. Suppose 500 yuan is spent on using machines.

The conduct of sensory tests need to pay the participants. (15yuan per person, 20 people~300yuan)

Total: approximately 1700yuan

Project timeline:

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Project Planning	X					
Sensory Panel Organization	X					
Dough Preparation (Trial 1)	X					
Dough Rheology Measurements (1)	X					
Bread Quality Assessment (1)		X				
Laser Profilometry		X				
Texture Analyzer		X				
LCMS Analysis		X				
Sensory Evaluation Round 1		X				
Data Analysis (Trial 1)			X			
Dough Preparation (Trial 2)			X			
Dough Rheology Measurements (2)			X			
Bread Quality Assessment (2)				X		
Laser Profilometry				X		
Texture Analyzer				X		
LCMS Analysis				X		
Sensory Evaluation Round 2					X	
Data Analysis (Trial 2)					X	
Manuscript Preparation & Reporting						X
Interpretation of Results						X
Final Report Writing						X
Conference Presentations						X

Intellectual merit and Implications:

This proposal is important because it offers insight into how stevia and erythritol impact whole wheat bread production. Few scholars have explored this area, and many aspects remain unclear. Moreover, limited studies have investigated the synergistic effect of adding both stevia and erythritol in bread production. This proposal quantitatively explores different concentrations of stevia, erythritol, and sugar. By measuring the physical and sensory properties of the bread, this study will suggest a better recipe that incorporates different concentrations of sugar substitutes to produce a healthier and more delicious bread alternative. What's more, further research on the long term impact of having this food may have positive outcomes as both stevia and erythritol can help to treat some diseases while also lower blood pressure and sugar level.

Additionally, this proposal highlights the role of different types of yeasts: the high/low sugar tolerant yeast, for which researchers have not yet delved into. This is important because if the low sugar tolerant yeast demonstrates a higher fermentation result and a better flavour, then the application of low sugar tolerant will be prosperous for bakery companies as well as for companies who produce and sell this type of yeasts.

Another thing that manifests the importance of this research is that it is not only highly connected to research field such as food and science but also biology, psychology and neuroscience. This is because when conducting the sensory results, I may expect different tastes of different breads. And the taste balance between sugar and salt, or sugar substitutes with salt would be different in a way that participants may feel saltier. And the way people feel salty, or the micro mechanism of the taste balance between sweetness and other flavours have not been fully explored. It might have some connections with how the neurons in our brains works or might be influenced by out moods. These are all the factors that may contribute to individual's different perceptions of taste.

Risk control

This research proposal acknowledges the potential risks involved in studying sugar substitutes in whole wheat bread production. To address these risks and ensure project success, comprehensive risk control measures will be implemented.

1) **Technical Risks:** Equipment Failure

A potential malfunction of specialized equipment such as the Anton Paar rheometer, laser profilometry system, or HPLC-LCMS could delay data collection. Routine maintenance and calibration will be scheduled for all equipment, and laboratory staff will be trained in basic troubleshooting. If equipment fails, nearby laboratories will be approached for equipment sharing as an alternative.

2) **Methodological Risks:** Data Accuracy and Reproducibility

Variability in measurements could affect data accuracy and reproducibility. Multiple replicate experiments will be conducted using standardized protocols, and pilot testing will refine measurement techniques. If significant variability persists, alternative methodologies will be explored, such as adopting different measurement systems or protocols.

3) **Ingredients Risks**: Supply Chain Delays

Supply chain delays for materials like stevia and erythritol could impact the timeline. We will source materials from multiple suppliers and maintain an inventory of critical consumables. If primary sources are unavailable, equivalent alternatives will be substituted to ensure consistency.

4) **Project Management Risks:** Time Management

Delays in specific project stages could affect the overall timeline. A detailed timeline with milestones and deadlines will be developed, and progress will be monitored regularly. If delays occur, the project timeline will be adjusted, and resources will be reallocated to critical tasks. As a last resort, project scope modifications will be considered to align with available resources and timelines.

AppendixI: DIY lab result

DIY lab is different from my research proposal in some ways. Firstly, DIY lab is based on my pre-proposal before I have finalised other new ideas. Therefore, DIY lab is a practice to prove that some of the content of final research proposal is feasible. In this DIY lab, I conducted three different groups. The first group was to use sugar to make whole wheat bread, the second and third group were to use stevia, or erythritol to completely replace sugar (100 percent substitution). At the meantime, I used machines such as Anton Paar rheometer, compression test machine to measure the physical properties of the doughs. Then, I baked the bread and invite participants to taste. The sensory test shows that under the context of same amount of salt was added, bread with sugar substitutes are saltier. But the participants would not think that the three types of bread taste significantly different. Some of them consider the bread with erythritol is better to taste.

Recipe:

1 cup of whole wheat flour

1/2 cup of water

1 tsp of sugar, or stevia, or erythritol

5 grams of butter

1 tsp of erythritol

My findings of the DIY lab include:

1. When preparing doughs, doughs with sugar substitutes are more viscous, which can be explained by Stefan et al. (2019)------adding emulsifier such as lecithin might help
2. The doughs with sugar ferments best, approximately doubling its size, while doughs with sugar substitutes have a less significant fermentation result.

3. After fermentation, doughs with sugar appear the best elasticity, stevia next, erythritol last.
4. After fermentation, doughs with sugar appear the largest viscosity, stevia next, erythritol last.
5. After fermentation, doughs with erythritol appear softest, sugar next, stevia last.

Appendix II DIY lab data(in a respective way)

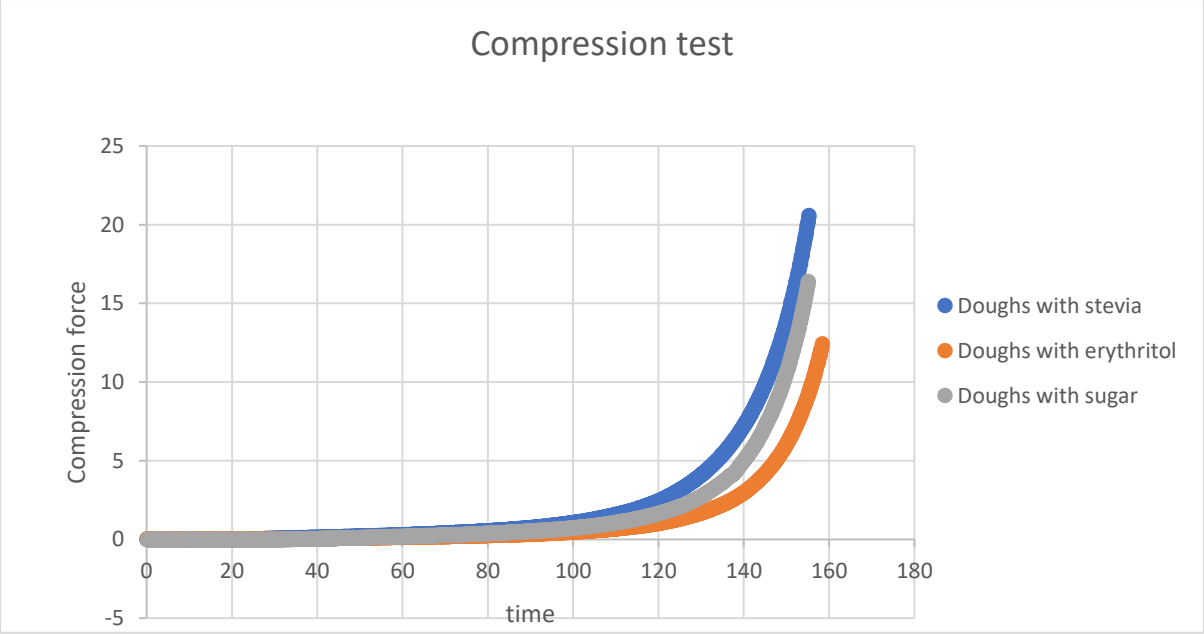

Figure1: compress test results

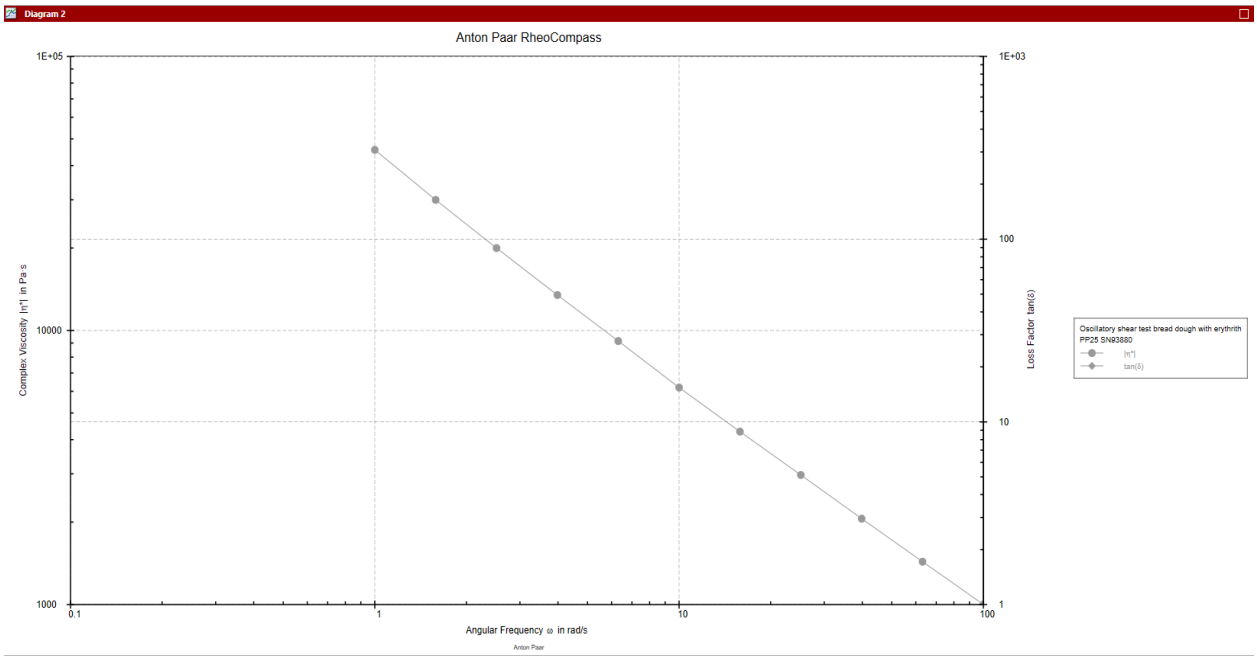

Figure 2.1: complex viscosity of erythritol dough

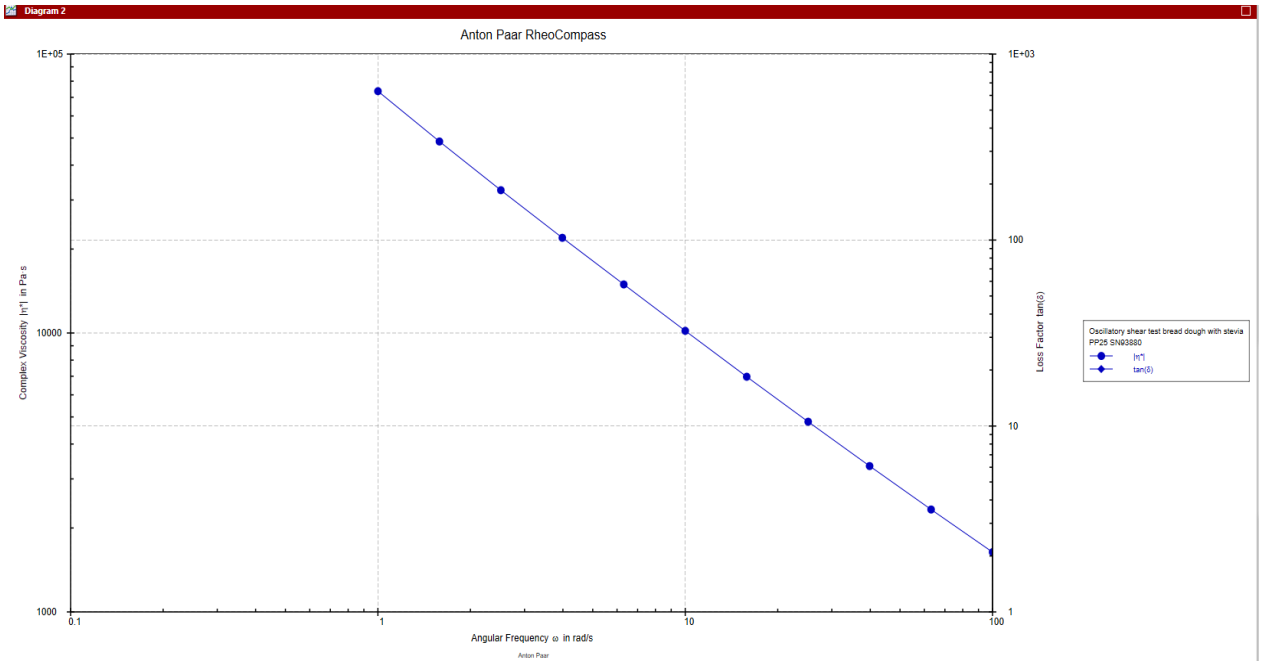

Figure 2.2: complex viscosity of stevia dough

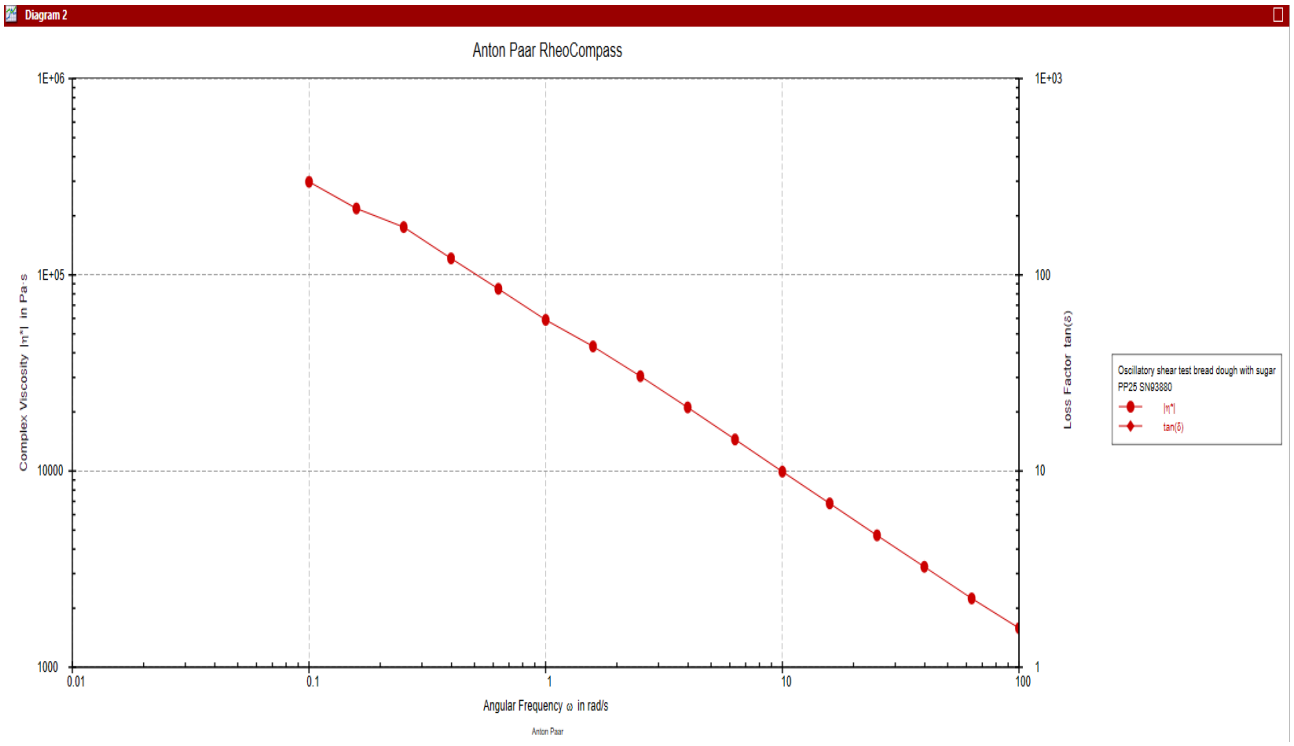

Figure 2.3: complex viscosity of sugar dough

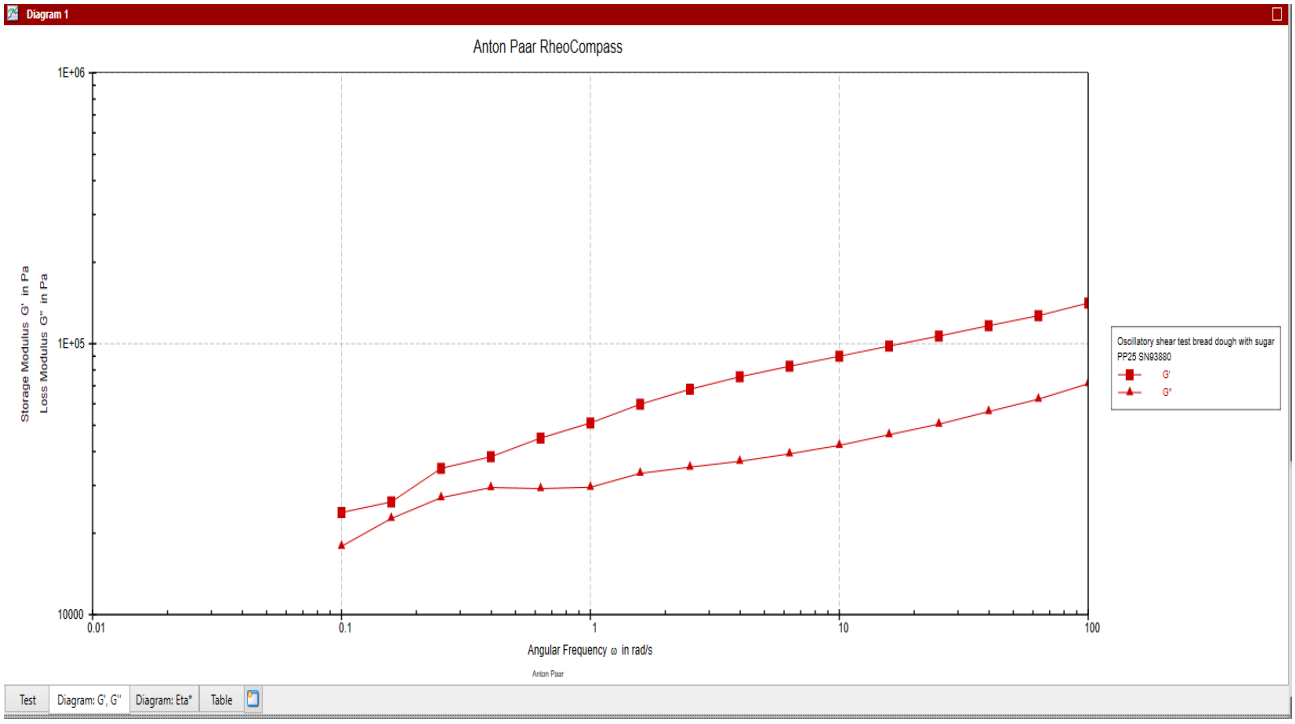

Figure 3.1: The storage and loss modulus of sugar dough

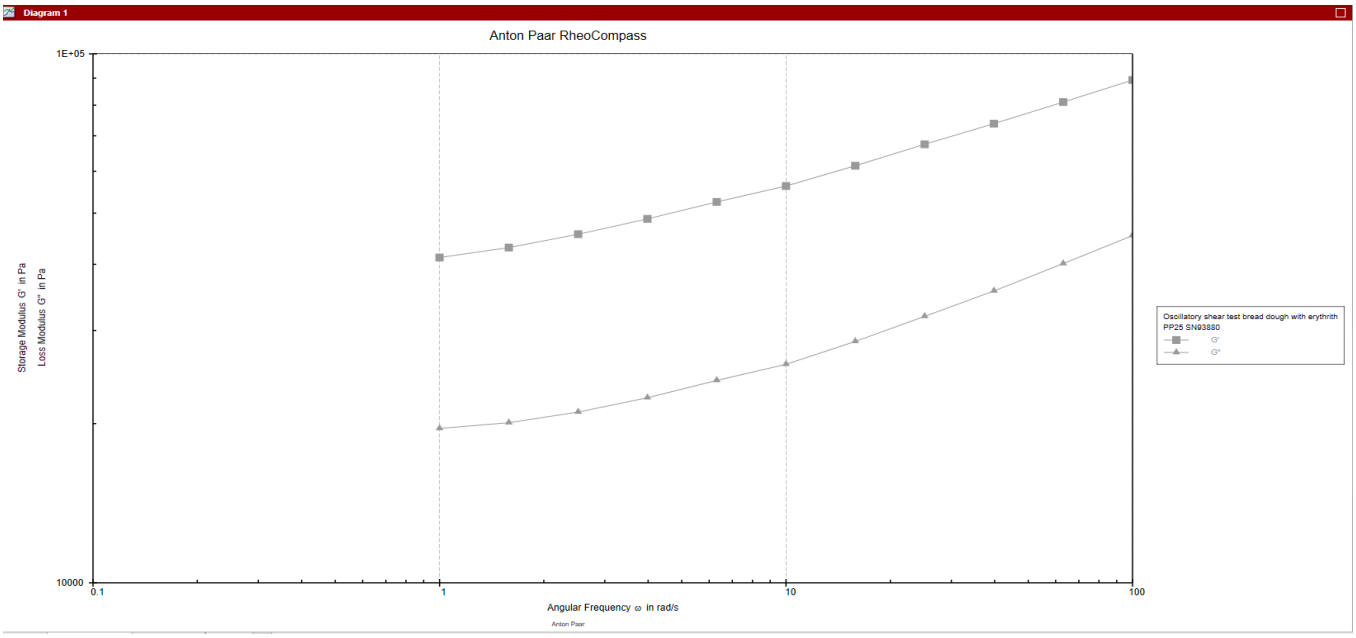

Figure 3.2: The storage and loss modulus of erythritol dough

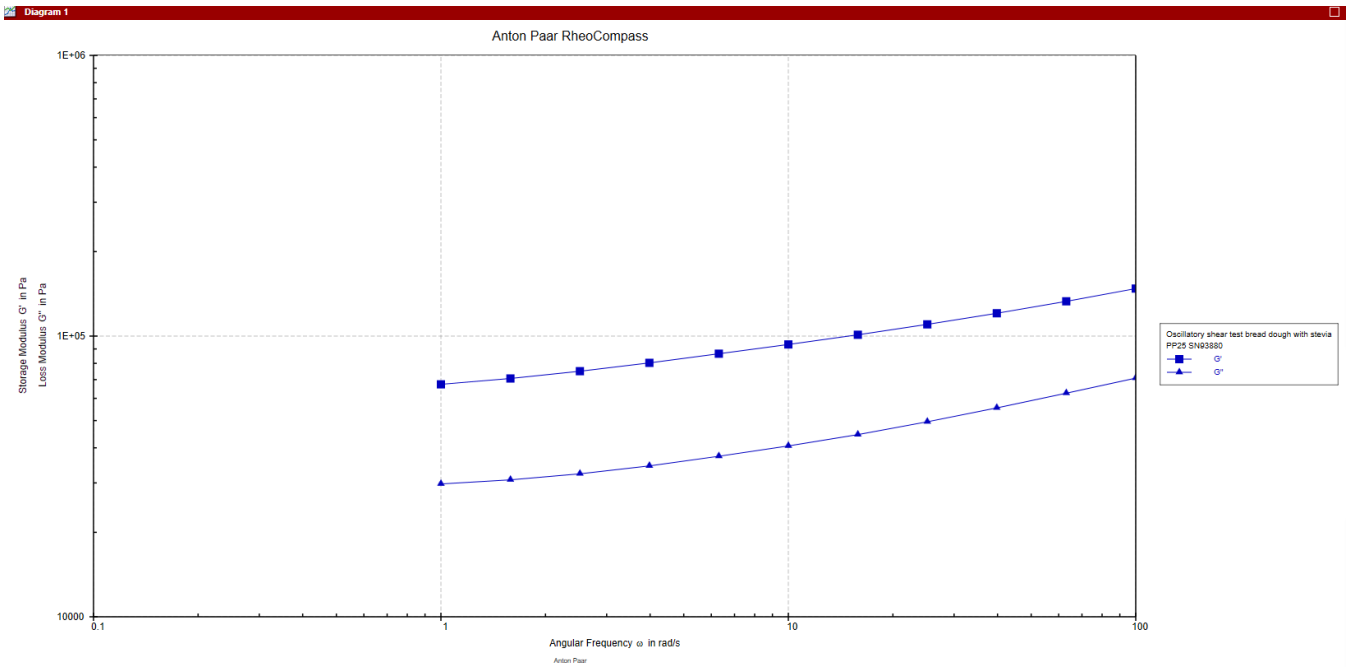

Figure 3.3: The storage and loss modulus of stevia dough

This is the sensory test:

	firmness	humidity	Salt	Sweet
Bread with sugar	5	1	1	1
Bread with erythritol	5	1	3	3
Bread with stevia	5	1	3	5

Figure 4: The sensory test graph

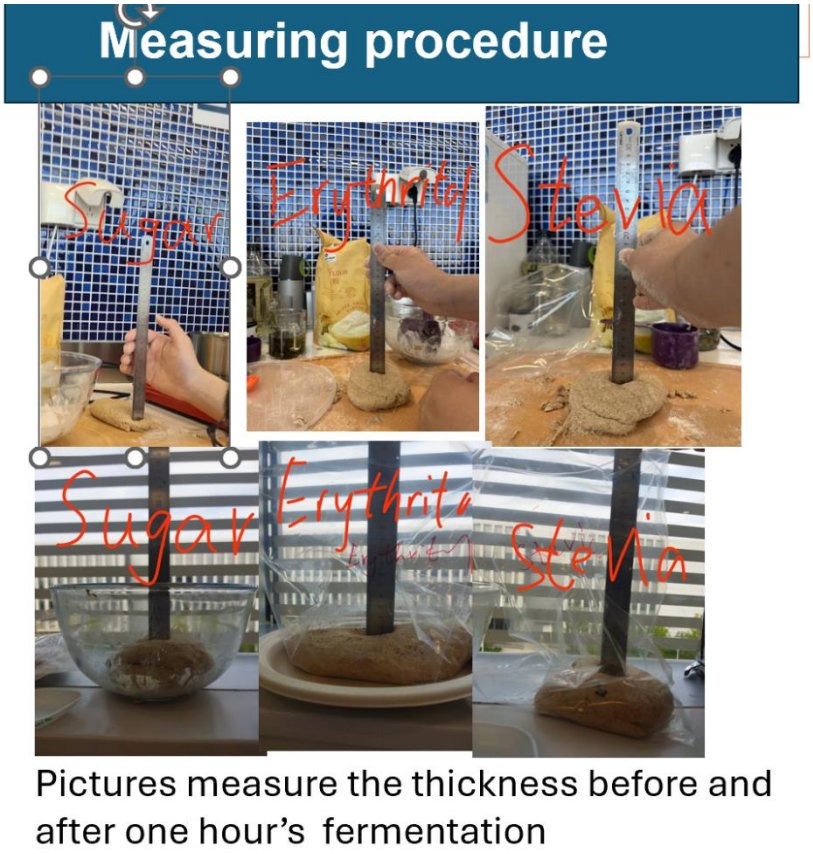

Figure 5: Using Shanghai brand ruler to approximately measure the thickness

References

Attia, E.S.A., Shehata, H.A., Askar, A., 1993. An alternative formula for the sweetening of reduced-calorie cakes. Food Chem. 48, 169–172.

Belkina, R. I., Letyago, Y. A., Gryaznova, O. A., & Gryaznov, A. A. (2022). Development of bread recipes based on natural fortifiers. In *IOP Conference Series: Earth and Environmental Science* (Vol. 954, No. 1, p. 012045). IOP Publishing.

Corsetti, A., Gobbetti, M., Balestrieri, F., Paoletti, F., Russi, L., Rossi, J., 2008. Sourdough Lactic Acid Bacteria Effects on Bread Firmness and Stalin. J. Food Sci.63, 347-351.

Danby, F. W. (2010a). Nutrition and aging skin: Sugar and glycation. *Clinics in Dermatology*, *28*(4), 409–411. https://doi.org/10.1016/j.clindermatol.2010.03.018

Greenberg, J. A. (2013). Obesity and early mortality in the United States. Obesity, 21(3), 405–412. https://doi.org/10.1002/oby.20023

Jan, S. A., Habib, N., Shinwari, Z. K., Ali, M., & Ali, N. (2021a). The anti-diabetic activities of Natural Sweetener Plant Stevia: An updated review. SN Applied Sciences, 3(4). https://doi.org/10.1007/s42452-021-04519-2

Karp, S., Wyrwisz, J., Kurek, M., & Wierzbicka, A. (2016). Physical properties of muffins sweetened with steviol glycosides as the sucrose replacement. *Food Science and Biotechnology*, *25*(6), 1591–1596. https://doi.org/10.1007/s10068-016-0245-x

Kawanabe, J., Hirasawa, M., Takeuchi, T., Oda, T., & Ikeda, T. (1992). Noncariogenicity of erythritol as a substrate. *Caries Research*, *26*(5), 358–362. https://doi.org/10.1159/000261468

Marzec, A., Kowalska, J., Domian, E., Galus, S., Ciurzyńska, A., & Kowalska, H. (2021). Characteristics of dough rheology and the structural, mechanical, and sensory properties of sponge cakes with sweeteners. *Molecules*, *26*(21), 6638. https://doi.org/10.3390/molecules26216638

McHugh, M. L. (2011). Multiple comparison analysis testing in ANOVA. Biochemia medica, 21(3), 203-209.

Mora, M. R., & Dando, R. (2021). The sensory properties and metabolic impact of natural and synthetic sweeteners. Comprehensive Reviews in Food Science and Food Safety, 20(2), 1554-1583.

Nastaj, M., Sołowiej, B. G., Terpiłowski, K., Kucia, W., Tomasevic, I. B., & Peréz-Huertas, S. (2023). The effect of erythritol on the physicochemical properties of reformulated, high-protein, and sugar-free macarons produced from whey protein isolate intended for diabetics, athletes, and physically active people. Foods, 12(7), 1547. https://doi.org/10.3390/foods12071547

Paula, A. M., & Conti-Silva, A. C. (2014). Texture profile and correlation between sensory and instrumental analyses on extruded snacks. *Journal of Food Engineering*, *121*, 9–14. https://doi.org/10.1016/j.jfoodeng.2013.08.007

Pong, L., Johnson, J.M., Barbeau, W.E., Stewart, D.L., 1991. Evaluation of Alternative Fat and Sweetener Systems in Cupcakes. Cereal Chem. 68, 552–555.

Prada, M., Saraiva, M., Garrido, M. V., Sério, A., Teixeira, A., Lopes, D., Silva, D. A., & Rodrigues, D. L. (2022). Perceived associations between excessive sugar intake and health conditions. *Nutrients*, *14*(3), 640. https://doi.org/10.3390/nu14030640

Quitral, V., Venegas, A., Zúñiga, R. N., Bunger, A., & Pedreschi, F. (2019). The role of non-caloric sweeteners in sensory characteristics of pastry products. Foods, 8(8), 329. https://doi.org/10.3390/foods8080329

Ruiz-Ruiz, J. C., Moguel-Ordoñez, Y. B., Matus-Basto, A. J., & Segura-Campos, M. R. (2015). Antidiabetic and antioxidant activity of stevia rebaudiana extracts (var. morita) and their incorporation into a potential functional bread. Journal of Food Science and Technology, 52(12), 7894–7903. https://doi.org/10.1007/s13197-015-1883-3

Rutkowska, J., Baranowski, D., Antoniewska-Krzeska, A., & Kostyra, E. (2023). Comparison of storage-related volatile profiles and sensory properties of cookies containing xylitol or sucrose. *Foods*, *12*(23), 4270. https://doi.org/10.3390/foods12234270

Rzechonek, D. A., Dobrowolski, A., Rymowicz, W., & Mirończuk, A. M. (2017). Recent advances in biological production of erythritol. *Critical Reviews in Biotechnology*, *38*(4), 620–633. https://doi.org/10.1080/07388551.2017.1380598

Sahin, A.W., Axel, C., Arendt, E.K., 2017. Understanding the function of sugar in burger buns: a fundamental study. Eur. Food Res. Technol. 243, 1905–1915.

Singh, P., Ban, Y. G., Kashyap, L., Siraree, A., & Singh, J. (2020). Sugar and sugar substitutes: Recent developments and future prospects. *Sugar and Sugar Derivatives: Changing Consumer Preferences*, 39–75. https://doi.org/10.1007/978-981-15-6663-9_4

Stefan, E. M., Voicu, G., Constantin, G. A., Munteanu, G. M., & Ipate, G. (2019). Effect of sugar substitues on wheat dough rheology. Scientific Study & Research. Chemistry & Chemical Engineering, Biotechnology, Food Industry, 20(2), 313-320.

World Health Organization. (2015). Guideline: Sugars intake for adults and children. Geneva, Switzerland