Available online at www.ujpronline.com
Universal Journal of Pharmaceutical Research
An International Peer Reviewed Journal
ISSN: 2831-5235 (Print); 2456-8058 (Electronic)

REVIEW ARTICLE

THE ROLE OF ALLULOSE AND SUGAR ALCOHOLS IN GUT MICROBIOTA MODULATION AND METABOLIC HEALTH: A REVIEW

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Article Info:

Article History:
Received: 5 October 2024
Reviewed: 12 November 2024
Accepted: 22 December 2024
Published: 15 January 2025

Cite this article:
Eissa ME. The role of allulose and sugar alcohols in gut microbiota modulation and metabolic health: A review. Universal Journal of Pharmaceutical Research 2024; 9(6): 39-44.
http://doi.org/10.22270/ujpr.v9i6.1238

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Abstract

Allulose and sugar alcohols, like erythritol and xylitol, are low-calorie sweeteners gaining attention for their potential to positively influence metabolic health. This brief review explores how these sweeteners can shape the gut microbiota. Acting as prebiotics, they can foster the growth of beneficial bacteria and stimulate the production of short-chain fatty acids. These effects may contribute to improved insulin sensitivity, reduced inflammation and a stronger gut barrier. However, excessive sugar alcohol intake can lead to digestive discomfort. Further research is needed to assess the long-term impact of these sweeteners on gut microbiota and metabolic health, as well as their interactions with other dietary factors. By understanding the intricate relationship between these sweeteners, gut microbiota and metabolic health, it will be possible to develop well-informed dietary guidelines to optimize health and well-being.
Keywords: Allulose, gut microbiota, maltitol, prebiotics, sorbitol, xylitol.

INTRODUCTION

The global obesity epidemic has spurred a relentless search for healthier alternatives to traditional sugar. Consumers are increasingly seeking sweeteners that can satisfy their sweet tooth without the detrimental health consequences associated with excessive sugar intake. Allulose and sugar alcohols have emerged as promising candidates in this quest for low-calorie sweetness[1]. While artificial sweeteners have offered a solution for decades, concerns over their potential long-term health effects have prompted a search for more natural and benign alternatives[2]. Allulose and sugar alcohols have emerged as promising candidates, offering a sweet taste without the caloric burden and potential health risks associated with traditional sugar and artificial sweeteners[3]. These low-calorie sweeteners have gained significant attention for their potential to improve metabolic health, modulate gut microbiota, and provide a satisfying taste experience[4-6]. Table 1 provides a comparison between the ordinary sucrose alternatives.

The gut microbiota: A key player in health and disease

The human gut houses a diverse community of microorganisms, collectively known as the gut microbiota[7]. This intricate ecosystem significantly influences human health, impacting digestion, metabolism, and immune function. A balanced and varied gut microbiota is key to optimal well-being[8]. However, dietary choices, lifestyle factors, and antibiotic use can disrupt this delicate balance, leading to dysbiosis and potential health issues[9]. To promote a healthy gut, individuals should focus on a diet rich in fiber, fermented foods, and prebiotics[10]. Seeking advice from a healthcare professional or registered dietitian can offer tailored guidance for maintaining gut health[11]. Thus, the impact of the human intake of food, drinks and medications should not be underestimated, as they might possess a profound effect on health in multidimensional aspects.

Diet and gut microbiota

The makeup of gut bacteria is heavily influenced by dietary choices. A diet packed with fiber, fruits and vegetables fosters the growth of beneficial gut bacteria. Conversely, a diet high in processed foods and sugar can lead to an overgrowth of harmful bacteria. Consuming specific dietary components like prebiotics and probiotics can significantly impact both the composition and function of gut microbiota[12]. Beyond diet, factors such as stress, sleep, and physical activity also play a role in gut health[13].

Table 1: Comparison allulose, sugar alcohols and other artificial sweeteners.

Feature[5,6]	Allulose	Sugar alcohols	Other artificial sweeteners
Source	Naturally occurring in small quantities in some fruits and foods	Found naturally in some fruits and vegetables; mostly manufactured	Synthetic compounds
Common Types	Allulose	Xylitol, erythritol, sorbitol, maltitol, mannitol, isomalt, lactitol	Aspartame, sucralose, saccharin, acesulfame potassium
Sweetness	About 70% as sweet as sugar	Generally, less sweet than sugar, varies by type	Hundreds to thousands of times sweeter than sugar
Calories	Less than 10% of the calories in sugar	Fewer calories than sugar, but more than allulose (e.g., erythritol: 0.2 cal/g)	Zero calories
Blood Sugar Impact	Does not substantially alter blood glucose or insulin levels	Minimal impact on blood sugar levels	No impact on blood sugar levels
Taste	Similar to sugar, no bitter aftertaste	Often have a cooling effect, can cause digestive issues in large amounts	Can have a bitter or metallic aftertaste
Safety	Recognized as safe by FDA and other authorities	Generally recognized as safe, but excessive consumption can cause digestive issues	Approved by FDA, but some studies suggest potential long-term health effects

Allulose and sugar alcohols: Low-calorie sweeteners with potential health benefits

Allulose and sugar alcohols have emerged as popular low-calorie sweeteners due to their minimal impact on blood sugar levels and their potential to improve metabolic health. Allulose, a rare sugar, is not readily absorbed by the body and has a negligible effect on blood glucose levels. Sugar alcohols, such as erythritol, xylitol, maltitol, and sorbitol, are partially digested and absorbed, resulting in a lower caloric content compared to traditional sugars. These sweeteners can be used as alternatives to sugar in various food products to help individuals reduce their overall calorie intake and improve their gut health[14-18]. Incorporating allulose and sugar alcohols into a balanced diet may contribute to better weight management and metabolic function.

Allulose and sugar alcohols: What are they?

Allulose is a low-calorie sweetener that is not fully absorbed by the body. Sugar alcohols, on the other hand, are partially digested and absorbed, providing fewer calories than regular sugar. Both can be used as substitutes for sugar in foods to aid in weight management and promote better gut health[19-22]. The key is to consume them in moderate amount to mitigate any risks associated with them, especially on the long-term use.

Allulose

Allulose is a rare monosaccharide that occurs naturally in small amounts in certain foods[19]. It has a similar structure to fructose but with a different arrangement of atoms and is not metabolized in the same way[20]. Allulose is poorly absorbed by the body and has a minimal impact on blood glucose levels[21].

Sugar alcohols

Sugar alcohols are a group of polyols that are derived from sugars but have different metabolic properties[22]. They are generally less sweet than sugar and have a lower caloric content[23]. Common sugar alcohols include:

- **Erythritol**: A natural sugar alcohol found in fruits and fermented foods. It is approximately 60-70% as sweet as sugar and often has a cooling sensation[24].
- **Xylitol**: A natural sugar alcohol found in berries, mushrooms, and birch bark. It is about 100% as sweet as sugar and has a similar taste[25].
- **Maltitol**: A synthetic sugar alcohol derived from maltose. It is 70-90% as sweet as sugar and has a slightly different taste profile[26].
- **Sorbitol**: A natural sugar alcohol found in fruits and berries. It is 50-60% as sweet as sugar and has a slightly bitter aftertaste[27].

Chemical structure, effect and taste

Allulose, a scarce monosaccharide naturally present in limited quantities within certain fruits and vegetables, bears a structural similarity to fructose[28]. Nevertheless, it is less sweet and has a negligible effect on insulin levels[29]. Sugar alcohols, a group of compounds structurally related to sugars, possess unique metabolic characteristics[27,30,31]. Generally, less sweet and lower in calories than sugar, common sugar alcohols include erythritol, xylitol, maltitol and sorbitol[32]. These sugar alcohols are often employed as sugar substitutes in food products marketed to individuals with diabetes or those seeking to reduce their sugar intake[33]. Despite their lower caloric content, consuming excessive amounts of sugar alcohols may result in adverse consequences[34].

Caloric content, impact on blood sugar and applications in the food industry

Allulose is a low-calorie sugar substitute, containing only 0.4 calories per gram compared to 4 calories per gram in regular sugar. Research suggests that allulose may help regulate blood sugar levels by mitigating post-meal glucose spikes. Sugar alcohols, such as erythritol and sorbitol, also offer lower calorie content than sugar, ranging from 0.2-0.3 calories to 2.6 calories per gram, respectively. However, their impact on blood sugar can vary based on the specific compound and individual factors. Allulose and sugar alcohols have become popular in the food industry as tools to reduce sugar content and calories in various products. They can be used as sweeteners in a diverse range of applications, including baked goods, candies, beverages and dairy products. Nevertheless, the unique properties of each compound may influence their suitability for different applications[35-41].

Gut microbiota modulation

Sugar alcohols such as erythritol and xylitol have little to no effect on blood glucose levels, making them suitable for individuals with diabetes or those adhering to a low-carbohydrate eating plan[42]. Additionally, some sugar alcohols like sorbitol can have a laxative effect if consumed in large amounts, so it's important for consumers to be mindful of their intake[43]. Gut microbiota modulation involves using specific foods or compounds to influence the makeup and behavior of the bacterial community in the digestive tract[44]. This can significantly impact various aspects of health, such as digestive processes, immune system function and mental well-being[45]. Table 2 shows some important aspects of these types of sweetening agents[35,36, 39-43,46].

Emerging research suggests that allulose and sugar alcohols may have prebiotic effects, stimulating the growth of beneficial bacteria in the gut[47]. Allulose has been shown to increase the abundance of *Bifidobacterium* and *Akkermansia muciniphila*, which are associated with improved metabolic health[48]. Sugar alcohols, particularly xylitol, have also been linked to increased levels of beneficial bacteria, such as *Bifidobacterium* and *Lactobacillus*[49]. These changes in gut microbiota composition may have potential benefits for overall gut health and metabolic function[50]. However, it is important to note that individual responses to allulose and sugar alcohols can vary, so moderation is key when consuming these ingredients[51].

Table 2: Caloric content, impact on blood sugar, gastrointestinal effects and applications in the food industry.

Compound	Caloric content (calories/gram)	Impact on blood sugar	Potential gastrointestinal effects	Common Applications
Allulose	0.4	Minimal	Bloating, diarrhea (in high doses)	Baked goods, candies, beverages, ice cream
Erythritol	0.2-0.3	Minimal	Bloating, gas, diarrhea (in high doses)	Candies, chewing gum, baked goods
Xylitol	2.4	Minimal	Bloating, gas, diarrhea (in high doses)	Chewing gum, toothpaste, baked goods
Maltitol	2.1	Moderate	Bloating, gas, diarrhea (in high doses)	Candies, chocolate, baked goods
Sorbitol	2.6	Moderate	Bloating, gas, diarrhea (in high doses)	Candies, gum, diabetic-friendly foods

Mechanisms by which these substances modulate gut microbiota

The exact mechanisms by which allulose and sugar alcohols influence gut microbiota composition remain unclear. More research is necessary to fully comprehend how these substances interact with gut bacteria and their potential long-term health implications. Individuals should consult with healthcare professionals before making significant dietary changes involving these ingredients[52-54]. Several potential mechanisms have been suggested:

- **Prebiotic Effects:** Allulose and sugar alcohols may act as substrates for beneficial bacteria, stimulating their growth and metabolic activity[52]. The intricate relationship between alcohols and gut microbiota necessitates further investigation.
- **Short-Chain Fatty Acid (SCFA) production:** Gut bacteria can ferment sugar alcohols, resulting in the production of SCFAs, which offer numerous health benefits, such as improved insulin sensitivity and reduced inflammation[53]. SCFAs also contribute to maintaining gut barrier integrity and supporting overall digestive health[54].
- **Gut pH modulation:** The fermentation of sugar alcohols can lower gut pH, creating an environment conducive to the growth of beneficial bacteria[55]. This can help establish a healthy balance of gut microbiota and prevent the overgrowth of harmful bacteria[56]. Additionally, a slightly acidic gut pH can enhance nutrient absorption and support overall digestive function[57].

Importance of a diverse and balanced gut microbiota for overall health

A varied and well-balanced gut microbiome is crucial for optimal health. A diverse microbiome can improve nutrient uptake, bolster the immune system and offer protection against various diseases[58]. Dysbiosis, an imbalance in the gut microbiome, has been associated with a range of health issues, including obesity, type 2 diabetes, inflammatory bowel disease and mental health conditions[59]. Thus, fostering a diverse and balanced gut microbiome through a nutritious diet rich in fiber, fermented foods and probiotics is essential for overall well-being[60]. It's also important to avoid factors that can disrupt the microbiome, such as antibiotics, processed foods and chronic stress[61]. Maintaining a healthy gut microbiome can also enhance digestion and reduce inflammation throughout the body[62]. Adding prebiotic-rich foods like garlic, onions and bananas can further support the growth of beneficial bacteria in the gut[63].

Metabolic health benefits

Metabolic health benefits include improved digestion, reduced inflammation and better regulation of blood sugar levels[64]. Additionally, a diverse gut microbiota has been associated with a lower risk of metabolic disorders such as obesity and diabetes[65]. Maintaining a healthy gut microbiota through a balanced diet rich in fiber and fermented foods is crucial for promoting overall metabolic health[12]. Furthermore, studies have shown that a healthy gut microbiota can also help in the absorption of nutrients and the production of certain vitamins essential for metabolic processes[66]. Therefore, prioritizing gut health through dietary choices can have long-term benefits for overall metabolic function and well-being[45].

Impact on blood glucose levels: Allulose and sugar alcohols have been shown to have minimal impact on blood glucose levels. This is particularly beneficial for individuals with diabetes or prediabetes, as it can help to maintain stable blood sugar levels and reduce the risk of complications[67].

Potential role in weight management and obesity prevention: Allulose and sugar alcohols can contribute to weight management by reducing calorie intake. They can also help to increase satiety, leading to reduced food intake[68]. Additionally, the prebiotic effects of these sweeteners may indirectly contribute to weight management by improving gut health and reducing inflammation[69].

Effects on insulin sensitivity and metabolic syndrome risk factors: Allulose and sugar alcohols have been shown to improve insulin sensitivity and reduce the risk of metabolic syndrome[1]. These effects may be mediated through various mechanisms, including the modulation of gut microbiota, reduced inflammation, and improved lipid metabolism[19].

Potential challenges and considerations

While allulose and sugar alcohols offer potential health benefits, it is important to consider potential challenges and limitations. Excessive consumption of sugar alcohols can lead to gastrointestinal side effects, such as bloating, gas, and diarrhea[70]. Additionally, individual tolerance to sugar alcohols may vary. Furthermore, the long-term effects of consuming allulose and sugar alcohols on gut microbiota composition and metabolic health are not fully understood[71]. More research is needed to determine the optimal dosage and duration of use for these sweeteners[48]. Digestive issues associated with excessive consumption of sugar alcohols may be a concern for some individuals, especially those with sensitive stomachs[72]. It is recommended for each consumer to monitor their body's response and adjust consumption accordingly to avoid discomfort[73]. Individual variability in tolerance to allulose and sugar alcohols should also be taken into consideration, as some people may experience bloating, gas or diarrhea with even small amounts[74]. Consulting with a healthcare provider or nutritionist before incorporating these sweeteners into one's diet is advisable to ensure they are suitable for individual needs and health goals[75]. The need for further research on long-term effects on gut microbiota and metabolic health is also crucial in order to fully understand the impact of these sweeteners on overall health[76]. Additionally, staying informed about new studies and findings in this area can help individuals make more informed decisions about their dietary choices.

Future research directions

While interest in allulose and sugar alcohols is growing, their long-term health effects and potential benefits remain incompletely understood[12]. To gain a more comprehensive understanding of their impact on overall health, future research should focus on various populations, including children, pregnant women and individuals with specific health conditions[34]. Additionally, exploring the interactions of these sweeteners with other dietary components and their role in metabolic health and well-being is crucial[77]. Future studies should prioritize the following areas:

Long-term safety and efficacy: Long-term studies are needed to assess the safety and efficacy of allulose and sugar alcohols in human populations[7,8]. Research should also explore their potential effects on gut health, metabolic function and weight management[9,10]. A comprehensive understanding of their impact is essential for evidence-based recommendations regarding their consumption[11].

Impact on gut microbiota: The potential effects of these compounds on gut microbiota, a key factor in overall health, should be investigated[12,13]. Studying the interaction between allulose and sugar alcohols with gut bacteria can provide valuable insights into their impact on digestion and nutrient absorption[14]. This research can help determine if these sweeteners have any long-term effects on gut microbiota composition and function[15].

Interactions with other nutrients: The interactions between allulose and sugar alcohols with other nutrients and dietary components should be examined[16,17]. Understanding how these sweeteners may affect the absorption and utilization of essential vitamins and minerals in the body is important for assessing their overall impact on health[18]. Additionally, investigating potential synergistic or antagonistic effects with other dietary components can provide a more comprehensive understanding of their physiological effects[19].

Consumer acceptance and preferences: Studies on consumer acceptance and preferences for allulose and sugar alcohols can inform product development and marketing strategies[20,21]. Furthermore, exploring the potential long-term health implications of regular consumption of these sweeteners can help guide recommendations for their use in various populations[22]. It is also important to consider the environmental impact of producing and using these sweeteners as alternatives to traditional sugars[23].

CONCLUSIONS

Allulose and sugar alcohols are low-calorie sweeteners with potential health benefits. These sweeteners can positively impact gut microbiota, leading to a healthier gut environment and reduced risk of metabolic disorders. However, moderation is key and individual tolerance varies. Future research should delve into the mechanisms behind these sweeteners' effects and their long-term impact on human health. By understanding the complex interactions between these sweeteners, gut microbiota and metabolic health, it is possible to create evidence-based dietary guidelines for optimal health. Incorporating gut health into metabolic health and disease prevention strategies is essential for personalized nutrition. By exploring the relationship between gut microbiota and metabolic health, development of targeted interventions to promote well-being and reduce chronic disease risk could be attained.

ACKNOWLEDGEMENTS

None to declare.

AUTHOR'S CONTRIBUTIONS

Eissa ME: conceived the idea, writing the manuscript, literature survey, formal analysis, critical review.

CONFLICT OF INTEREST

None to declare.

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