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Review

Substituting Sugar in Pastry and Bakery Products with Functional Ingredients

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Abstract: Replacing the amount of sugar in pastries with functional ingredients may be a strategy of interest to food manufacturers. Reducing the content of sugar in pastries and bakery products could be a measure to reduce diseases such as obesity, diabetes, cardiovascular disease, tooth decay, and cognitive impairment. Additionally, energy consumption, greenhouse gas emissions, and global warming potential are the main issues in sugar beet agricultural production systems. Due to the multiple roles that sugar has in the dough (i.e., provide energy, sweeten, improve the structural characteristics, extend shelf life, limit the swelling of the starch, give color and flavor to ripe products, and ensure the preservation of products), there have been attempts at substituting sugar in percentages of up to 100% in different products such as cakes, muffins, pies, biscuits, cookies, and bread. From the points of view of technology and consumer perception, the best substitutes are apple puree, inulin, oligofructose, stevia, apple pomace, polydextrose, dried apples, *Nypa fruticans* sap, grape juice/syrup, and date powder/syrup. Depending on the substituent, when substituting sugar in percentages from 10 to 100%, improvements were obtained in terms of texture, rheological properties, sensory properties, consumer acceptability, and physicochemical and nutritional properties.

Keywords: sugar; substitution; pastries; functional ingredients

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1. Introduction

With over 1 billion people estimated to suffer from obesity and over 300 million people suffering from diabetes (according to the International Diabetes Federation), there is a double epidemic of diabetes and obesity. In the last 30 years, the obesity rate has increased by 40% in the United States (66 million obese people, 74 million overweight people) and varies between 20–30% in European countries. What is worrying is the fact that there will be a doubling of diabetes by 2035 and an increase in obesity by 1.5 billion people by 2030, a forecast based on current food trends [1–3]. It is also expected that the number of children with cardiovascular disease caused by obesity will increase by more than 1 million by 2035 in the US [2].

To prevent comorbidities and mortality associated with childhood obesity, preventive measures must be implemented that involve both educating children and adolescents in adopting a healthy diet and setting new directions for food producers to reduce and replace sugar in foods [2,4–7].

Over the years, sugar consumption has increased; while our ancestors consumed only fruit and honey sugars, today, sugar is added to most foods [8]. In addition to the natural sugar found in food (cereals, fruits, vegetables, and milk), manufacturers add sugar to pastries both to improve the sweet taste and for the many roles it has (texture, flavor, color, and preservation) [9]. Sucrose is the most widely used sweetener in the world due to both its technological and sensory functions [10]. Substitution of sugar in food products can lead to changes in the structure and sensory characteristics of food, because sugar plays many roles in their formation (sweetness, color, flavor, structural, texture, and fermentation) [9,11–22]. According to [23], desserts are considered the second most important source of added sugars [23].

The consumption of pastries has gradually increased in recent years, and they are obtained at the industrial level and available at reduced prices. Every year, approximately 4.5 thousand tons of cakes are produced worldwide. What is being studied is their high sugar content [11,24]. The high sugar content of pastries and their number of calories is the main problem of these products, although they are highly valued by consumers [12,25,26]. Given the multifaceted role of sugar in food, substituting sugar in confectionery is a challenge for producers and researchers in the food industry because they need to redesign traditional products in a healthier way without affecting their sensory and structural properties/characteristics. This is both a technical and a sensory challenge, as it is difficult to reformulate products without affecting the sensory properties, and acceptability can also be compromised.

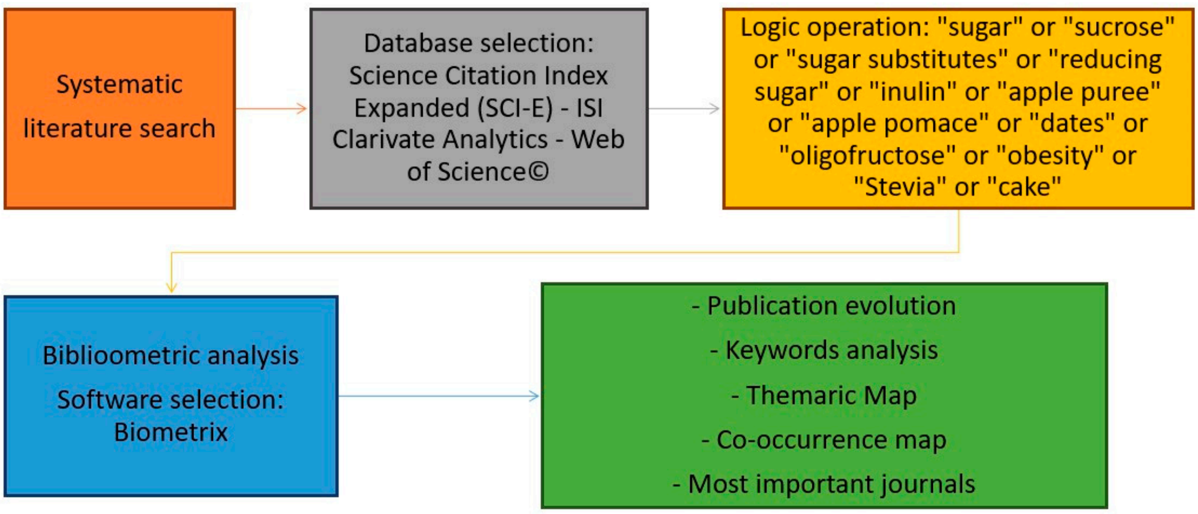
Furthermore, the substitution of some percentage of the quantity of sucrose in desserts is both expensive and time consuming. This reformulation involves two strategies: reducing the amount of sugar or replacing all or part of the sugar [11–14,27–31]. In 2015, the WHO recommendation was to reduce the amount of sugar consumed (less than 10% of total energy consumption) by introducing a sugar tax [6,13,27,32–42].

Replacing sugar in food is a measure taken as a result of WHO reports and as a result of the demand of consumers who take special interest in nutrition and are aware of the effects of sugar on their health (diabetes, obesity, cancer, etc.) [3,4,11,12,16,17,27,43–46].

Another worldwide problem is represented by energy consumption in modern agricultural systems (49,517.2 MJ/ha of sugar beet). In addition, greenhouse gas emissions and the total global warming potential (9847.77 kg CO_2 eq/ha of sugar beet) have become critical problems in agricultural systems in recent years [47].

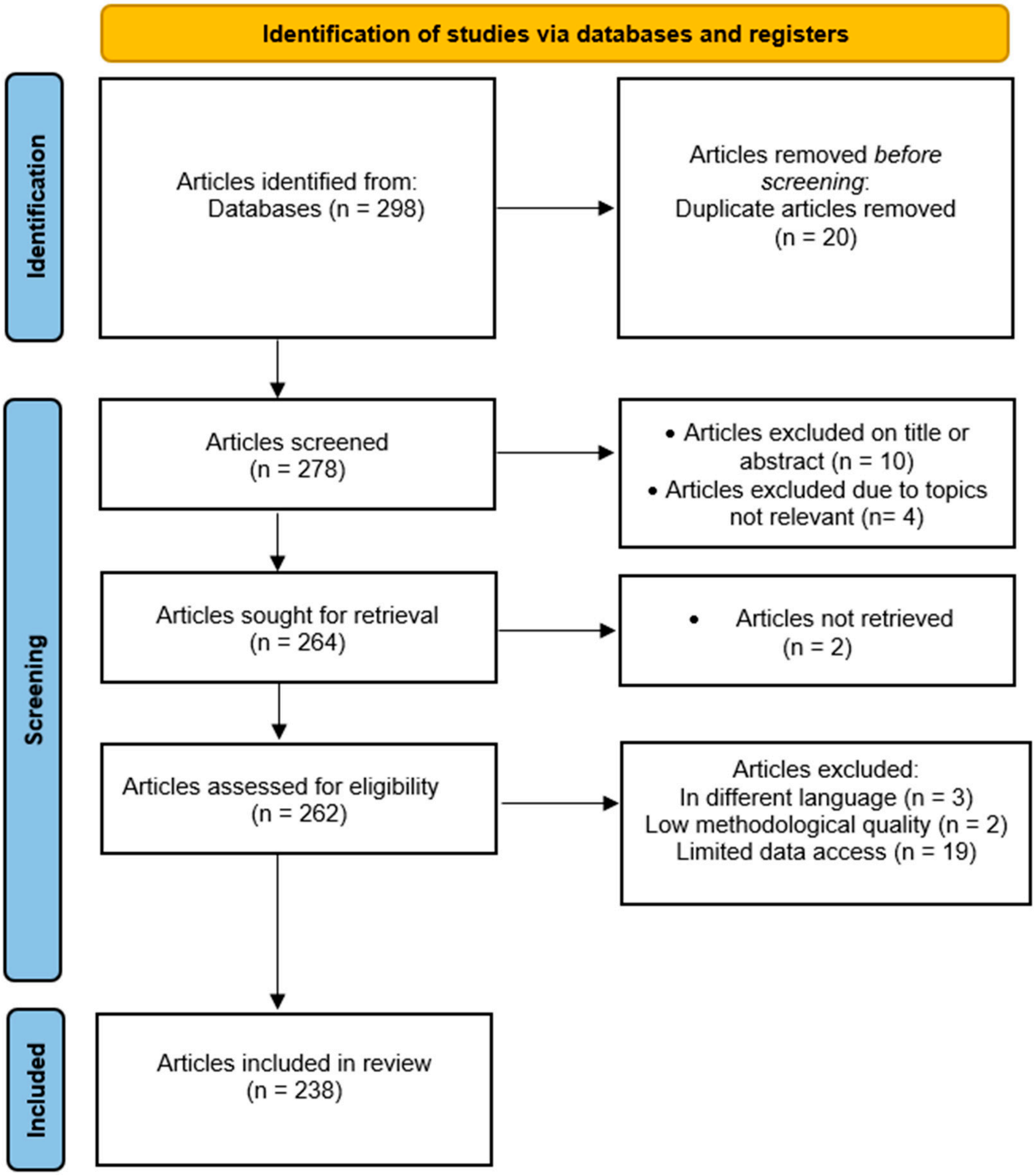
2. Methodology for the Systematic Literature Search and Bibliometric Analysis

This literature search involved the use of scientific data from the core collection of Science Citation Index Expanded (SCI-E)—ISI Clarivate Analytics—Web of Science. The logical operation applied to the search was “sugar” or “sucrose” or “sugar substitutes” or “reducing sugar” or “inulin” or “apple puree” or “apple pomace” or “dates” or “oligofructose” or “obesity” or “Stevia” or “cake”. The purpose of this search was to select specific, accurate, and reliable information based on the title, abstract, and author keywords of each document published in the database (Figure 1a).



(**a**)

Figure 1. *Cont.*



(**b**)

Figure 1. (**a**) The main steps for the systematic literature search and bibliometric analysis [48]. (**b**) PRISMA checklist for article selection.

The PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guidelines were used for the systematic review of the literature. The initial number of works used in this study was 298, and the exclusion criteria of the articles were topics not relevant, low methodological quality, limited access to data, and different language. Figure 1b shows the article selection process in the form of a flow chart.

Multivariate techniques, such as multiple correspondence analysis and hierarchical clustering, were employed to assess the conceptual structure within RStudio software (version 4.3.3 (29 February 2024 ucrt)) using the Bibliometrix package.

This type of scientific productivity can be assessed through bibliometric mapping of authors' keywords, which aids in identifying the main research focuses and helps uncover new study trends.

Keywords are extracted as metadata and, after mathematical treatment, projected into a low-dimensional Euclidean space, representing their "co-occurrence" in various studies due to their simultaneous frequency. The number of occurrences refers to the total number of words detected in the articles used for analysis. The map features a network of words, where the size of nodes is proportional to the number of publications, separated into distinct, differently colored clusters (Figure 2).

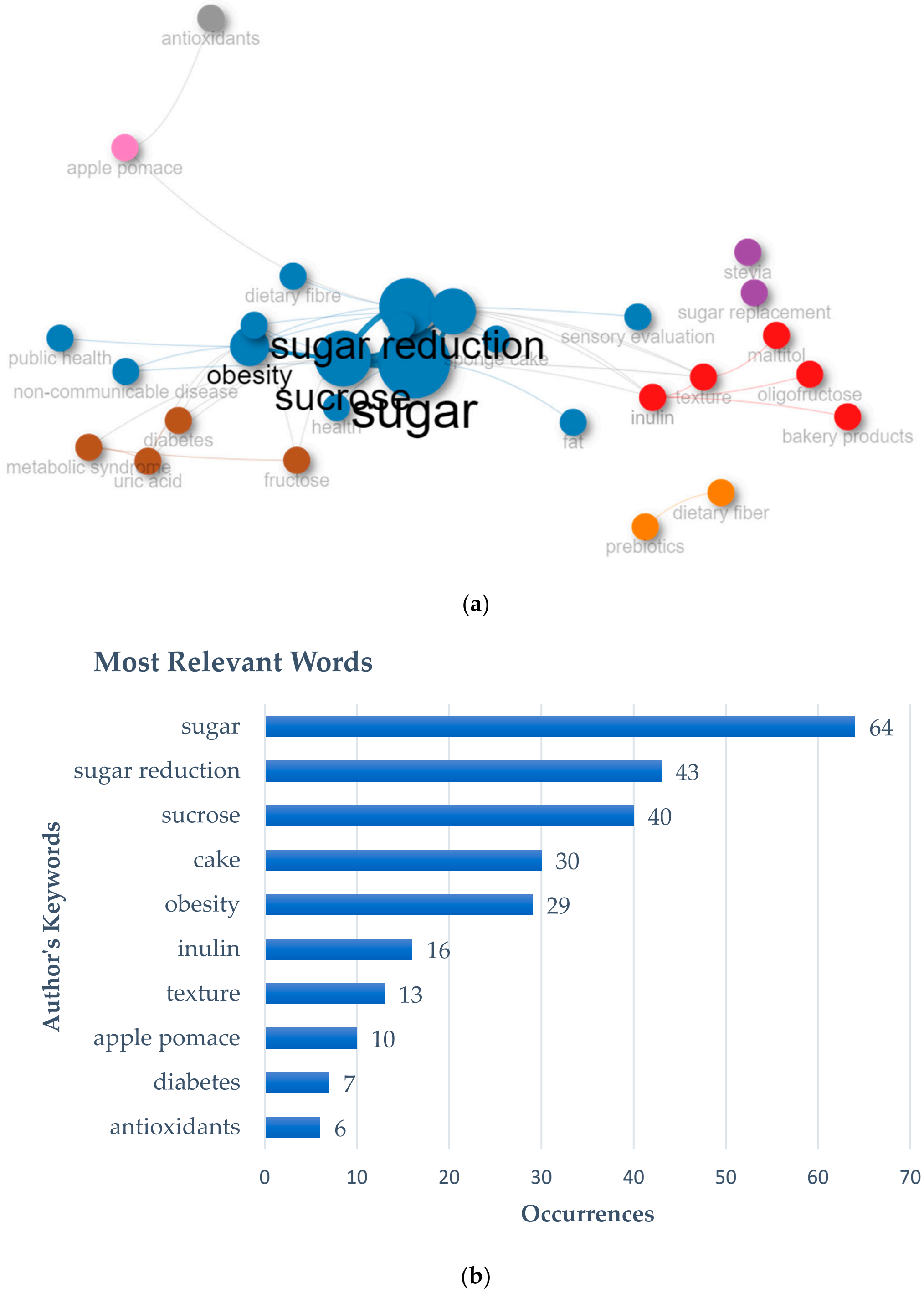


Figure 2. Co-occurrence bibliometric map (**a**) and most relevant keywords related to sugar reduction (**b**).

Over the years, the subjects and fields of research have evolved; some have become outdated, while others have gained more prominence. With this diversity of themes and interests, key terms also vary accordingly. A thematic map classifies clusters based on their significance in the research area, showcasing their density and centrality along thematic axes (Figure 3). Thematic maps are a powerful tool in bibliometric analysis provided by the Bibliometrix package in R. These maps help visualize the thematic structure of scientific literature by representing the relationships between terms (such as keywords or topics) based on their co-occurrence in documents.

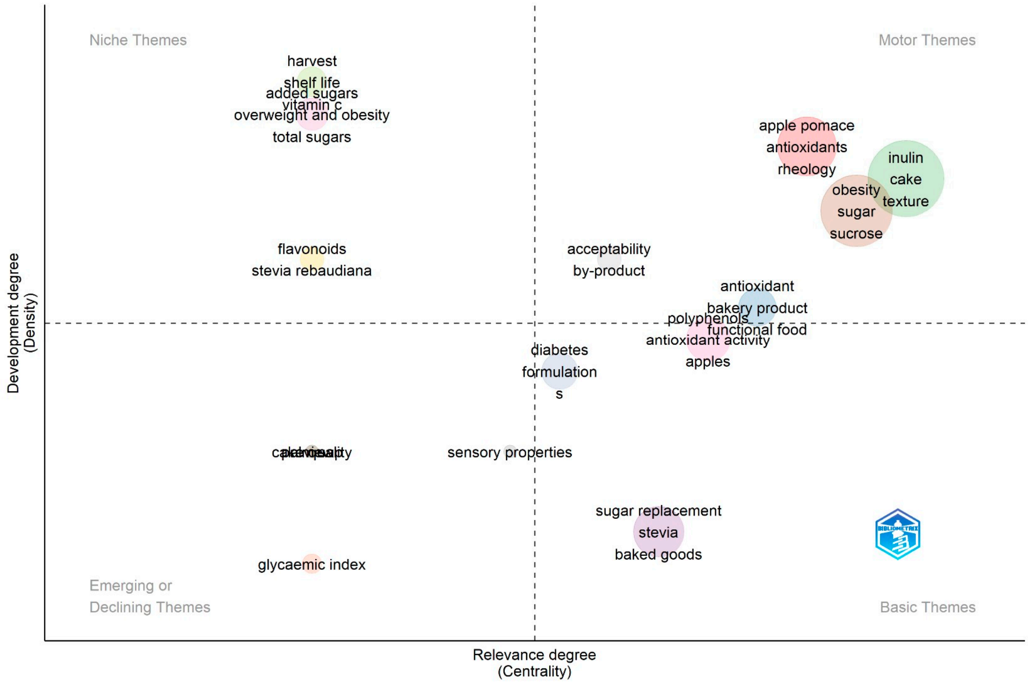


Figure 3. Thematic map of the clusters from the most frequent authors' keywords.

Reducing the amount of sucrose in pastry and bakery products has been a topic of interest in recent years. Figure 4 shows the evolution of peer-reviewed publications reporting the reduction in sucrose in pastry and bakery products (2014–2022).

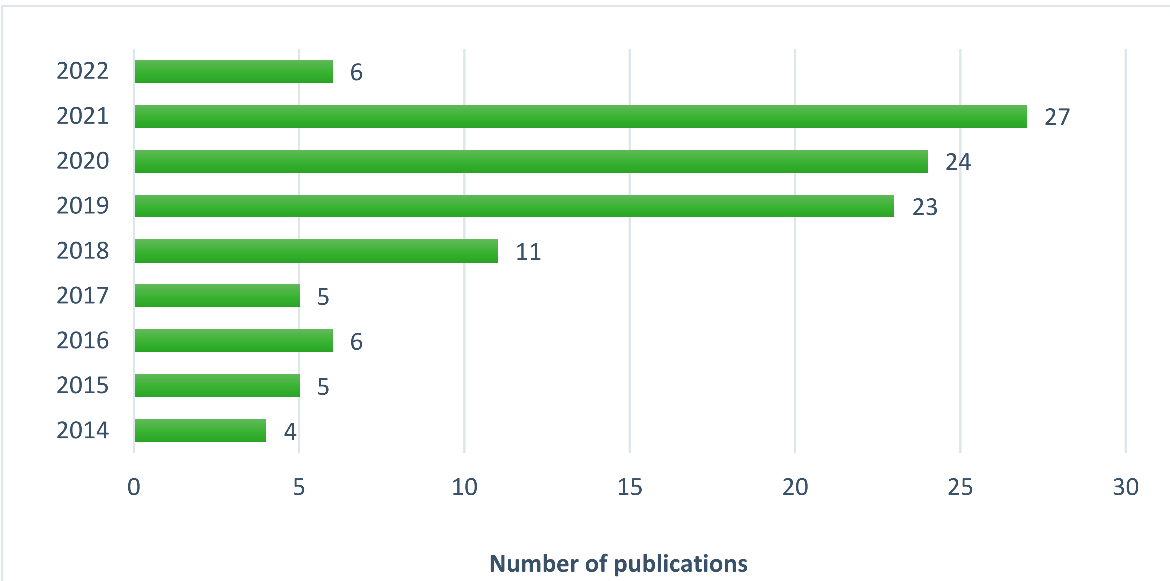


Figure 4. Evolution of peer-reviewed publications reporting on sucrose reduction in pastry and bakery products (2014–2022).

3. The Effects of Sugar on Health

3.1. Obesity

Obesity is a very common disease in recent years, and affects the general health of the population. Prevention of obesity has become an issue of global interest, especially in developed countries but also in developing countries [13,23,34,49–59]. Accumulation of body fat, with serious consequences for psychosocial and metabolic health, is a chronic disease called obesity.

The causes of obesity are energy imbalance due to the consumption of products and beverages with a high sugar content, sedentary lifestyle, and genetic structure [1,2,6,13,23,29,32,33,36,38,43,49,50,53,60–81].

Research has revealed a significant link between a higher proportion of carbohydrate intake and obesity. This connection was evident at the individual level, as there was a strong correlation between the percentage of calories derived from carbohydrates and the body mass index (BMI) of adults. This suggests that the consumption of carbohydrates played a significant role in weight gain and the development of obesity. These findings align with previous research by Mozaffarian, who observed that foods with a high glycemic index, such as potato products, refined grains, sweets, and desserts, were most closely associated with weight gain. Interestingly, the weight gain resulting from the consumption of sweets and desserts appears to be comparable to that caused by the consumption of refined grains [10,82].

The main cause of obesity is the imbalance between calories consumed and calories burned. Obesity is considered a risk factor for various health conditions, including type 2 diabetes and cardiovascular disease. The excess body fat in obesity can contribute to insulin resistance, a hallmark of type 2 diabetes, where the body's cells become less responsive to insulin, leading to elevated blood glucose levels. Obesity is also associated with chronic low-grade inflammation and metabolic abnormalities, which can increase the risk of developing cardiovascular disease, including heart disease and stroke [34,39,46,53,59,69,70,72–75,77,83–95].

3.2. Diabetes

The main factors of diabetes are excessive sucrose consumption and obesity. High consumption of sucrose leads to increased blood glucose levels and thus to hyperglycemia [18,20,23,28,36,39,46,49,50,53,54,64–68,74,96–101].

Diabetes is a chronic metabolic disease characterized by high levels of sugar (glucose) in the blood, which is due to the body's inability to produce enough insulin or to properly use the insulin it produces. The four main types of diabetes are type 1, type 2, gestational, and type 3 (Alzheimer's-related). The long-term elevated glucose levels in diabetes can lead to a range of complications, including eye, kidney, nerve, heart, and blood vessel damage, as well as retinopathy, renal sclerosis, and neuropathy. Effective management of blood sugar levels can help to prevent or delay the onset of these complications [10,96,102,103].

3.3. Tooth Decay

Tooth decay is caused by the interaction between acid-producing bacteria and fermentable sugars, which accelerate the development and multiplication of oral microorganisms. Additionally, the stickiness of sucrose causes microorganisms to adhere to the surface of the teeth, and the protective layer of the tooth is affected by the acidic products of the bacteria's metabolism [28,38,50,62,67–70,86,87,90,97,98,104,105].

3.4. Cognitive and Memory Functions

It has been observed that foods and beverages rich in sucrose can adversely affect the cognitive and memory functions of children, in particular. Excessive sugar consumption can lead to mental disorders in young people. Sugar can also be addictive, as can cocaine or other drugs. Excessive sugar consumption can lead to inflammation in the brain and impair the neural ability to form and consolidate memories. Sugar can disrupt the chemical balance of neurotransmitters, such as dopamine and serotonin, which play a critical role in regulating mood. Rapid fluctuations in blood sugar can also lead to mood swings and irritability. Sugar increases dopamine levels, which induces a state of pleasure, but this effect is short-lived. The brain quickly develops a tolerance, meaning that to get the same effect, people need increasing amounts of sugar. This cycle can lead to addiction, especially in children and adolescents, whose neural systems are more susceptible to habit formation [53,68,106,107].

3.5. Cardiovascular Disease

Consumption of foods with a high sugar content leads to increased triglycerides and increased cholesterol, and therefore may lead to cardiovascular disease. Sugar is mainly metabolized by the liver. In this process, some of the sugar is converted into fatty acids, which are then released into the bloodstream as triglycerides. Excessive sugar consumption can increase the concentration of low-density lipoproteins (LDL—"bad cholesterol") and decrease the level of high-density lipoproteins (HDL—"good cholesterol"). Oxidized LDL cholesterol is directly involved in the formation of atheroma plaques, thus contributing to the narrowing of the arterial lumen and the reduction in blood flow, increasing the risk of myocardial infarction and stroke [1,2,6,23,33,38,39,53,55,63,67,70,101,108].

Consequently, reduced sugar consumption can reduce the risk of high blood pressure and heart disease. Sugar has a high caloric content and often excessive sugar consumption is associated with obesity. Reducing sugar intake can help control weight and prevent obesity. Eating too much sugar can lead to insulin resistance and type 2 diabetes. Reducing sugar intake helps keep blood sugar in a healthy range and can prevent type 2 diabetes [39,96,109].

4. The Role of Sugar in Pastries

Due to the multiple roles that sugar has in the dough, sugar substitution can lead to products with altered sensory, rheological, and textural properties. Therefore, the interest in the partial or total substitution of sugar with ingredients that can fulfill similar roles to those of sugar is an important step in the food industry [11,110–113]. In addition to providing sweetness, sugar plays other important roles in the food industry. Sugar can be used to mask unpleasant tastes such as bitter, salty, or sour flavors [114]. Additionally, due to the multiple functionalities of the sugar and its percentage in the manufacturing recipe (30–40%), the partial or total substitution of the sugar has proven to be difficult, requiring scientific research in this regard [27,115].

The factors that influence the quality of pastries are the quality of raw materials and their added percentage according to the recipe. Thus, reducing the sugar in the products can create changes and imbalances in the interactions of the ingredients, which could affect their quality and acceptability. Therefore, substituting sugar with ingredients with similar functional properties is a promising strategy in reducing the energy/caloric value of products. In order to be able to substitute sugar in a product, it is necessary to understand the functions that it has in products [116]. The main role of sucrose is to provide energy, but this role can be a drawback if this energy is not consumed [12,14,32,116–119].

4.1. Sweetness

One of the most recognizable roles of sugar is the sweetness it offers to a wide range of foods. In addition to providing sweetness, sugar can also be used to mask bitter, salty, or sour tastes. Additionally, sucrose can accelerate the release of volatile compounds causing the intensification of fruit aromas in some foods, the sweet taste, and the aroma of the fruit functioning synergistically [9,12–14,16–22,28,31,113,115–117,120,121]. Studies have found that sugar can amplify the aroma of strawberries in strawberry-flavored solutions, boost the vanilla and caramel flavors in milk chocolate, enhance the fruity notes in blueberry and cranberry juice, and increase the range of fruity and leafy aromas in dairy desserts. The mechanism behind this effect is attributed to congruent aroma–taste interactions and, in some cases, a physicochemical reaction where the presence of sucrose can increase the release of volatile compounds from the solution [13,122].

The perception of sweetness in food can be intensified by odors that are associated with sugary products, as shown in a study by Frank and Byram (1988). The study found that the addition of a strawberry odor to whipped cream resulted in an increase in the perceived sweetness and duration, while the addition of a peanut butter odor had no effect on the sweetness rating. The effect of the strawberry aroma on sucrose solutions was also confirmed in a study by Frank, Ducheny, and Mize (1989). Stevenson, Prescott, and Boakes (1999) discovered that sweet food aromas like caramel and strawberry heightened the perceived sweetness, while non-food odors like angelica oil suppressed it [13,122].

4.2. Structural

Sugar can also be used to improve the structural characteristics of pastry and bakery products. One of these characteristics is the viscosity, with sucrose being responsible for reducing the viscosity of the dough, creating volume during baking, and reducing the relaxation time. The amount of sugar added to food can cause an increase in the gelatinization temperature of starch, as well as the coagulation of proteins at high temperatures [13,16,21,22,28,61,115,123–127].

The porosity of pastries is an important characteristic that directly influences the acceptability of consumers; this characteristic is in turn influenced by the amount of sucrose used in the manufacturing recipe [13,126].

4.3. Color and Flavor

Another important role of sugar is to give color and flavor to ripe products due to Maillard caramelization and browning reactions. Caramelization is a desired process in ripe products, which contributes to improving their sensory characteristics. At high temperatures, the sugars are caramelized, leading to a caramel aroma and a dark brown color. Via the reaction between the sugar added in the pastries and the amino acids from the other ingredients in the manufacturing recipe, the Maillard reaction takes place, which produces a non-enzymatic browning of the products, with the aroma and color desired by consumers [9,20,31,117].

4.4. Texture

Another essential role of sugar is to help obtain a texture suitable for the pastry and bakery products. During the preparation of the dough, the sugar contributes to the incorporation of carbon dioxide bubbles in the dough. Furthermore, the viscosity is influenced by the amount of sugar added, which binds water and leads to a softening of the dough. In addition, sugar can also act as a humectant in baking. Sugar helps to maintain the moisture content of a product by attracting and retaining water. In baking, sugar helps to retain moisture and prevent the baked goods from drying out. This can result in a softer, fresher, and more tender crumb [115,128,129]. The fine texture of the products is also obtained by the ability of the sugar to limit the swelling of the starch. In addition, sugar prevents or delays the gelatinization of starch, increases the temperature of denaturation of proteins, and slows proteins' denaturation [9,12–14,16,18–22,28,31,61,113,115,117].

4.5. Fermentation

Sugar is one of the main sources of carbohydrates consumed by yeasts, which explains the importance of sugar in the fermentation of pastries. In addition, due to fermentation, carbon dioxide is released and contributes to obtaining high-volume products [9].

5. Sugar Substitutes

Excessive consumption of pastry and bakery products with a high sucrose content is an unhealthy habit. The use of fruits or fruit purees in obtaining pastries can be a method of sugar substitution. This method involves obtaining pastries with a low energy value but a high nutritional value due to the high content of nutrients (bioactive compounds, fiber, etc.) [11,110,123,130]. Sugar substitutes include apple puree or other fruits, inulin, oligofructose, stevia, apple pomace, polydextrose, whey permeate, dried apples, *Nypa fruticans* sap, grape juice, grape syrup, dates powder, dates syrup, date liquid sugar, jaggery sugar, banana puree, black currant/aronia pomace, and sucralose [11,12,16,28,66,98,110,125,131–163].

5.1. Apple Products and By-Products

Apple is one of the most widely consumed fruits, being grown in many parts of the world [164]. In 2017, world apple production reached 83.1 million tons, and the apple puree industry is the second largest after that for banana puree. Apple puree is a dispersion of insoluble particles (pulp) in an aqueous medium. In addition to its high nutritional value, low caloric value, and beneficial effects on the body, apple is an affordable and inexpensive fruit. These arguments support the potential for its incorporation into food as a functional ingredient [165–169].

Due to the high content of carbohydrates in apples, especially fructose, which is sweeter than sucrose, they can be a substitute with good potential for sugar; apples are rich in fructose (5.9%), glucose (2.4%), and sucrose (2.07%). Additionally, the high fructose content makes apple puree a suitable basis for fermentation [170–172]. Due to its antioxidant potential, apple can be used as a functional ingredient in obtaining pastries [21,168–187].

The antioxidant activity of apples is determined by the high content of phenolic compounds. In addition, apples are rich in nutrients (carbohydrates, minerals, fiber, and vitamins), and the use of apple puree as a sugar substitute leads to a decrease in the caloric value of pastries and an increase in nutritional value [21,164,168–187]. Dietary fiber in apples can prevent colon cancer, diabetes (by lowering blood glucose), coronary heart disease, and obesity [21,168–187].

Apple puree is a good source of natural sugars and fiber, which can help maintain stable blood sugar levels during physical activity [188]. Carbohydrates in the form of apple puree can provide energy for endurance exercise and have potential health benefits [188]. Apple puree is a rich source of compounds such as vitamins, fatty acids, amino acids, proteins, and other compounds with a wide range of applications in the food industry [179]. Additionally, apple puree contains a high quantity of polyphenols (Table 1) [189].

The data suggest that apple pomace has a higher phenol content compared to wheat flour. Phenols are a type of antioxidant that have potential health benefits, such as reducing the risk of chronic diseases. However, it is important to note that the nutritional value of a food depends on various factors such as the type of apple, the processing method, and the portion size [190]. Apple pomace is a good source of total dietary fiber (TDF) and can be used as an ingredient in cake to add fiber to the diet. Fiber is important for digestive health and can help regulate blood sugar levels, among other benefits [190]. Additionally, apple pomace can be used in cake making as a source of polyphenols, which have antioxidant properties (Table 1) [190].

Apple fiber is a by-product of juice or wine production and its use in food products can add dietary value while not significantly increasing costs. As consumers are becoming more health-conscious, they are looking for food with decreased fat content and increased fiber. Adding apple fiber to food products can help meet this demand and provide added health benefits, such as improved digestive health [191].

5.2. Inulin

Inulin is part of the fructosans group obtained from plants, fruits, or vegetables. This fiber has many nutritional, sensory, and technological roles, being a prebiotic with many beneficial effects on the body: it stimulates the immune system, increases calcium absorption, improves digestive and intestinal activity, and increases the feeling of satiety [192,193]. In addition, fibers such as inulin and oligofructose may help prevent disease, such as type 2 diabetes, colorectal cancer, cardiovascular disease, obesity, and intestinal infections [192].

From a technological point of view, inulin influences the viscosity of the dough, and it can be used as a volume agent and to improve the structure of pastries. It is used for its high ability to bind water in these products. Like sucrose, inulin has the role of binding water to the product and delaying the gelatinization of starch, which makes it a possible substitute for confectionery ingredients [12,28,193–197]. Inulin also improves the sensory properties of food [28,30,192–194,197–204].

Inulin has the ability to form microcrystals in water, which leads to a consumer-accepted texture [148,197,205]. In terms of sweetness, this polysaccharide provides 10% of the sweetness offered by sucrose, but provides 25–35% of the energy compared to sucrose [198,200,204].

Substituting sugar from pastries with this fiber leads to low-calorie products with a high nutritional value [16,196,197,205–207]. When crossing the gastrointestinal tract, it is largely undigested, so it has a low caloric value (1.5 kcal/g). In the colon, it functions as a prebiotic, improving the intestinal microflora and blocking the action of pathogenic microorganisms [192–194,196,198–200,203,204,206,208,209].

5.3. Oligofructose

Oligofructose is a fructan composed of fructose polymers, and has functional properties similar to those of sugar, but, compared to sugar, oligofructose has a lower caloric value. Considered a prebiotic, oligofructose has a beneficial effect on the intestinal microflora: it stimulates beneficial microorganisms and inhibits the growth of bacteria, such as *E. coli* and Salmonella [12,97,131,192,200–202,210–212].

Oligofructose is a compound that has functional properties similar to those of sugar. This fructan has 35% of the sweetening power of sugar, but has the ability to accentuate fruit flavors [12,201]. Being stable at high temperatures, oligofructose contributes to the browning of pastries, a process that is desirable in the case of baked products [131,196,201,210].

5.4. Stevia rebaudiana

Stevia rebaudiana is a sweetener extracted from a shrub, which has a sweetening power greater than 200–300 times that of sucrose. The advantage of this sweetener is that it has no calories and does not increase the level of glucose or insulin in the blood [28,50,74,76,110,204,213–215].

Stevia has both nutritional benefits (high content of minerals, vitamins, proteins, and polyphenols) (Tables 1 and 2) and technological benefits (does not change color at high temperatures, is stable to heat) [67,76]. In addition to the advantage of obtaining low-energy pastries, it is a good antioxidant and has beneficial effects on health: it reduces the risks of diabetes and cardiovascular disease, and improves the immune system [31,67,110,216].

5.5. Nypa fruticans sap

Nypa fruticans sap is a sugar substitute due to its saccharide content. The advantage of *Nypa fruticans* sap is its high nutritional value (minerals, bioactive compounds, phenolic acids, vitamins, and amino acids) (Table 1) [139,140,217,218]. *Nypa fruticans* sap has higher nutrient and antioxidant content, with a lower glycemic index, than sugarcane [218,219]. *Nypa fruticans* sap can be obtained by evaporation at 110 °C to 70° Brix, cooling at 27–30 °C, and storage at 4–10 °C. The sap is mainly composed of approximately 80% water and 10–15% sugars (glucose, fructose, inositol) [219]. In addition, *Nypa fruticans* sap is rich in minerals (Na, Cl) (Table 2), essential amino acids, antioxidants (phytonutrients such as flavonoids, anthocyanidin, and polyphenols), and vitamins (C, B complex) (Table 2) [219]. *Nypa fruticans* sap is rich in inulin, which is a polymer of fructose that can be used as a natural sugar replacer and has prebiotic properties [219].

5.6. Date Products

Dates are a rich source of glucose (32%), fructose (23.7%), sucrose (8.2%), fiber, minerals, protein, pectin, vitamins, and antioxidants, making them a suitable substitute for confectionery sugar [144,150,154]. Dates are an important and rich source of essential minerals (potassium, magnesium, iron, copper, zinc, and selenium) (Table 2) [220,221].

Additionally, dates contain vitamins (thiamine, folic acid, ascorbic acid, riboflavin, and retinol) [221]. Vitamins B_2, B_3, B_6, and B_9 are present in moderate concentrations in dry dates [220]. Date fruit contains 8 g/100 g total dietary fiber [220]. Antioxidants present in dates are glutathione, polyamines, and phenolics (Table 1) [220]. Dates are a good source of essential amino acids (histidine, alanine, glycine, proline, arginine, asparagine, glutamate) [221].

Bioactive components are natural compounds that have a beneficial effect on human health. These components are typically present in small amounts but can have a significant impact on the body's biological processes when consumed regularly [173].

Examples of bioactive components include antioxidants, polyphenols, flavonoids, and carotenoids (Table 1). These components have been linked to various health benefits, such as reducing inflammation, improving cardiovascular health, boosting the immune system, and reducing the risk of certain cancers [166,173,222].

Table 1. The content of bioactive components of the substituents.

Substitutes	TPC	PA	Flavonols	Flavon-3-ols	Dihydrochalcones	C	T	CV	A	Tannins	Reference
Apples	x	x	X	x	x	x	x	x	x	x	[172–174,179,183,184, 189,190,223–228]
Nypa fruticans sap	x	x	-	-	-	x	x	x	x	-	[139,140,217–219]
Dates	x	x	X	-	-	x	x	x	x	x	[150,154,220,221]
Stevia	x	x	-	-	-	-	-	-	-	x	[50,215]

TPC—Total Phenolic Content; PA—Phenolic acids; C—Carotenoids; T—Tocopherols; CV—C Vitamin; A—Anthocyanidin.

Minerals are important nutrients in the functioning and maintenance of the human body in an optimal health status. Minerals are indispensable for the body to function correctly. The most important are potassium, sodium, calcium, phosphorus, and magnesium, with roles in the construction of tissues, the triggering of muscle contractions, the functioning of the internal organs and the nervous system, the metabolism, and the maintenance of the acid–base balance in the body [221,229–232]. The presence of minerals from sugar substitutes is shown in Table 2.

Table 2. The mineral content of the substituents.

Substitutes	Na	K	P	Ca	Mg	Zn	Cu	Fe	Mn	Se	Reference
Apples	x	x	x	x	x	x	x	x	x	-	[173,229,230,233,234]
Nypa fruticans sap	x	x	x	x	x	x	x	x	x	-	[140,218,219]
Dates	x	x	x	x	x	x	x	x	x	X	[220,221]
Stevia	x	x	x	x	x	x	x	x	x	-	[96,216,235]

6. The Effects of Replacing Sucrose in Pastry and Bakery Products

6.1. The Effects of Replacing Sucrose with Apple Products and By-Products

Replacing sugar in pastry with apple puree or apple pomace may lead to changes in the final product. The partial substitution of sugar with apple cider vinegar or apple puree leads to an increase in protein content (Table 3) [11,134].

Table 3. The effects of replacing sucrose with apple products and by-products.

Substitute	PSS (%)	Product	Effects	Reference
Apple puree	100%	Cake	the energy value, and the quantities of carbohydrates and lipids, were reduced to almost half compared to the control sample; the fiber content doubled; the protein content increased; darker crumb color than the control sample.	[11]

Table 3. *Cont.*

Substitute	PSS (%)	Product	Effects	Reference
Apple pomace	21–27	Cake	decrease in specific volume; increase in crumb firmness;	[131]
Apple fiber	0, 30, 60, 100%	Muffins	increase in the viscosity of the dough; decrease in the volume of the dough due to the high water-binding capacity of fibers; improvement in crust color lightness with increasing amount of substituted sugar; increase in crumb firmness with the sucrose reduction level; increase in density with increasing amount of substituted sucrose; reduction in variations in the diameter of the muffin and the loss of baking; increase in the hardness of the crumb; decrease in cohesiveness; substitution of 30% sucrose resulted in muffins with satisfactory characteristics.	[133]
Apple puree	10, 20, 30, 40, 50%	pie dough	increase in gelatinization temperatures (20, 50%); decrease in gelatinization temperatures (10, 30%); increase in the deformation resistance of the dough (>30%); decrease in the extensibility of the dough (>30%); the values of modulus of elasticity and viscosity decrease; the sample obtained by substituting 40% of the amount of sugar and fat had the values of the viscosity module with the frequency closest to those of the control sample; the behavior of the dough at creep and recovery most similar to the control sample was in the case of the sample obtained by substituting 40% of the amount of sugar and fat.	[48]
Dried Apples	0, 25, 50, 75%	pound cake	with the increase in the percentage of dried apples, the carbohydrate content and energy value decreased; increase in the fiber content	[132]
Apple puree	10, 20, 30, 40, 50%	pie dough	increase in the elasticity of the dough; increase in the hardness of the dough; the sample obtained by substituting 30% of the sugar content with apple peel has the most similar textural characteristics to the control sample.	[236]
Dried apple pomace	36.7%	muffins/ cookies	improvement in the texture of muffins; improvement in the flavor of muffins; greater preference over muffins obtained by substituting sugar; increase in the total dietary fiber content in moon cookies; decrease in the amount of carbohydrates of moon cookies; decrease in the energy value of moon cookies: obtaining moon cookies less dry than the control; improvement in the sweet taste of moon cookies; improvement in the consistency of moon cookies; improvement in the appearance of moon cookies; improvement in the color of moon cookies.	[153]

PSS—Percentage of sugar substituted (%).

Thus, by substituting the sugar with apple pomace (21–27%) in a cake, Milner (2020) obtained a cake with a lower specific volume than the control sample and an increase in the firmness of the core. This was a similar result to that of Struck (2016), who replaced sugar with apple fiber in percentages of 0, 30, 60, and 100% in muffins (Table 3) [131,133].

Several researchers obtained a decrease in the energy value due to the reduction in the amount of sugar and the increase in the fiber content, which comes from the composition of apples (Table 3) [11,48,132,134].

After partial substitution of sugar with dried apple pomace sugar and apple fiber, Wang (1989) and Struck (2016) concluded that this substitution increases the hardness of the muffin core, but the advantage is that it improves the color of the core and the acceptability of consumers (Table 3) [133,134].

The change in dough viscosity and texture is due to the high water-binding capacity of the fibers, with apples being a rich source of fibers [11,48,132–134,236].

6.2. The Effects of Replacing Sucrose with Inulin/Oligofructose/Stevianna

The partial substitution of sugar for oligofructose has been studied in both a cake and a bread sample. In the case of the cake, the viscosity and stability decreased, but from a sensory point of view, the sample with a 30% substitution had organoleptic characteristics similar to those of the control sample (Table 4) [12].

Table 4. The effects of replacing sucrose with oligofructose.

Substitute	PSS (%)	Product	Effects	Reference
Oligofructose	0, 20, 30, 40, 50%	cake	the apparent viscosity of the dough decreased significantly ($p < 0.05$) as the percentage of sugar substitution increased; the stability of the dough during heating decreased; sensory evaluation showed that cakes with 30% sugar substitute were similar to the control;	[12]
Oligofructose	10%	bread	improving the volume of bread; texture similar to the control sample; crust and crumb color similar to those of the control.	[97]

PSS—Percentage of sugar substituted (%).

In the case of bread, where the substitution was 10%, much more satisfactory results were obtained, so that the volume was improved and the color and texture were similar to those of the control sample (Table 4) [97].

Jingrong et al. (2018) and Rößle (2011) found the texture and structure of the core were similar to those of the control sample after substituting 50% of the amount of sugar with inulin in a muffin sample and 10% of the amount of sugar with inulin in a sample bread test, respectively (Table 5) [97,135].

Krupa-Kozak et al. (2020) produced a sponge cake by substituting 100% sugar with inulin and obtained a viscoelastic behavior similar to that of the control sample, while the elasticity decreased. Tsatsaragkou et al. (2021) produced a cake sample in which 30% of the sugar was substituted with inulin (Table 5) [16,66].

Table 5. The effects of replacing sucrose with inulin/oligofructose/stevianna.

Substitute	PSS (%)	Product	Effects	Reference
Inulin/ oligofructose	10%	bread	improving the volume of bread; texture similar to the control sample; crust and crumb color similar to that of the control.	[97]
Inulin/stevianna	0, 25, 50, 75, 100%	muffins	decreases the average size of air cells (inulin substitution); decreases the area of air cells (substitution with inulin: >50%); substitution of sugar with 50% inulin does not affect the structure of the sample compared to the control sample; increases the number of air cells (substitution with stevianna); decreases the quality of the general texture (substitution with stevianna 100%); similar firmness in the case of sugar substitution with 50% inulin; similar elasticity in the case of sugar substitution with 50% inulin; similar texture in the case of sugar substitution with 50% inulin.	[135]

Table 5. *Cont.*

Substitute	PSS (%)	Product	Effects	Reference
Inulin	100%	sponge cake	similar viscoelastic behavior to that of the control sample; increases hardness; decreases cohesiveness; increases gumminess; increases chewiness; light-color sample; decreases elasticity.	[66]
Inulin	30%	cakes and biscuits	viscoelastic properties of cakes very similar to those of the control sample in case of sugar substitution with inulin with a lower degree of polymerization; cake crumb structure very similar to that of the control sample; mouthfeel and the texture of the cake very similar to that of the control sample; more golden color of the cake in the case of inulin with a lower degree of polymerization; increased viscosity when substituting sugar with inulin with a high degree of polymerization; inhomogeneous structure of the cake core in the case of substitution with inulin with a high degree of polymerization; low elasticity of the biscuit dough in the case of sugar substitution with inulin with a low degree of polymerization; biscuits less hard and less crunchy than the control sample.	[16]

PSS—Percentage of sugar substituted (%).

In the case of 100% substitution of sugar with inulin, the texture showed changes compared to the control sample, while the substitution of 30% sugar with inulin resulted in a texture similar to that of the control sample (Table 5) [16,66].

Due to the high water-retention capacity of stevia, products obtained by Vatankhah et al. (2015) and Gao et al. (2019), i.e., biscuits and muffins, respectively, had a higher humidity than the control samples. Additionally, in his four studies on sugar substitution with stevia, Gao et al. reported that substituting 50% sugar with stevia results in a texture similar to that of the control sample, due to the ability of stevia to retain water and increase moisture (Table 6) [28,97,135,137,138].

Vatankhah et al. (2015) and Gao et al. (2017) obtained the highest acceptability score in the case of substituting a percentage of 50% sugar [136,137]. At the same time, Gao et al. (2019) and Majzoobi et al. (2020) obtained a density of samples with low sugar content similar to that of the control sample [110,138]. In 2015, Vatankhah et al. produced biscuits by substituting 50% and 100% sugar with stevia/stevianna, resulting in products with a high content of ash and protein, and low carbohydrate content, which led to a decrease in the energy value of the products (Table 6) [136].

Following the research carried out in replacing sugar in percentages up to 100% in products such as cookies, sponge cakes, and biscuits, several researchers, such as Alsenaien et al. (2015), Raei et al. (2016), Maghsoudlou et al. (2017), and Majzoobi et al. (2016), concluded that substituting sugar with date syrup leads to increased product moisture, a darker color, and products with improved overall acceptability or acceptability similar to that of the control sample [146,147,153,154]. Moreover, Alsenaien et al. (2015) and Karazhyan et al. (2021) observed a decrease in the firmness of the samples following the substitution of sugar with date syrup (Table 6) [146,148].

Table 6. The effects of replacing sucrose with stevianna.

Substitute	PSS (%)	Product	Effects	Reference
Stevianna	0, 50, 100%	muffins	firmer texture than the control sample in case of total sucrose substitution; texture, firmness, and elasticity similar to the control in the case of partial substitution of sugar with stevianna (50%).	[28]

Table 6. *Cont.*

Substitute	PSS (%)	Product	Effects	Reference
Stevianna	0, 50, 100%	muffins	increases the moisture content; decreases the height; the volume decreases significantly (50% stevianna); increases firmness; springiness decreases; decreases the air retention capacity; decreases the gelatinization temperature of starch; decreases the protein denaturation temperature; the replacement of 50% sugar with stevianna had similar physical quality characteristics in terms of volume, density, and texture of a control muffin.	[138]
Stevioside	0, 50, 100%	biscuits	decreases the energy value; increases the pH value; increases the moisture content; increases the ash content; increase in protein content; decreases the carbohydrate content; decreases diameter; decreases the specific volume and expansion coefficient; increases bulk density, thickness, flexibility; increases water activity; decreases hardness; the sample with 50% substitution shows the highest scores for general acceptability, color, aroma, taste.	[136]
Stevianna	0, 50, 100%	muffins	similar visual appearance to the control sample (50% sugar); similar color to the control sample (50% sugar, 50% stevianna); similar texture to the control sample (50% sugar); similar mouthfeel to the control sample (50% sugar); similar general acceptability to the control sample (50% sugar); bitter after taste (0% sugar, 100% stevianna); poor appearance (0% sugar, 100% stevianna); hard texture (0% sugar, 100% stevianna).	[137]
Stevia rebaudioside A		cake	Reb A did not have a significant effect on the consistency, density and viscosity of the dough.	[110]

PSS—Percentage of sugar substituted (%).

6.3. The Effects of Replacing Sucrose with Date Products

Moreover, the substitution of sugar with date syrup led to a decrease in pH in the biscuit and cake samples analyzed by Kalajahi and Sadr (2020) and Karazhyan et al. (2021) [148,155]. Studies conducted by Kalajahi and Sadr (2020) show that the substitution of sugar with date syrup in percentages of 50% and 100% leads to an increase in fiber content and an increase in nutritional value [155]. Regarding antioxidant activity, Majzoobi et al. (2016) and Kalajahi and Sadr (2020) found that substituting sugar with date syrup in biscuits leads to increased antioxidant content (Table 7) [154,155].

Majzoobi et al. (2016) reported that the substitution of sugar with date syrup in biscuits resulted in an increase in ash content, softness, and adhesiveness. In addition, Karazhyan et al. (2021) and Majzoobi et al. (2016) obtained samples with lower cohesiveness than the control sample following the substitution of sugar with date syrup in the samples of cakes and biscuits (Table 7) [148,154].

Regarding the substitution of sugar with date powder in bread and rock buns, Obiegbuna (2013), Brouwer and Mosack (2015), and Awofadeju et al. (2021) obtained similar results of the studied parameters, namely, an increase in the nutritional value and the contents of fiber, fat, protein, and ash, and a decrease in the carbohydrate content and energy value (Table 7) [150–152]. In addition, Brouwer and Mosack (2015) observed an improvement in the texture of the product when substituting 50% of the amount of sugar with date powder. Obiegbuna (2013) obtained an increase in weight and a decrease in the volume of bread with the increase in the amount of sugar substituted, but the general acceptability was similar to that of the control sample (Table 7) [150,151].

Table 7. Sugar substitution with date products.

Substitute	PSS (%)	Product	Effects	Reference
Date syrup	0, 20, 40, 60%	cake	decreases pH; decreases stiffness/firmness; decreases cohesiveness; decreases springiness.	[148]
Date palm fruit flour	0, 50, 100%	bread	increases the fiber content; decreases the fat content; increases the protein content; increases the ash content; decreases the carbohydrate content; increases the content of calcium, phosphorus, iron, zinc, copper and selenium; increases nutritional value; decreases the energy value.	[152]
Date syrup (DS)/date liquid sugar (DLS)	0, 20, 40, 60, 80, 100%	biscuits	increase in moisture content; increasing the ash content; increased antioxidant capacity decreased pH; decreased cohesiveness; increased softness; increased adhesiveness; increases density; increases spread ratio; increases hardness; darker color sample; similar sensory characteristics to control (40% DS or 60% DLS).	[154]
Date liquid sugar (DLS)	0, 50, 100%	biscuits	decreased pH; decreased fracture strength; increased the content of reducing sugars; increased the content of dietary fiber; no adverse effects on sensory properties were identified; increasing the nutritional value; substitution of 50% sugar with date liquid sugar can lead to the desired sensory, physico-chemical, rheological, and antioxidant properties.	[155]
Date fruit powder (DP)	0, 50, 80, 100%	rock buns	increase in fiber content; increase in crude fat content; increase in protein content; increasing the ash content; decrease in carbohydrate content; increase in the content of potassium, calcium, iron; increase in nutritional value (especially in samples with 50% date powder); texture: the most appreciated sample was the one with 50% DP.	[150]

Table 7. *Cont.*

Substitute	PSS (%)	Product	Effects	Reference
Date palm pulp meal	0, 25, 50, 75, 100%	bread	increases the crude fiber content; increases the crude fat content; increases the content of crude protein; increases the ash content; decreases the carbohydrate content; increases the nutritional value of bread; decreases the specific volume; increases the weight of the bread; had no negative effects on general acceptance; insignificant decrease in the fermentation capacity of the dough.	[151]
Date powder/date syrup	0, 25, 50, 75, 100%	cookies	decrease in diameter spread ratio decrease decrease in firmness; increase in moisture content; darker and redder color of cookies; darker and redder color of cookies; substituting sugar with 50% date powder doesn't affect the quality of the cookies; substituting sugar with 50% liquid sugar date does not affect the quality of the cookies.	[146]

PSS—Percentage of sugar substituted (%).

6.4. The Effects of Replacing Sucrose with Grape Proucts

Demir (2014), Mohtarami (2018), and Koushki, Azizi, and Mehrabi (2020) studied the texture of the products obtained by substituting up to 100% sugar with grape syrup/powder and observed an increase in the firmness of the samples in relation to the witness sample (Table 8) [125,142,143].

Demir (2014), Mehrabi, Koushki, and Azizi (2017), Shahidi, Kalantari, and Boostani (2017), Mohtarami (2018), and Moosivand et al. (2020) used grape syrup/powder for partial or total sugar substitution in some cupcake and sponge cake samples and obtained an increase in humidity and darker products, and the general acceptability was the highest in the case of 50% sugar substitution relative to the case of total substitution (Table 8) [98,125,141,143,145].

Table 8. Sugar substitution with grape products.

Substitute	PSS (%)	Product	Effects	Reference
Grape juice concentrate	0–100%	sponge cake	increase in moisture content; decrease the specific volume; increasing firmness; decreased cohesiveness; decreased elasticity; gumminess and chewiness were not affected; insignificant differences in general acceptance for 50% sucrose cakes; decrease in porosity; in terms of physical, textural, and sensory properties, the highest desirability can be achieved by substituting 65% of the sucrose content.	[125]
Grape syrup	0, 25, 50, 75, 100%	sponge cake	increases the density; increases the volume; increases stiffness (>25% grape syrup); increases porosity.	[142]

Table 8. *Cont.*

Substitute	PSS (%)	Product	Effects	Reference
Liquid grape pekmez/pekmez powder (PP)	0, 25, 50, 75, 100%	cake	increases nutritional values; increases moisture content; increases ash content; increases the content of potassium, magnesium, calcium, iron, and zinc; decreases spread ratio; increases hardness; darker color of the cakes; the highest score of general acceptance is presented by the sample with a sugar substitution of 50%.	[143]
Grape juice	0, 20%, 40%, 60%	sponge cake	increases the consistency of the dough; increases the viscosity of the dough; increases specific gravity; decreases the gas retention capacity; increases the moisture content; decreases the volume of the cake; decreases softness; decreases hardness; darker color of the cakes.	[98]
Grape syrup	0, 50, 75, 100%	sponge cake	increases the moisture content; increases water activity; darker color for 100% grape syrup best score for general acceptance (100% grape syrup): aroma, peel color, texture, and taste.	[141]
Grape/date syrup	0, 25, 30,50,70 and 100%	cake	increases the crude fiber content; decreases the fat content; decreases the ash content; the texture is not affected.	[144]
Grape syrup powder	0, 25, 50, 75, 100%	cup cake	increases the moisture content; decreases specific gravity; decreases the firmness of the cake; decreases the volume; decreases porosity; improves the smell of the cake; improves the taste; the sample with 25% grape syrup powder shows higher volume and porosity; the sample with 25% grape syrup powder shows the highest score of general acceptance.	[145]

PSS—Percentage of sugar substituted (%).

A decrease in volume of the samples compared to the control sample was reported by Shahidi, Kalantari, and Boostani (2017), Mohtarami (2018), and Moosivand et al. (2020), and a decrease in porosity was observed by Mohtarami (2018) and Moosivand et al. (2020). In contrast, Koushki, Azizi, and Mehrabi (2020) obtained an increase in the volume of samples in which sugar was substituted (Table 8) [98,125,142,145].

In 2018, Mohtarami observed that the elasticity and cohesiveness decreased in the samples in which the sugar was substituted, and the gumminess of the samples was similar to that of the control sample (Table 8) [125].

In 2019, Alsirrag et al. found that the partial or total substitution of sugar in cakes with grape or date syrup resulted in a cake with a high fiber content and a low fat content, without affecting the texture (Table 8) [144].

In 2020, Moosivand et al. reported that substituting sugar from cupcakes with grape powder or syrup improves the taste and smell of the products (Table 8) [145].

6.5. The Effects of Replacing Sucrose with Nypa fruticans sap

Following the substitution of sugar in cakes with *Nypa fruticans* sap, significant improvements were achieved in terms of textural characteristics and physico-chemical properties of the final product (mineral content, fiber content, and total polyphenol content) (Table 9) [139,140]. The dense, compact structure, and also the smaller number of air cells, are due to the reduction in the amount of sugar, which plays an important role in the foam stabilization stage [139,140].

Table 9. The effects of replacing sucrose with *Nypa fruticans* sap.

Substitute	PSS (%)	Product	Effects	Reference
Nypa fruticans sap	0, 20%	cake	obtaining a more homogeneous, dense or compact structure compared to the control; decrease in the value of the glycemic index; decreasing the number of air cells in the crumb of the cake.	[139]
Nypa fruticans sap	0, 5, 10, 15, 20%	cake	increases in moisture content; increases the ash content; increases the total dietary fiber content; increases sodium and potassium content; increases Total Phenolic Content; increases antioxidant capacity; decreases energy value; decreases springiness, hardness, cohesiveness and resilience; increasing chewiness; in terms of appearance, texture, and color, the highest score was obtained by the sample with 20% substitution; the highest score for general acceptance was given to the sample with 20% substitution; in terms of taste and aroma, the most appreciated was the 15% substitution sample.	[140]

PSS—Percentage of sugar substituted (%).

The increase in the content of fibers, minerals (Na, K), and polyphenols is due to the high content of these compounds in *Nypa fruticans* sap [139,140,219].

7. Future Trends

Substituting sugar in cake recipes with alternative ingredients is already a trend that is expected to continue in the future. With increasing awareness of the negative health effects of sugar, many people are looking for healthier options to satisfy their sweet tooth. The paragraphs below outline some reasons why replacing sugar with alternative ingredients is likely to be a trend for the future.

Health benefits: Many alternative sweeteners, such as inulin and stevia, are lower in calories and have less of an impact on blood sugar levels than sugar. This can lead to various health benefits, such as weight loss, improved insulin sensitivity, and reduced risk of chronic diseases like type 2 diabetes and heart disease. The simultaneous use of several sugar substitutes can lead to an increase in the nutritional value of the final product, an increase in the antioxidant capacity, and an increase in the mineral content (Ca, Mg, K, and Na). For example, the simultaneous use of stevia and apple puree can result in a product with a high content of polyphenols, a high content of minerals, and a sweet taste.

Increased availability: As the demand for sugar substitutes increases, we can expect to see more options become available in the market. This will make it easier for consumers to find and use these ingredients in their baking.

Taste and texture improvements: With more research and development, we can expect to see improvements in the taste and texture of cakes made with sugar substitutes. For example, apple puree can add moisture and flavor to cakes, while inulin can improve texture and mouthfeel.

Overall, substituting sugar in cake recipes with alternative ingredients is likely to be a trend for the future as people become more health-conscious and look for ways to reduce their sugar intake.

In general, the addition of functional sugars and dietary fiber to pastry and bakery products can be beneficial from a health perspective, but requires special care to ensure that they do not adversely affect the quality or production process of the finished products. Constant testing and tweaking of formulations is essential to achieve the desired results.

8. Conclusions

To sum up, reducing the amount of sugar in desserts is a necessary step to help consumers choose healthy products. Reducing the amount of sugar consumed can also reduce the number of cases of obesity, type 2 diabetes, cardiovascular disease, cognitive impairment, and tooth decay. The purpose of this research was to follow from a technological point of view the problem of partial or total substitution of sugar with functional ingredients. Thus, the total or partial substitution of sugar with functional ingredients (puree of apple or other fruits, inulin, oligofructose, stevia, apple pomace, polydextrose, whey permeate, dried apples, *Nypa fruticans* sap, grape juice/syrup, dates powder/syrup, jaggery sugar, banana puree, and black currant/aronia pomace) is a favorable strategy both for the producer, obtaining products with characteristics similar to those of the control samples, and for the buyer, as the consumer who benefits from a product with similar sensory characteristics but with improved nutritional characteristics: low energy value, high nutritional value, high mineral content (K, Ca, Mg, Fe, Zn, and Cu), low carbohydrate content, high content of bioactive compounds (antioxidants, phenolic compounds), high protein content, high fiber content, and improved flavor.

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