Foods and Raw Materials, 2018, vol. 6, no. 2

ISSN 2308-4057 (Print)
ISSN 2310-9599 (Online)

Review Article
Open Access

DOI: http://doi.org/10.21603/2308-4057-2018-2-392-402
Available online at http:jfrm.ru

Natural sweeteners: health benefits of stevia

Sukhmani Gandhi[a], Yogesh Gat[a,b,]* Shalini Arya[b], Vikas Kumar[a], Anil Panghal[a], and Ashwani Kumar[a]

[a] Lovely Professional University,
Jalandhar - Delhi G.T. Road, Phagwara, Punjab 144411, India

[b] Institute of Chemical Technology,
NM Parekh Marg, Matunga, Mumbai 400019, India

* e-mail: yogeshcft10@gmail.com

Received September 1, 2018; Accepted in revised form October 3, 2018; Published December 20, 2018

Abstract: *Stevia rebaudiana* (Bertoni), a perennial shrub, is the sweetest plant belonging to the *Asteraceae* family. Stevia leaves are an excellent source of diterpene glycosides stevioside, rebaudioside A-F, dulcoside, and steviolbioside, which are responsible for sweetness and have been utilized commercially for sugar substitution in foods, beverages, and medicines. To the best of our knowledge, a large number of studies have been carried out on composition, health implications, and safety of steviol glycosides. However, commercial production of stevia-incorporated food products needs further research in order to meet the huge global demand. Stevia-incorporated products possess better sweetening potency and maximum consumer acceptability, when compared with other sugar substitutes. Hence, the current research attempts to review the health promoting effects of stevia with special emphasis on its application in the food system. The paper majorly features 1) the anti-hyperglycemic, anti-hypertensive, anti-caries, anti-inflammatory, and anti-cancer benefits of stevia, 2) value-added stevia-incorporated products, e.g. bakery, dairy, and beverages, 3) the effect of incorporation of stevia on physicochemical, rheological, and nutritional food properties, 4) the current status and regulatory perspective of utilizing stevia at national and international level. Due to legislative actions and growing consumer awareness, public interest in natural sweeteners has significantly increased. Since the use of artificial sweetener has recently been questioned, the data the present article provides will be useful for consumers and manufacturers that seek an alternative.

Keywords: *Stevia rebaudiana*; sugar substitutes, health benefits, value addition, product characteristics, consumer acceptability

Please cite this article in press as: Gandhi S., Gat Y., Arya S., et al. Natural sweeteners: health benefits of stevia. *Foods and Raw Materials*, 2018, vol. 6, no. 2, pp. 392–402. DOI: http://doi.org/10.21603/2308-4057-2018-2-392-402.

INTRODUCTION

One out of the six basic taste sensations in humans is sweetness. Honey, coconut sugar, blackstrap molasses, table sugar, agave, high fructose, corn syrup, maple syrup and other natural sweeteners contain glucose, fructose, and sucrose as their primary constituents. However, sweeteners obtained from natural sources possess a high caloric value, which may lead to obesity, diabetes, and cardiovascular diseases. There has been a gradual rise in the number of diabetic patients all over the world. India has become the diabetic capital of the world with about 72 million cases of diabetes in 2017 (International Diabetes Federation, Diabetic Atlas, 2017). Due to the growing health awareness, there has been a huge demand for sugar substitutes that would provide lesser or no calories and possess better sweetening potency. There is a variety of artificial zero-calorie sweeteners on the market, e.g. saccharin, aspartame, acesulfame potassium, cyclamates, etc. However, artificial sugar substitutes became associated with health complications, and the use of these artificial sugar substitutes has subsequently been restricted. Thus, there is a continuous search for high intensity low-calorie or non-caloric sweeteners of natural origin that are safe for consumption. Stevia, which plays an important role as a non-nutritive natural sweetener, emerged as a safe sugar substitute that does not pose any threat to human health [1].

RESULTS AND DISCUSSION

Stevia rebaudiana (Bertoni) is a perennial shrub belonging to *Asteraceae* family, native to Paraguay. Out of 230, only two species – *rebaudiana* and *phlebophylla* – produce sweet steviol glycosides [2]. Stevia leaves contain eleven diterpene glycosides, such as stevioside, rebaudioside A-F, dulcoside, etc. Stevioside and rebaudioside are the sweetest glycosides present in stevia leaves, which are 250–300 times sweeter than sucrose, and are chemically and thermally stable. Stevioside and rebaudioside obtained from stevia leaves have been utilized commercially in Japan, South America, China, and Korea to sweeten various foods. Dietary supplements containing stevia extracts have been utilized in USA extensively [3]. Market stevia products contain such steviol glycosides as stevioside or rebaudioside A [4].

Health benefits. Stevia is known to provide a wide variety of health benefits (Fig. 1). The leaves possess functional properties superior to those of many other high potency sweeteners. Hence, stevia is likely to become the ultimate natural sweetener in the food industry.

Anti-hyperglycemic. According to WHO global report on diabetes (2016), as many as 422 million adults were suffering from diabetes all over the world, and diabetes-related deaths accounted for 1.5 million. Diabetes mellitus is one of the major metabolic diseases characterized by hyperglycemia. It is a chronic disease resulting either from defects in insulin secretion of β-cells of pancreatic islets (islets of Langerhans) or from the response to insulin, or combination of both. Type 1 diabetes mellitus is juvenile-onset, or insulin independent diabetes mellitus, in which the exact etiology of the disease is unknown, while in type 2 diabetes the risk to predisposal depends upon metabolic and the genetic factors.

Traditionally, the extract obtained from stevia leaves proved its effectiveness in treatment of diabetes [5, 6]. There is a stimulation of insulin secretion from β cells of islets of Langerhans and INS-1 cells by direct action of stevioside and steviol [7, 8]. The antihyperglycemic effect of stevioside was investigated in type 2 diabetic Goto-Kakizaki rats, and it was concluded that the hypoglycemic action of stevioside was due to increased secretion of insulin and induction of genes of glycolytic pathway [9].

A limited number of human studies have been reported to depict the mechanism of stevioside (Fig. 2). A study of acute effects of stevioside was conducted on twelve type 2 diabetic patients. It was observed that there was an average 18% decline in the post-prandial blood glucose levels of the diabetic patients after supplementing the standard test meal with 1 g stevioside. However, the slight increase in the insulin levels was not statistically significant [10]. The effect of steviol glycosides on insulin sensitivity and glucose metabolism have been elucidated [11]. In diabetic rats, intake of steviol glycosides resulted in a decrease in blood glucose levels, along with a decrease in the rate of gluconeogenesis and reduction in insulin resistance. Similar findings suggest that oral administration of medium polar extract of stevia leaves at 200 and 400 mg/kg body weight basis for 10 days in alloxan-induced diabetic rats resulted in delayed but significant antihyperglycemic effect without producing hypoglycemia, along with lesser body weight loss in contrast to standard positive control drug glibenclamide [12].

There was a research on the blood glucose lowering effects of rebaudioside A on the activity of carbohydrate metabolizing enzymes in induced diabetic rats [13]. An increase in the rate of glycolysis and reduction in gluconeogenesis produced a significant antihyperglycemic effect. Another study featured the antihyperglycemic mechanism of stevia. It was found that stevia (400 mg/kg) reduced blood glucose levels better than pioglitazone (10 mg/kg), which can be used to control blood sugar levels in diabetics. There was an elevation in insulin levels due to the impact of stevia on the pancreatic tissue, and the valuable anti-hyperglycemic action was exerted via PPARϒ dependent mechanism and its antioxidant property [14].

Anti-hypertensive. Persistent elevation of systolic blood pressure (≥ 140 mm Hg), or diastolic blood pressure (≥ 90 mm Hg), or both is the principal cause for developing cardiovascular diseases, which are associated with high mortality rates globally. In primary hypertension, etiology is unknown and accounts for 90% of the hypertension cases. By contrast, secondary hypertension is known, and it affects less than 10% of the hypertensive population. It is precipitated by another medical condition affecting kidneys, arteries, heart, or endocrine system.

An early investigation conducted on rats showed that stevia extract at doses greater than those used for the purpose of sweetening resulted in vasodilation and a lower mean arterial pressure in hypertensive rats [15]. A reduction in blood pressure was elucidated upon studying the effectiveness of stevioside (250 mg three times a day for a period of 3 months) in human subjects suffering from mild or moderate primary hypertension [16]. The mechanism by which stevioside produces vasodilatory effect is analogous to that of verapamil, an antihypertensive drug which acts by blocking calcium channels in myocardial and arterial smooth muscle cells (Fig. 3). The antihypertensive effect of stevioside was antagonized by administration of indomethacin (parostaglandin synthesis inhibitor), suggesting stevioside produces reduction in mean arterial pressure via prostaglandin activity [17]. In the study, to evaluate the effect of stevia on renal function, it was reported that steviol increased the excretion of sodium and potassium along with glomerular filtration rate in a dose dependent manner. It acted as a diuretic agent by preferably affecting the Na^+-glucose coupled cotransporter in proximal convulated tubule of kidney [18]. The hemodynamic effects of rebaudioside A were investigated in human trial. No significant changes in mean arterial pressure or heart rate were observed after daily intake of 1000 mg/kg body weight Rebaudioside A in healthy individuals who were normotensive or having low normal mean arterial pressure [19].

Anti-caries. Dental caries is a widespread chronic disease in humans and affects oral health. Dental caries may lead to the development of painful sensation in tooth, infections, oral and pharyngeal cancers, oral tissue lesions, and the outcome may be life-threatening if untreated, as in case of cavernous sinus thrombosis and Ludwig's angina.

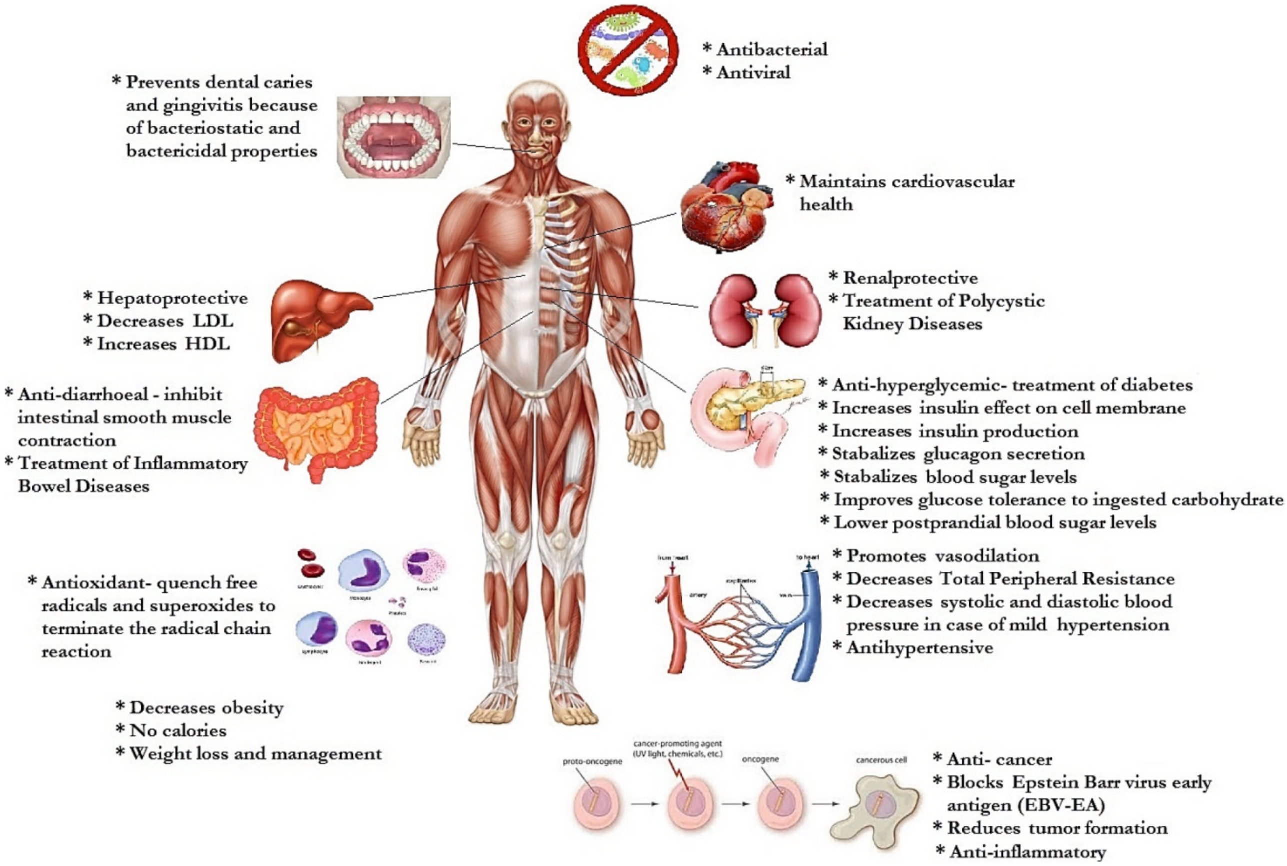

Fig. 1. Health benefits of stevia on various organs.

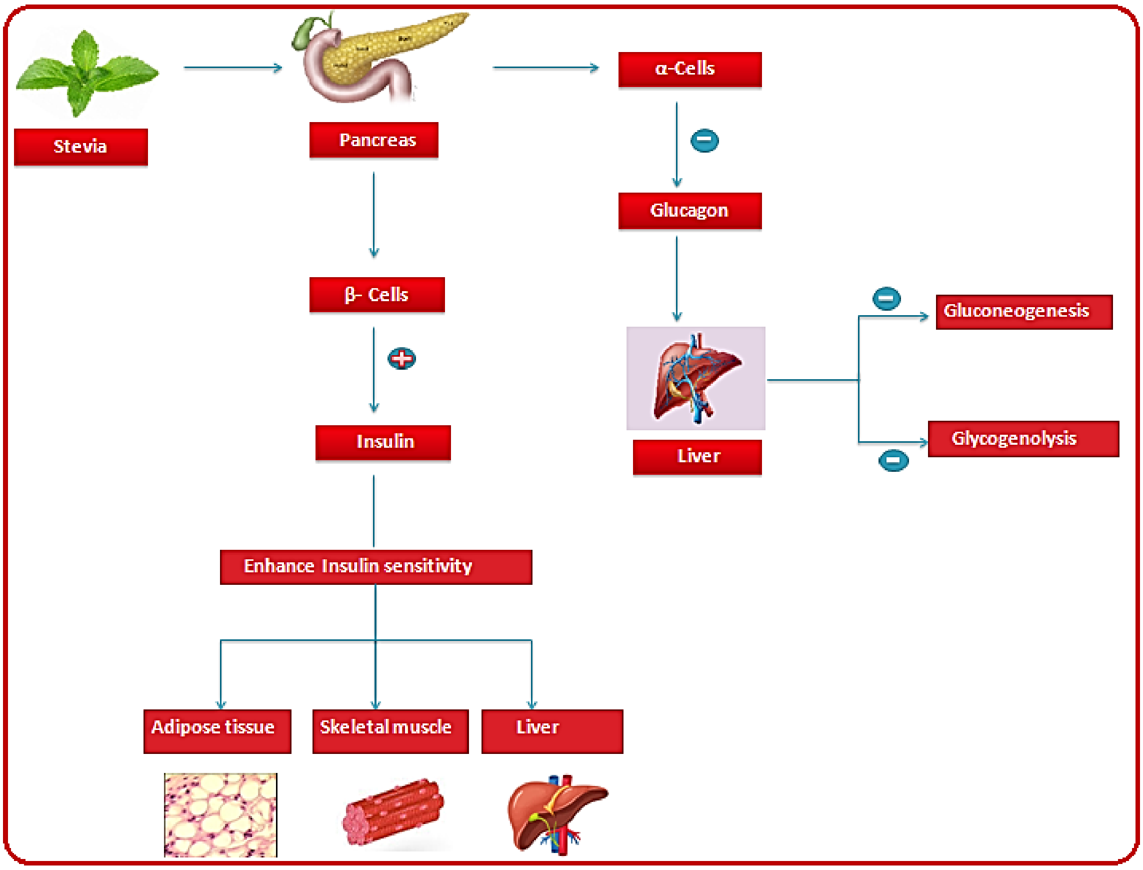

Fig. 2. The possible mechanism of anti-hyperglycemic action of stevia.

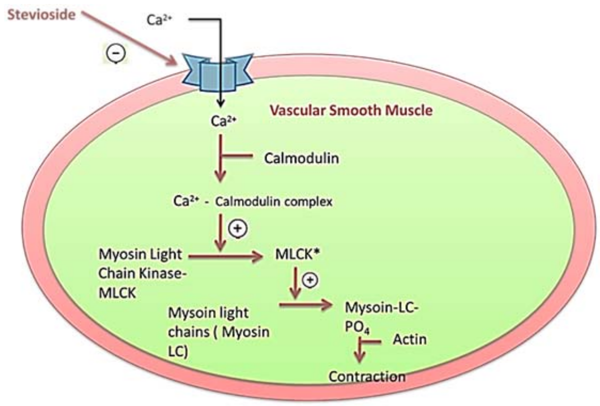

Fig. 3. Antihypertensive action of stevioside. Inhibition of Ca^{2+} influx in vascular smooth muscle resulting in vasodilation and hence reduction in systemic vascular resistance.

Routine consumption of caloric sweeteners, such as sucrose, results in ingestion of carbohydrates, which boosts the amount of harmful microbes in the oral cavity. That may ultimately result in plaque and gingivitis [20]. Stevia is a non-caloric sweetener that possesses antimicrobial properties benefiting oral health via prevention of dental caries. There are 57.82% less chances of developing a plaque with consumption of stevia, compared to sucrose recorded by aid of Silness-Loe plaque index [21]. A study on the cariogenic potential of commercial sweeteners conducted on artificial enamel proved that stevia-incorporated products exhibited antimicrobial activity and showed the least potential to act as cariogenic in contrast to sucrose and other commercial artificial sweeteners [22].

Anti-inflammatory. Inflammatory bowel disease, or IBD, is a group of chronic diseases that involve the inflammation of the alimentary tract. It includes Crohn's disease (inflammation of the entire lining of alimentary canal) and ulcerative colitis (inflammation of the innermost lining of intestine). Ample evidences are available showing that stevioside acts as an anti-inflammatory *in vivo*, as well as *in vitro*. Stevia stem extract was suggested to act as a gastroprotective since it reduced histamine-induced gastric abnormality in rainbow trout [23]. The suggested mechanism of action was inhibition of smooth muscle contraction by blocking the calcium channel. The active substance in the stem extract was stevioside, which was potentially responsible for decreasing the acid secretion caused by histamine and inhibiting the action of pepsin [24]. Similar findings were reported when the anti-ulcerogenic activity of stevia was examined by oral administration of stevia extracts leading to a significant reduction in the free acidity, which resulted in inhibition of gastric lesions [25].

Anti-cancer. Cancer can be defined as a group of diseases involving the abnormal proliferation of cells, which is associated with high mortality rate. The anticancer effect of stevioside, isosteviol, and the derivatives obtained from isosteviol upon microbial transformation was evaluated. All the components were found to be potent in inhibiting Epstein-Barr virus early antigen (EBV-EA) while the highest potency was exhibited by the derivatives obtained by microbial transformation [26].

The ent-kaurene diterpene glycosides isolated from *Stevia rebaudiana* were investigated for anti-inflammatory activity against inflammation induced by 12-O-tetradecanoylphorbol-13-acetate (TPA), and it was found to suppress inflammation along with a significant inhibitory effect on the tumour formation [27, 28]. The methanolic and ethanolic extract of stevioside exhibited anti-cancer potential against the Caco cell line [29]. Stevioside exhibited *in vitro* anticancer activity against MCF-7 cells, which are most commonly used for breast cancer studies in humans. The suggested mechanism of antibreast cancer activity was enhanced expression of proteins participating in apoptotic pathway [30].

Value-added products prepared with incorporation of stevia. Value-added products are prepared for enhancing the value of food items through the addition of ingredients, processing or packaging. Value-added food products are more attractive and usable by the consumer than the original commodity. Commercially, leaves of stevia are exploited directly or after processing in preparation of various value-added products. As a functional food ingredient, stevia has been partially or fully incorporated into baked, dairy, confectionery products, etc. The present review features the commercial use of stevia in various food products and its effect on various properties.

Bakery products. Sweetened food items, such as cakes, cookies, muffins, and biscuits, are the major contributors to sugar intake globally [31]. Sucrose is a crucial ingredient in baked goods. It contributes not only to the taste but also to the characteristic texture and structure [32]. However, excessive consumption of sugar leads to acute elevation in postprandial glucose levels [33]. There is an increased risk of obesity, diabetes, dental caries, and coronary heart disease associated with regular consumption of high amounts of sugar-containing foods.

The use of stevia in baked products is suitable since it maintains its stability throughout the baking process and can be heated up to 200°C [34]. The non-nutritive high intensity sweeteners contribute to the sweet taste of the product, but the maintenance of texture, colour, and flavour is also crucial. Hence, whenever stevia is used as a partial replacement of sugar, other additives, such as bulking agents, hydrocolloids, proteins, etc., should be added to compensate for the loss of texture.

To evaluate the physical properties of muffins sweetened with stevia suggested a study that muffins with 25% of the sucrose replaced by steviol glycosides were ranked best in terms of browning index, texture, cooking yield, and sensory acceptance. Sucrose replacement greater than 50% had a negative impact on the quality characteristics of muffins [35]. Low glycemic index muffins were made by adding stevia and cocoa dietary fibre. The replacement of 20% sucrose with stevia along with substitution of cocoa powder with cocoa fibre did not produce any negative impact on the quality attributes and consumer acceptability [36]. Functional cookies prepared by 20% replacement with defatted soy flour and powder obtained from stevia leaves were ranked best for all the sensory characteristics [37].

Dairy products. Milk and milk-based products are a vital component of functional foods. Dairy processors are investigating novel technologies to sweeten their products without adding more calories, since people are averted from the consumption of intensely sweetened dairy-based products. There has been a continual search for natural low-calorie alternatives to sweeten dairy products that would reduce the sugar content while maintaining the texture, body and mouthfeel. Stevia has emerged as a suitable choice for dairy products since it preserves its stability, when subjected to heat treatment.

One of the most popular frozen dairy products is ice cream. Sugar influences its texture, viscosity, and freezing point and, hence, plays a significant role in determining the consumer acceptability. The most popular ice cream sweetener is sucrose because of its cost effectiveness and consumer acceptability. However, stevia and other non-nutritive sweeteners are gaining popularity due to health hazards associated with sucrose. The replacement of sugar with stevia in ice cream and kulfi can lead to a significant decrease in the caloric value. Studies revealed that ice cream mixtures in which sucrose had been partially replaced with stevia had better sensory scores than those with stevia only [38, 39].

Yogurt is one of the best-known foods that contain probiotics. Sensory analysis of strawberry flavoured yogurt with stevia elucidated that yogurt with a mixture of stevia and sucrose had the best sensory profile [40]. Stevia exhibited a synergistic sweetening effect when used in combination with other sweeteners to sweeten strawberry flavoured yogurt [41].

Flavoured milk supplies vital nutrients equivalent to plain milk. Studies have revealed that flavoured milk is preferred for consumption by children and adults [42]. However, flavoured milk contains a high quantity of sugar, which has been linked to promotion of obesity amongst children and adults [43, 44]. The use of stevia is an appealing alternative in order to reduce the caloric value of flavoured milk. It is of primary importance to maintain the acceptance of the product by the consumer while decreasing the sugar content. In the study [45], the perception of sweetness intensity in skim chocolate milk prepared by addition of extracts of stevia and monk fruit was defermind. It was established that flavoured milk containing stevia had a maximum consumer acceptability.

Beverages. The primary function of stevia is sweetening, but it may modify the flavour in certain cases.

Peach juice was formulated with a blend of stevia (160 mg/L) and sucrose (56 g/L), which led to 25% reduction in calories without affecting the sensory attributes of the product compared to the control sample containing 9% sucrose [46]. Orange juice is one of the most popular non-carbonated beverages globally since it contains high amounts of vitamin C, carotenoids, folic acid, flavonoids, etc. It acts as an antioxidant preventing the damage caused by free radicals to tissues and also decreases the chances of heart disease and cancer [47, 48]. Low calorie orange nectar and orange juice were formulated with the addition of stevia [49, 50]. Other beverages, such as mango nectar and passion fruit juice, were developed with partial replacement of sucrose with stevia and evaluated for their sensory as well as physicochemical parameters [51, 52].

Effect of incorporation of stevia on different properties. *Physicochemical properties***.** Physical properties of food material are its measurable and quantifiable characteristics. They are used to describe matter without altering its composition. They elucidate the unique way a food material will react to physical treatments – thermal, optical, electromagnetic, mechanical, etc. Knowing these properties helps design optimum operation parameters and equipment to ensure the quality and safety of foods.

Some important physicochemical parameters for evaluation of ice cream are overrun ratio, first melting point, last melting point, and fat destabilization. The addition of stevia in ice cream resulted in a higher first melting time being the longest for the sample containing stevia and cocoa. Table 1 shows that the last melting time for ice cream containing cocoa with sucrose and cocoa with stevia was lower as compared to plain ice cream with sucrose and plain ice cream with stevia [38]. The overrun ratio for ice cream with stevia and cocoa was found to be the highest, while the overrun ratio was the lowest for plain ice cream with stevia [38]. Similarly, the overrun ratio of soft ice cream increased when stevia was added [39]. Fat destabilization was reported to be slightly higher in ice cream containing stevia [38]. Increasing levels of sugar replacement with stevia in kulfi resulted in a decrease in melting rate [53]. In case of juices, the important physicochemical properties to be evaluated are °Brix and titratable acidity.

Rheological and textural properties. Texture may be referred to as a collection of physical attributes that emerge from structural makeup of food. They are perceptible via sense of touch and associated with disintegration, distortion, and flowability under the influence of force. Some important textural properties in foods are hardness, cohesiveness, springiness (elasticity), adhesiveness, chewiness, gumminess, resilience fracturability, stringiness, and initial modulus.

Viscosity (the resistance to flow) is an important evaluation parameter for ice cream mix. As given in Table 2, a decrease in viscosity of ice cream was observed when nothing but stevia was added. However, the ice cream sample containing both stevia and cocoa possessed the highest viscosity amongst all other ice cream samples. With a gradual increase in stevia concentration in ice cream, the viscosity was relatively lowered, compared to the sample containing sucrose only [39]. A disaccharide produces the solution with high osmolality due to its hydrophilicity and high solubility, as well as its ability to form hydrogen bonds [54].

Table 1. Effect of stevia on physicochemical properties of various food products

Product	Stevia form	Amount of stevia, %	Description	Reference
Ice cream	Stevia leaf powder	0.862	↑ in last melting time ↓ in over run ratio	[38]
Ice cream with cocoa	Stevia leaf powder	0.786	↑ in first melting time ↑ in fat destabilization ↑ in over run ratio	[38]
Ice cream	Stevia powder (> 90% steviol glycosides)	0.02–0.11	↑ in over run ↓ in melting resistance compared to ice cream sweetened with sucrose	[39]
Kulfi	Stevia extract powder with 91.1% stevioside	0.05–0.07	↓ in specific gravity ↑ in the freezing point compared to kulfi sweetened with sucrose ↓ in melting rate ↓ in penetration	[53]
Herbal Kulfi	Stevia powder	0.05–0.07	↓ in melting rate	[58]
Passion fruit juice	Stevia extract	0.09924	↓ in °Brix ↑ in titrable acidity	[52]
Mango nectar	Stevia with 97% Rebaudioside	0.052	↓ in °Brix value was lower as compared to nectar sweetened with sucrose ↑ in °Brix valueas compared to nectars with other sweeteners ↔ in °Brix during storage	[51]
Orange nectar	Stevioside powder (85–95% purity)	0.02–0.06	↓ in titrable acidity during storage ↓ in °Brix with addition of stevioside ↔ in °Brix during storage	[49]

Note. ↑ – increase, ↓ – decrease, ↔ – non-significant

Table 2. Effect of stevia on rheological and textural properties of various food products

Product	Form of stevia	Amount of stevia, %	Description	Reference
Plain ice cream	Stevia leaf powder	0.862	↓ viscosity	[38]
Ice cream with cocoa	Stevia leaf powder	0.786	↑viscosity amongst all samples of stevia	[38]
Ice cream	Stevia powder (> 90% steviol glycosides)	0.02–0.11	↓ viscosity	[39]
Orange nectar	Stevioside powder (85–95% purity)	0.02–0.06	↑ in viscosity	[49]
Mango nectar	Stevia with 97% Rebaudioside	0.052	↑ in viscosity	[51]
Muffin	Stevianna with 98% Rebaudioside A	9.97 and 19.76	↑ in firmness value in contrast to muffin with sucrose ↓ in firmness value in contrast to muffin with inulin ↑ in springiness value in contrast to muffins with inulin and sucrose	[32]
Muffin	Stevia powder with 95% steviol glycosides	0.075–0.300	↑ in hardness and springiness as more sugar was replaced with stevia ↔ in cohesiveness with addition of stevioside	[35]
Muffin	Stevia powder with 95% steviol glycosides	0.09	↑ in firmness with addition of stevia ↓ in porosity when stevia and sucrose were used in combination	[36]
Functional yoghurt cake	Stevia leaves liquid extract	3.33	↑ in firmness Similar deformation to regular yoghurt cake	[56]
Bittersweet chocolate	Stevia extract	0.16	↑ in hardness values in low fat samples sweetened with stevia	[57]

Note. ↑ – increase, ↓ – decrease, ↔ – non-significant

Viscosity of the low calorie nectar (sugar content reduced to 70% compared to the control sample) was found to be slightly higher than that in the blank sample, which was possibly due to incorporation of 0.03% pectin in the sample [49]. Similar results were seen in the case of mango nectar, in which the sample sweetened with stevia exhibited a higher viscosity compared to nectar sweetened with other sweeteners [51]. The critical textural variables for muffins are firmness, springiness, and cohesiveness. The texture profile analysis (TPA) of muffins revealed that with the increase in replacement of sucrose with stevia, a significant increase in hardness and springiness was observed [36]. The possible reason for this was the decrease in the amount of sucrose in the muffins since sucrose played a significant role in governing the texture [55]. Reduction in the amount of sucrose led to an increase in porosity. However, when sucrose was used in combination with stevia, the value of porosity was slightly lower [36]. In a functional yogurt cake, an increase in firmness and hardness after adding ground stevia leaves has been reported [56]. When bittersweet chocolate was combined with rebaudioside A, which is the sweetest component present in stevia leaves, it resulted in an increase in hardness of low fat chocolate [57].

Nutritional properties. Excessive consumption of food containing high content of sugar and saturated fats is one of the most critical nutritional issues mankind have to face in the current scenario. It has been linked to serious health problems. Health awareness is growing nowadays, and this has led to a significant rise in demand for low-calorie/fat products. Many low-calorie food products have been developed with the addition of dietary fibre or low calorie sweeteners as the consumers are striving to choose healthier food alternatives (Table 3).

Significant reduction of glycemic index and caloric value was reported in ice cream prepared with addition of stevia, which propounds the utilization of stevia as a substitute for sugar and a healthy alternative for people who are predisposed to diabetes [39]. Kulfi samples prepared with incorporation of stevia showed a decrease in calorific value but a significant increase in fat, ash and protein content, due to a decrease in total solids, which resulted from partial replacement of sugar with stevia [53]. Similar results were reported for herbal kulfi that contained both stevia and a mixture of herbs including *Foeniculum vulgare*, *Ocimum sanctum,* and *Piper betle* [58]. A hot water extract of stevia leaves was used to produce a functional yoghurt cake. There was a reduction in calories by 35.72% as compared to a regular yoghurt cake. The biological evaluation of yoghurt cake in diabetic rats revealed that there was no significant change in blood levels of cholesterol, alkaline phosphatase, bilirubin, glucose, creatinine, and triglycerides. However, the level of urea and Aspartate transaminase (AST), as well as HDL cholesterol, decreased slightly. Lower doses did not produce any effect on serum glucose, AST, ALT, total cholesterol, protein, and triglycerides, but higher doses produced a slight elevation in these parameters [56]. Similarly, muffins prepared by partial replacement of sugar with steviol glycosides showed a decrease in caloric value [32, 36]. The incorporation of stevia into muffins led to a prolonged release of reducing sugars during the digestion of starch *in vitro*, thus, reducing the predicted glycaemic response [32]. A decrease in energy value was noted when sucrose free chocolates were prepared with the addition of stevia [59].

Sensory properties. Sensory properties of a food product are regarded as one of the most crucial attributes since they are most noticeable by the consumer [60]. Sensory evaluation refers to the scientific technique of invoking, computing, analysing, and interpreting the responses by the perception of senses [61]. The palatability of the product has become the primary criteria for consumers nowadays, whereas such parameters as nutritional value and the wholesomeness of the product are secondary. Therefore, to ensure market success, a product must have the desired sensorial characteristics, i.e. taste, flavour, aroma, mouthfeel, aftertaste, and textural parameters.

As described in Table 4, kulfi prepared with addition of stevia indicated maximum overall acceptability, whereas no significant effect was observed on the body, texture, and flavour of the kulfi if the level of replacement of sugar with stevia was less than 50%. However, a negative impact on the textural properties, as well as flavour, was observed when the level of sugar replacement with stevia exceeded 50% [53].

Table 3. Effect of stevia on nutritional properties of various food products

Product	Stevia form	Amount of stevia, %	Description	Reference
Ice cream	Stevia powder (> 90% steviol glycosides)	0.02–0.11	↓ in calorific value and glycemic index	[39]
Kulfi	Stevia extract powder with 91.1% stevioside	0.05–0.07	↓ in calorific value	[53]
Herbal Kulfi	Stevia powder	0.05–0.07	↑ in fat and protein content ↓ in carbohydrate content	[58]
Muffin	Stevianna with 98% Rebaudioside A	9.97 and 19.76	↓ in calories and post prandial insulin levels	[32]
Muffin	Stevia powder with 95% steviol glycosides	0.09	↓ in caloric value	[36]
Functional yoghurt cake	Stevia leaves liquid extract	3.33	↓ caloric and energy values	[56]
Chocolate	Stevia extract with Glucosyl stevioside	0.5	↓ in energy value	[59]
Orange nectar	Stevioside powder (85–95% purity)	0.02–0.06	↓ in phenolic, ascorbic acid and stevioside content after 2 month storage at room temperature and 4°C	[49]

Note. ↑ – increase, ↓ – decrease, ↔ – non-significant

Table 4. Effect of stevia on sensory properties of various food products

Product	Stevia form	Amount of stevia, %	Description	Reference
Ice cream	Stevia leaf powder	0.862	↑in overall acceptance than sucrose sweetened ice-cream	[38]
Ice cream with cocoa	Stevia leaf powder	0.786	More preferred in terms of taste, color , flavor, melting in mouth and texture	[38]
Ice cream	Stevia powder (> 90% steviol glycosides)	0.04	Higher suitability in terms of taste, texture and mean liking	[39]
Herbal Kulfi	Stevia powder	0.05–0.07	↓ in overall acceptability	[58]
Passion fruit juice	Stevia extract	0.09924	↓ in aroma, flavor and overall impression	[52]
Muffin	0.075	0.075–0.300	↑ in scores for color, porosity and overall quality	[35]
Muffin	Stevia powder with 95% steviol glycosides	0.09	↑ in scores for overall quality, softness and taste	[36]
Bittersweet chocolate	Stevia extract with different Rebaudioside A contents (60%, 80% and 90%)	0.16	Stevia with 60% rebaudioside was more preferred in terms of sweetness, bitterness and melting rate	[57]

Note. ↑ – increase, ↓ – decrease, ↔ – non-significant

Current status and future perspective of utilizing sweeteners at national and international front. The US Food and Drug Administration regulate sweeteners as food additives. Food additives must be approved by the FDA, which publishes a Generally Recognized as Safe (GRAS) list of additives. To date, the FDA has not been presented with scientific information that would support a change in conclusions about the safety of the five approved artificial sweeteners (saccharin, aspartame, sucralose, neotame, and acesulfame potassium). The safe conclusions are based on a detailed review of a large body of information, including hundreds of toxicological and clinical studies. Steviol glycoside has been used as a non-nutritive low calorie sweetener in beverages, teas, and medicines in Japan, China, South America, and Korea. Many international beverage industries use stevia as a sweetener in different fruit juice drinks. The incorporation of stevia into such bakery products as puddings and cakes is highly suitable since stevioside is required in minute quantities to sweeten the product. It neither ferments nor exhibits any browning reaction during cooking, which broadens the field of application in baking and makes it possible to enhance the quality, decrease the calories, and increase the shelf-life. Stevia can be used as a sugar substitute in confectionery to sweeten chewing gums, candies, mints, chocolates, etc. Besides, stevia can be extensively used to sweeten various products, e.g. ice-cream, chocolates, fruit drinks, biscuits, soft drinks, yoghurt, biscuits, beverages like tea, and coffee.

The joint FAO/WHO expert committee on food additives (JECFA, 2008) stated that steviol glycosides were safe for use in foodstuffs and beverages. JECFA also suggested the acceptable daily intake (ADI) of 0–4 mg/kg body weight of steviol glycosides, which is equivalent to 0–10 mg/kg stevioside [62]. Currently, the largest market for production and application of stevia and its glycosides is in China and Japan. In 2009, the use of rebaudioside A was permitted in France. In European Union, the approval for use of steviol glycosides as food additive was granted by European Commission in 2011.

In India, the use of steviol glycosides was permitted by FSSAI in a notification issued in 2015 for a variety of products, including yoghurts, carbonated beverages, jams, fruit nectars, dairy based desserts, ready-to-eat cereals, etc.

CONCLUSION

Diterpene glycosides obtained from *Stevia rebaudiana* can be used to sweeten various foods and beverages without increment in calories. Apart from sweet contents, the other constituents of *Stevia rebaudiana* exert various health benefits, such as anti-hyperglycemic, anti-cancer, hepatoprotective, anti-hypertensive, anti-caries, antioxidant, and antimicrobial. Low-calorie stevia-incorporated products are rich in antioxidants, amino acids, and certain vitamins. They possess many other therapeutic properties in that they are anti-diabetic, anti-hypertensive, antitumor, antiulcer, etc.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this article.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Food Technology and Nutrition, Lovely Professional University, for providing all the necessary resources.

FUNDING

The authors received no specific funding for this work.

REFERENCES

1. Savita S.M., Sheela K., Sunanda S., Shankar A.G., and Ramakrishna P. *Stevia rebaudiana* – a functional component for food industry. *Journal of Human Ecology*, 2004, vol. 15, no. 4. pp. 261–264. DOI: https://doi.org/10.1080/09709274.2004.1190573.

2. Brandle J.E. and Telmer P.G. Steviol glycoside biosynthesis. *Phytochem*, 2007, vol. 68, no. 14, pp. 1855–1863. DOI: https://doi.org/10.1016/j.phytochem.2007.02.010.
3. Koyama E., Kitazawa K., Ohori Y., et al. In vitro metabolism of the glycosidic sweeteners, stevia mixture and enzymatically modified stevia in human intestinal microflora. *Food and Chemical Toxicology*, 2003, vol. 41, no. 3, pp. 359–374. DOI: https://doi.org/10.1016/S0278-6915(02)00235-1.
4. Carakostas M.C., Curry L.L., Boileau A.C., and Brusick D.J. Overview: The history, technical function and safety of rebaudioside A, a naturally occurring steviol glycoside, for use in food and beverages. *Food and Chemical Toxicology*, 2008, vol. 46, no. 7, pp. S1–S10. DOI: https://doi.org/10.1016/j.fct.2008.05.003.
5. Megeji N.W., Kumar J.K., Singh V., Kaul V.K., and Ahuja P.S. Introducing *Stevia rebaudiana*, a natural zero-calorie sweetener. *Current Science*, 2005, vol. 88, no. 5, pp. 801–804.
6. Soejarto D.D., Kinghorn A.D., and Farnsworth N.R. Potential sweetening agents of plant origin. III. Organoleptic evaluation of *Stevia* leaf herbarium samples for sweetness. *Journal of Natural Products*, 1982, vol. 45, no. 5, pp. 590–559. DOI: https://doi.org/10.1021/np50023a013.
7. Jeppesen P., Gregersen S., Alstrup K., and Hermansen K. Stevioside induces antihyperglycaemic, insulinotropic and glucagonostatic effects *in vivo*: Studies in the diabetic Goto-Kakizaki (GK) rats. *Phytomedicine*, 2002, vol. 9, no. 1, pp. 9–14. DOI: https://doi.org/10.1078/0944-7113-00081.
8. Jeppesen P., Gregersen S., Poulsen C., and Hermansen K. Stevioside acts directly on pancreatic β cells to secrete insulin: Actions independent of cyclic adenosine monophosphate and adenosine triphosphate-sensitive K^+-channel activity. *Metabolism: Clinical and Experimental*, 2002, vol. 49, no. 2, pp. 208–214. DOI: https://doi.org/10.1016/S0026-0495(00)91325-8.
9. Jeppesen P.B., Gregersen S., Rolfsen S.E.D., et al. Antihyperglycemic and blood pressure-reducing effects of stevioside in the diabetic Goto-Kakizaki rat. *Metabolism: Clinical and Experimental*, 2003, vol. 52, no. 3, pp. 372–378. DOI: https://doi.org/10.1053/meta.2003.50058.
10. Gregersen S., Jeppesen P.B., Holst J.J., and Hermansen K. Antihyperglycemic effects of stevioside in type 2 diabetic subjects. *Metabolism: Clinical and Experimental*, 2004, vol. 53, no. 1, pp. 73–76. DOI: https://doi.org/10.1016/j.metabol.2003.07.013.
11. Chen T.H., Chen S.C., Chan P., et al. Mechanism of the Hypoglycemic Effect of Stevioside, a Glycoside of *Stevia rebaudiana*. *Planta Medica*, 2005, vol. 71, no. 2, pp. 108–113. DOI: https://doi.org/10.1055/s-2005-837775.
12. Misra H., Soni M., Silawat N., et al. Antidiabetic activity of medium-polar extract from the leaves of *Stevia rebaudiana* Bert. (Bertoni) on alloxan-induced diabetic rats. *Journal of Pharmacy and Bioallied Sciences*, 2011, vol. 3, no. 2, pp. 242–248. DOI: https://doi.org/10.4103/0975-7406.80779.
13. Saravanan R., Babu K.V., and Ramachandran V. Effect of Rebaudioside A, a diterpenoid on glucose homeostasis in STZ-induced diabetic rats. *Journal of Physiology and Biochemistry*, 2012, vol. 68, no. 3, pp. 421–431. DOI: https://doi.org/10.1007/s13105-012-0156-0.
14. Assaei R., Mokarram P., Dastghaib S., et al. Hypoglycemic Effect of Aquatic Extract of Stevia in Pancreas of Diabetic Rats: PPARγ-dependent Regulation or Antioxidant Potential. *Avicenna Journal of Medical Biotechnology*, 2016, vol. 8, no. 2, pp. 65–74.
15. Melis M.S. A crude extract of Stevia rebaudiana increases the renal plasma flow of normal and hypertensive rats. *Brazilian Journal of Medical and Biological Research*, 1996, vol. 29, no. 5, pp. 669–675.
16. Chan P., Tomlinson B., Chen Y., et al. A double-blind placebo-controlled study of the effectiveness and tolerability of oral stevioside in human hypertension. *British Journal of Clinical Pharmacology*, 2001, vol. 50, no. 3, pp. 215–220. DOI: https://doi.org/10.1046/j.1365-2125.2000.00260.x.
17. Melis M.S. and Sainati A.R. Participation of prostaglandins in the effect of stevioside on rat renal function and arterial pressure. *Brazilian Journal of Medical and Biological Research*, 1991, vol. 24, no. 12, pp. 1269–1276.
18. Melis M. Effects of *Steviol* on renal function and mean arterial pressure in rats. *Phytomedicine*, 1997, vol. 3, no. 4, pp. 349–352. DOI: https://doi.org/10.1016/S0944-7113(97)80008-6.
19. Maki K.C., Curry L.L., Reeves M.S., et al. Chronic consumption of rebaudioside A, a steviol glycoside, in men and women with type 2 diabetes mellitus. *Food and Chemical Toxicology*, 2008, vol. 46, no. 7, pp. S47–S53. DOI: https://doi.org/10.1016/j.fct.2008.05.007.
20. Gupta P., Gupta N., Pawar A.P., et al. Role of Sugar and Sugar Substitutes in Dental Caries: A Review. *ISRN Dent*, 2013, 5 p. DOI: https://doi.org/10.1155/2013/519421.
21. Slavutzky S.M. *Stevia* and sucrose effect on plaque formation. *Journal fur Verbraucherschutz und Lebensmittelsicherheit*, 2010, vol. 5, no. 2, pp. 213–216. DOI: https://doi.org/10.1007/s00003-010-0555-5.
22. Giacaman R.A., Campos P., Munoz-Sandoval C., and Castro R.J. Cariogenic potential of commercial sweeteners in an experimental biofilm caries model on enamel. *Archives of Oral Biology*, 2013, vol. 58, no. 9, pp. 1116–1122. DOI: https://doi.org/10.1016/j.archoralbio.2013.03.005.
23. Shiozaki K., Nakano T., Yamaguchi T., Sato M., and Sato N. The protective effect of stevia extract on the gastric mucosa of rainbow trout *Oncorhynchus mykiss* (Walbaum) fed dietary histamine. *Aquaculture Research*, 2004, vol. 35, no. 15, pp. 1421–1428. DOI: https://doi.org/10.1111/j.1365-2109.2004.01164.x.

24. Shiozaki K., Fujii A., Nakano T., Yamaguchi T., and Sato M. Inhibitory Effects of Hot Water Extract of the Stevia Stem on the Contractile Response of the Smooth Muscle of the Guinea Pig Ileum. *Bioscience, Biotechnology and Biochemistry*, 2006, vol. 70, no. 2, pp. 489–494. DOI: https://doi.org/10.1271/bbb.70.489.

25. Pandiyan R., Velu R.K., Chandrasekaran S.K., and Bashiyam P. Effect on extracts of Stevia rebaudiana Bertoni. In ethanol induced gastric ulcer by using Wister rats. *Recent Research in Science and Technology*, 2009, vol. 1, no. 3, pp. 127–130.

26. Akihisa T., Hamasaki Y., Tokuda H., et al. Microbial Transformation of Isosteviol and Inhibitory Effects on Epstein−Barr Virus Activation of the Transformation Products. *Journal of Natural Products*, 2004, vol. 67, no. 3, pp. 407–410. DOI: https://doi.org/10.1021/np030393q.

27. Yasukawa K., Kitanaka S., and Seo S. Inhibitory Effect of Stevioside on Tumor Promotion by 12-*O*-Tetradecanoylphorbol-13-acetate in Two-Stage Carcinogenesis in Mouse Skin. *Biological and Pharmaceutical Bulletin*, 2002, vol. 25, no. 11, pp. 1488–1490. DOI: https://doi.org/10.1248/bpb.25.1488.

28. Takasaki M., Konoshima T., Kozuka M., et al. Cancer preventive agents. Part 8: Chemopreventive effects of stevioside and related compounds. *Bioorganic & Medicinal Chemistry*, 2009, vol. 17, no. 2, pp. 600–605. DOI: https://doi.org/10.1016/j.bmc.2008.11.077.

29. Deshmukh S.R. and Kedari V.R. Isolation, Purification and Characterization of Sweetners from *Stevia Rebaudiana* (Bertoni) for their Anticancerous Activity Against Colon Cancer. *World Journal of Pharmacy and Pharmaceutical Sciences*, 2014, vol. 3, no. 5, pp. 1394–1410.

30. Paul S., Sengupta S., Bandyopadhyay T.K., and Bhattacharyya A. Stevioside Induced ROS-Mediated Apoptosis Through Mitochondrial Pathway in Human Breast Cancer Cell Line MCF-7. *Nutrition and Cancer*, 2012, vol. 64, no. 7, pp. 1087–1094. DOI: https://doi.org/10.1080/01635581.2012.712735.

31. Azais-Braesco V., Sluik D., Maillot M., Kok F., and Moreno L.A. A review of total & added sugar intakes and dietary sources in Europe. *Nutrition Journal*, 2017, vol. 16, no. 1. DOI: https://doi.org/10.1186/s12937-016-0225-2.

32. Gao J., Brennan M.A., Mason S.L., and Brennan C.S. Effect of sugar replacement with stevianna and inulin on the texture and predictive glycaemic response of muffins. *International Journal of Food Science and Technology*, 2016, vol. 51, no. 9, pp. 1979–1987. DOI: https://doi.org/10.1111/ijfs.13143.

33. Grigor J.M., Brennan C.S., Hutchings S.C., and Rowlands D.S. The sensory acceptance of fibre-enriched cereal foods: a meta-analysis. *International Journal of Food Science & Technology*, 2016, vol. 51, no. 1, pp. 3–13. DOI: https://doi.org/10.1111/ijfs.13005.

34. Panpatil V.V. and Polasa K. Assessment of stevia (*Stevia rebaudiana*)–natural sweetener: A review. *Journal of Food Science and Technology*, 2008, vol. 45, no. 6, pp. 467–473.

35. Karp S., Wyrwisz J., Kurek M., and Wierzbicka A. Physical properties of muffins sweetened with steviol glycosides as the sucrose replacement. *Food Science and Biotechnology*, 2016, vol. 25, no. 6, pp. 1591–1596. DOI: https://doi.org/10.1007/s10068-016-0245-x.

36. Karp S., Wyrwisz J., Kurek M.A., and Wierzbicka A. Combined use of cocoa dietary fibre and steviol glycosides in low-calorie muffins production. *International Journal of Food Science and Technology*, 2017, vol. 52, no. 4, pp. 944–953. DOI: https://doi.org/10.1111/ijfs.13358.

37. Kulthe A.A., Pawar V.D., Kotecha P.M., Chavan U.D., and Bansode V.V. Development of high protein and low calorie cookies. *Journal of Food Science and Technology*, 2014, vol. 51, no. 1, pp. 153–157. DOI: https://doi.org/10.1007/s13197-011-0465-2.

38. Ozdemir C., Arslaner A., Ozdemir S., and Allahyari M. The production of ice cream using stevia as a sweetener. *Journal of Food Science and Technology*, 2015, vol. 52, no. 11, pp. 7545–7548. DOI: https://doi.org/10.1007/s13197-015-1784-5.

39. Alizadeh M., Azizi-Lalabadi M., and Kheirouri S. Impact of using stevia on physicochemical, sensory, rheology and glycemic index of soft ice cream. *Food and Nutrition Sciences*, 2014, vol. 5, no. 4, pp. 390–396. DOI: https://doi.org/10.4236/fns.2014.54047.

40. Lisak K., Jelicic I., Tratnik L., and Bozanic R. Influence of sweetener stevia on the quality of strawberry flavoured fresh yoghurt. *Mljekarstvo*, 2011, vol. 61, no. 3, pp. 220–225.

41. Reis R.C., Minim V.P., Bolini H., et al. Sweetness equivalence of different sweeteners in strawberry-flavored yogurt. *Journal of Food Quality*, 2011, vol. 34, no. 3, pp. 163–170. DOI: https://doi.org/10.1111/j.1745-4557.2011.00378.x.

42. Murphy M.M., Douglass J.S., Johnson R.K., and Spence L.A. Drinking Flavored or Plain Milk Is Positively Associated with Nutrient Intake and Is Not Associated with Adverse Effects on Weight Status in US Children and Adolescents. *Journal of the American Dietetic Association*, 2008, vol. 108, no. 4, pp. 631–639. DOI: https://doi.org/10.1016/j.jada.2008.01.004.

43. Berkey C.S., Rockett H.R., Field A.E., Gillman M.W., and Colditz G.A. Sugar-Added Beverages and Adolescent Weight Change. *Obesity Research*, 2004, vol. 12, no. 5, pp. 778–788. DOI: https://doi.org/10.1038/oby.2004.94.

44. Malik V.S., Schulze M.B., and Hu F.B. Intake of sugar-sweetened beverages and weight gain: a systematic review. *American Journal of Clinical Nutrition,* 2006, vol. 84, no. 2, pp. 274–288.

45. Li X.E., Lopetcharat K., and Drake M.A. Parents' and Children's Acceptance of skim Chocolate Milks Sweetened by Monk Fruit and Stevia Leaf Extracts. *Journal of Food Science*, 2015, vol. 80, no. 5, pp. S1083–S1092. DOI: https://doi.org/10.1111/1750-3841.12835.
46. Parpinello G.P., Versari A., Castellari M., and Galassi S. Stevioside as a replacement of sucrose in peach juice: sensory evaluation. *Journal of Sensory Studies*, 2001, vol. 16, no. 5, pp. 471–484. DOI: https://doi.org/10.1111/j.1745-459X.2001.tb00314.x.
47. Arthey D. and Ashurst P.R. *Fruit processing*. New York: Springer Publ., 1996. 248 p. DOI: https://doi.org/10,1007/978-1-4615-2103-7.
48. Vieira S.M., Silva T.M., and Gloria M.B.A. Influence of processing on the levels of amines and proline and on the physico-chemical characteristics of concentrated orange juice. *Food Chemistry*, 2010, vol. 119, no. 1, pp. 7–11. DOI: https://doi.org/10.1016/j.foodchem.2008.12.069.
49. Hosseini S., Goli S.A.H., and Keramat J. Production and characterization of low-calorie orange nectar containing stevioside. *Journal of Food Science and Technology*, 2015, vol. 52, no. 10, pp. 6365–6374. DOI: https://doi.org/10.1007/s13197-015-1739-x.
50. Maya D. and Ritu P. Formulation of fruit (orange juice) and whey based beverages flavoured with different herbs using natural sweetener as stevia. *International Journal of Scientific Research and Education*, 2016, vol. 4, no. 10, pp. 5975–5979. DOI: http://doi.org/10.18535/ijsre/v4i10.08.
51. Cadena R.S., Cruz A.G., Netto R.R., et al. Sensory profile and physicochemical characteristics of mango nectar sweetened with high intensity sweeteners throughout storage time. *Food Research International*, 2013, vol. 54, no. 2, pp. 1670–1679. DOI: https://doi.org/10.1016/j.foodres.2013.10.012.
52. Rocha I.F.D.O. and Bolini H.M.A. Passion fruit juice with different sweeteners: Sensory profile by descriptive analysis and acceptance. *Food Science and Nutrition*, 2015, vol, 3, no. 2, pp. 129–139. DOI: https://doi.org/10.1002/fsn3.195.
53. Giri A., Rao H.G. and Ramesh V. Effect of partial replacement of sugar with stevia on the quality of *kulfi*. *Journal of Food Science and Technology*, 2012, vol. 51, no. 8, pp. 1612–1616. DOI: https://doi.org/10.1007/s13197-012-0655-6.
54. Soukoulis C., Lebesi D., and Tzia C. Enrichment of ice cream with dietary fibre: Effects on rheological properties, ice crystallisation and glass transition phenomena. *Food Chemistry*, 2009, vol. 115, no. 2, pp. 665–671. DOI: https://doi.org/10.1016/j.foodchem.2008.12.070.
55. Struck S., Jaros D., Brennan C.S., and Rohm H. Sugar replacement in sweetened bakery goods. *International Journal of Food Science and Technology*, 2014, vol. 49, no. 9, pp. 1963–1976. DOI: https://doi.org/10.1111/ijfs.12617.
56. Abdel-Salam A.M., Ammar A.S., Galal W.K. Evaluation and properties of formulated low calories functional yoghurt cake. *Journal of Food, Agriculture and Environment*, 2009, vol. 7, no. 2, pp. 218–221.
57. Azevedo B.M., Morais-Ferreira J.M., Luccas V., and Bolini H.M.A. Bittersweet chocolates containing prebiotic and sweetened with stevia (*Stevia rebaudiana* Bertoni) with different Rebaudioside A contents: multiple time–intensity analysis and physicochemical characteristics. *International Journal of Food Science & Technology*, 2017, vol. 52, no. 8, pp. 1731–1738. DOI: https://doi.org/10.1111/ijfs.13470.
58. Singh D., Rai D.C., Bhinchhar B.K., and Choudhary B.L. Effect of Stevia on the Chemical Composition of Low Calorie Herbal *Kulfi*. *International Journal of Current Microbiology and Applied Sciences*, 2017, vol. 6, no. 8, pp. 1190–1196. DOI: http://doi.org/10.20546/ijcmas.2017.602.147.
59. Shah A.B., Jones G.P., and Vasiljevic T. Sucrose-free chocolate sweetened with *Stevia rebaudiana* extract and containing different bulking agents - effects on physicochemical and sensory properties. *International Journal of Food Science and Technology*, 2010, vol. 45, no. 7, pp. 1426–1435. DOI: https://doi.org/10.1111/j.1365-2621.2010.02283.x.
60. Singham P., Birwal P., Yadav B.K. Importance of Objective and Subjective Measurement of Food Quality and their Inter-relationship. *Journal Food Processing & Technology*, 2015, vol. 6, no. 9. DOI: https://doi.org/10.4172/2157-7110.1000488.
61. Sidel J.L. and Stone H. The role of sensory evaluation in the food industry. *Food Quality and Preference*, 1993, vol. 4, no. 1–2, pp. 65–73. DOI: https://doi.org/10.1016/0950-3293(93)90314-V.
62. Gardana C., Scaglianti M., and Simonetti P. Evaluation of steviol and its glycosides in *Stevia rebaudiana* leaves and commercial sweetener by ultra-high-performance liquid chromatography-mass spectrometry. *Journal of Chromatography A*, 2010, vol. 1217, no. 9, pp. 1463–1470. DOI: https://doi.org/10.1016/j.chroma.2009.12.036.

ORCID IDs
Sukhmani Gandhi https://orcid.org/0000-0003-3456-558X
Yogesh Gat https://orcid.org/0000-0002-6038-6123
Shalini Arya https://orcid.org/0000-0003-4255-7766
Ashwani Kumar https://orcid.org/0000-0001-6315-5710