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Agave Syrup in Traditional Indian Desserts: A Sensory Evaluation

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Abstract.
Sugar is among the least beneficial foods for health and is often referred to as a sweet poison due to its numerous health hazards. To address this issue, the food industry needs to explore, study, and shift to healthier food choices, such as agave syrup, which has a good potential as a natural sweetener. This study explores the acceptance level of traditional Indian desserts *seviyan kheer* and *rawa sheera* where sugar was substituted with agave syrup.

Sensory parameters were recorded for both the experimental samples and controls. The sensory evaluation involved two panels represented by culinary experts and semi-experts. The study included a nine-point hedonic scale test and a paired comparison test. Consumer acceptability was checked by calculating significant differences between the standardized formulations and the control samples.

Seviyan kheer made with agave syrup showed better acceptance rates in both expert and semi-expert panels ($p > 0.05$). Both panels preferred the formulations with agave syrup. The results were confirmed by a high-reliability score (Cronbach's alpha = 0.925); no significant differences occurred between the controls and the experimental samples after consumer acceptability trials.

Seviyan kheer demonstrated a higher acceptance rate while *rawa sheera* was only marginally accepted. The results revealed a good potential of agave syrup as a substitute for sugar in traditional Indian desserts and helped to understand customers preferences for healthier sweeteners. The research also highlighted the value of sensory assessment in determining customer acceptability and provided guidance for future initiatives to create healthier food substitutes. Further research is needed to test the commercial viability and nutritive properties of agave syrup for a wider range of traditional Indian sweets with different combinations of ingredients.

Keywords. Agave syrup, Indian traditional sweets, sensory analysis, nutrient analysis, product development

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Органолептическая оценка традиционных индийских десертов с добавлением сиропа агавы

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Аннотация.
Сахар является вредным для человеческого организма продуктом, за что его часто называют «сладкий яд». Поиск замены сахара - актуальная область научных исследований в пищевой промышленности. Альтернативным натуральным подсластителем может служить сироп агавы. Цель исследования заключалась в проведении органолептической оценки традиционных индийских десертов «кхир севьян» (пудинг с вермишелью) и «рава шира» (пудинг из манки), в которых сахар заменяли сиропом агавы.

Органолептическую оценку проводили группой кулинарных экспертов и полуэкспертов по девятибалльный гедонистической шкале и методом парной пробы, т. е. сравнительного анализа контрольного образца с экспериментальным. Потребительские качества проверяли путем расчета значимых различий между экспериментальными десертами, приготовленными по стандартизированным рецептурам, и контрольными образцами.

Десерт «кхир севьян», приготовленный с сиропом агавы вместо сахара, получил более высокую органолептическую оценку в обеих группах ($p > 0,05$): как эксперты, так и полуэксперты предпочли десерты с сиропом агавы контрольным образцам, приготовленным с использованием сахара. Результаты получили высокую степень надежности (альфа Кронбаха = 0,925). Тест на потребительские качества не выявил существенных различий между контрольными и экспериментальными образцами. При этом образцы десерта «рава шира» с сиропом агавы получили более низкую органолептическую оценку.

В целом сироп агавы был расценен как перспективная замена сахара в традиционных индийских десертах. Данное исследование помогло выявить предпочтения клиентов в отношении натуральных подсластителей и продемонстрировало важность органолептической оценки в определении потребительских качеств инновационных продуктов питания. Описанная методика может быть использована в качестве образца для будущих исследований полезных заменителей традиционных пищевых компонентов. Перспективы введения сиропа агавы в массовое производство в составе данных блюд традиционной индийской кухни требуют дальнейшего изучения. Питательные свойства сиропа агавы могут быть исследованы на материале более широкого спектра традиционных индийских десертов с различными комбинациями ингредиентов.

Ключевые слова. Сироп агавы, индийские традиционные десерты, органолептическая оценка, анализ питательных свойств, разработка продуктов питания

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Introduction

Pure, white, and deadly, public health enemy number one, highly palatable, sweet poison: these are some of the unexaggerated nicknames given to sugar [1–5]. No equitable laws curb the production or usage of sugar in day-to-day food products in spite of the fact that the health hazards of high sugar intake are widely known [6–16]. It is associated with obesity [7] and hypertension [8], as well as with numerous metabolic, cardiovascular, and nervous disorders [9], not to mention many more clinical conditions. The reasons why people cannot just stop consuming sugar are many: from capitalism, which governs the world economic dynamics, to simple consumerism philosophy [17]. One of the reasons is the absence of a perfect substitute. By perfect substitute, we mean that its availability, production, cost, utility, and health benefits should excel those of sucrose, commonly known as sugar.

Sucrose substitutes can broadly be classified into two main categories, i.e., artificial and natural. Artificial substitutes, or artificial sweeteners, add mere sweetness without any calories. Aspartame, Sucralose, and Neotame are some examples, with Saccharin being the first one to be produced by Constantin Fahlberg in 1879. Natural sweeteners are further subdivided into nutritive and non-nutritive, or classified by source, i.e., plants, animals, or microbes. The most popular natural sweeteners are honey, maple syrup, and stevia [18]. Agave syrup is a natural sweetener. The principal byproducts of agave processing include juice, leaves, bagasse, and fibers [19]. Additionally, agave fructans demonstrate promising results as an encapsulating material that can prevent food ingredients from deteriorating [20].

Tequila and other alcoholic beverages are traditionally made in Mexico using a variety of plants from the *Agave* genus. Agave fructans are relatively new to the food industry. Due to their positive effects on human health, they have become quite popular as part of functional foods [21].

Agave syrup is produced by crushing the agave plant into fibers, from which juice is released by gravity, natural hydrolysis, and vacuum evaporation. About 10% of harvested agave is used for syrup production, while the remaining 90% goes to fermented and alcoholic beverages, e.g., Pulque, Tequila, and Mascal, which are usually produced from *Agave tequilana* and *Agave salmiana*. The process involves removing residue, increasing temperature, and removing excess moisture. Because agave syrup has a low glycemic index, it can be used in foods that primarily rely on sucrose. Chemical properties of agave syrup extracted from two most widely used agave species show that *Agave tequilana* contains 71–92% fructose, 4–15% glucose, and 4% sucrose, whereas *Agave salmiana* contains ≥ 70% fructose, ≥ 25% glucose, and ≥ 2% sucrose [22]. Agave sweet extract is gaining popularity due to its low glycemic index, as well as good antioxidant and antibacterial properties. It was reported to reduce plasma glucose and lipids, improve colon function, and increase calcium absorption. In addition, it demonstrated anticancer, anti-inflammatory, and ulcer-protective properties. The extract also showed antioxidant effects and was able to inhibit such bacteria as *Bacillus subtilis* and *Escherichia coli*. Based on recent research and commercial substitution, agave syrup has a strong chance of replacing sucrose in the near future, but further exploration is needed for its long-term health benefits and functional food status [23]. Agave fructans provide food producers with a number of technological benefits, such as soluble fiber, micro-encapsulation carriers, low-calorie sweeteners, fat substitutes, texture and viscosity modifiers, etc. Additionally, agave fructans enhance human health in a significant way by regulating microbial activity, glucose metabolism, and obesity [24]. They were reported to lower blood triglycerides, improve hyperglycemia, and increase body weight in several rodent studies [25].

Commercialization of agave syrup. ***Agave as a sweetener in chocolate.*** Patented low-moisture agave syrup allowed for the production of sugar-free, natural chocolate that had good sensory properties and was stable at room temperature, i.e., it had the snap, luster, and flavor that consumers expect from chocolate [26].

Scientists compared the rheological, microstructural, and textural qualities of dark chocolates with natural substitutes (agave syrup and stevia) and traditional chocolates made with saccharose. The chocolate sample with the highest fat content and agave syrup substitute produced the smallest sugar crystal formation and had the lowest sugar levels. Because the rheometer employed was unable to quantify higher levels of viscosity, it demonstrated that the sample with less fat indicated stress [27].

Agave nectar as a nutritional supplement. Blue agave nectar was part of a dietary supplement with Omega-3 and Omega-6 fatty acids, which demonstrated a thermogenic effect and other health advantages [28].

Agave syrup as a sweetener in pastry. In muffins, agave syrup demonstrated a satisfyingly consistent structure. The syrup was used in place of or in addition to sucrose in gluten-free cakes, cereal bars, muffins, and cookies. The effects of agave syrup on the rheological, microstructural, and sensory qualities of baked goods remain understudied. As it was mentioned above, agave syrup proved quite effective in replacing sucrose in muffins; it yielded the best results in combination with xanthum gum and twice as much leavening agent [29].

Agave plant fructans (agavins) as fat substitutes in dairy products. Agavins were reported to provide low-fat or no-fat yogurt samples in a study that investigated agavins derived from *Agave angustifolia* and *Agave potatorum* for their physiochemical, rheological, and sensory characteristics. The experimental samples had excellent mouthfeel and texture while preserving the original sensory profile. However, the authors reported significant variations in the water retention capacity, syneresis, and viscosity. Every yogurt sample showed weak viscoelastic gel properties and strain thinning [30].

Agave ingredients in granola bars. Agave syrup, fructan sweeteners, and agave fiber could replace honey and flour in granola bars. Pulverized agave fiber was obtained as a byproduct of making agave syrup from the stems of *Agave tequilana*. The soluble agave dietary fiber that made up the body of granola bars was made from agave fructans and pulverized fiber [31].

Agave as a sweetener in raspberry jam. Jams made by mixing cooked fruits with sweeteners, i.e., sucrose, pectin, and acid, have always been a staple of human diet and nutrition. Saveski *et al.* [32] ascertained and evaluated the sensory variations that arose from replacing the sucrose in raspberry jams with other sweeteners, such as agave syrup. Sorbitol and agave syrup demonstrated better hedonistic qualities than sucrose and other sweeteners in raspberry jam.

Agave as a sweetener in teriyaki sauce. A Korean team substituted sugar with fructooligosaccharide, xylitol, erythritol, and agave syrup in teriyaki sauce to study how they affect consumers' health. They focused on moisture content and viscosity. Xylitol proved to be an excellent addition to teriyaki sauce in terms of flavor and taste [33].

Agave as a sugar and fat substitute in ice-cream. Agave fructans improved the sensory, thermal, and textural properties of ice-cream, highlighting the fact that agave is a feasible fat and sugar replacer [34].

Agave fructans with spray-dried pineapple and mango powder. Jimenez-Sánchez *et al.* studied the effect of native agave fructans on the physiochemical profile of spray-dried pineapple and mango powder [35]. In conjunction with maltodextrin as stabilizers, they had a positive effect on the physiochemical characteristics of the fruit powder during drying. However, high concentrations altered the physiochemical profile of the powders during storage at room temperature. Under unpredictable storage conditions, fructans led to glueyness and unwanted accumulations, thus increasing hygroscopicity and water retention of the final product.

Agave nectar in tequila and tequila-based spirits. Agave nectar was reported to enhance the natural flavor of tequila or tequila-like beverages [36].

Agave syrup in maqui gel. Maqui berries are rich in antioxidants and have good anti-atherosclerotic properties. Sobaszek *et al.* substituted beet sugar with agave syrup in maqui gel to maximize the sensory, textural, and antioxidant qualities [37]. Agave syrup proved to be a superior substitute for beet sugar in terms of increasing the antioxidant activity of gels when citric acid was added at a 0.5% concentration.

Ashen and green agave bagasse in functional cookies. The research featured the physical properties of cookies, as well as the functional and chemical characteristics of agave bagasse. Agave bagasse increased the oil-holding capacity of the cookies and transferred prebiotic fructooligosaccharides to both agave bagasse formulations. They remained active as a prebiotic ingredient after *in vitro* digestion and thermal treatment. Ashen and green agave bagasse demonstrated beneficial chemical and functional properties for the food industry. Therefore, agave bagasse may be a good substitute to other dietary fibers in healthy diets [38].

The abovementioned experimental studies illustrate the various uses of agave syrup in food products. However, a few important points need to be taken into account prior to general acceptance. In-depth studies of the sensory impact are often insufficient, especially when it comes to flavor, texture, and general customer acceptability. Whether agave-based substitutes can accurately mimic the sensory experience of conventional products remains an open question without extensive sensory analyses.

Furthermore, the long-term effect of agave syrup on human health remains understudied, even though it may be healthier than that of conventional sweeteners, e.g., sucrose. More research is required to clarify any possible negative consequences, particularly in light of the growing worries about the connection between excessive sugar consumption and some health issues.

India is sometimes called the diabetic capital of the world. One out of every five people suffering from diabetes in the world is Indian; a staggering estimation of 70 million Indians with diabetes is projected for 2025. Asian Indian phenotype presupposes such reasons as hereditary genes, dietary patterns, low physical activity, and low body mass index [39]. Traditionally, any celebration in India is considered incomplete without sweets. It is customary to sweeten the mouth after every meal, happy occasion, religious holiday, party, etc. Offering sweets to God is required on all religious occasions [40]. In fact, sugar was invented in India, which was recorded in Atharva Veda. The word sugar itself was derived from sharkara, a Sanskrit word for gravel. The army of Alexander the Great was surprised to discover another source of sweetening in the form of sugar. They described it as a reed that gives honey without bees. Indian culture, customs, and beliefs have all revolved around sugar and sweet dishes since ancient times. Dietary guidelines for Indians advocate consuming no more than 10% of daily energy from sugar, or even less.

Easy availability and liking towards westernized culture due to globalization has increased the sugar consumption levels among Indians [41]. A study conducted in four cities of India (Delhi, Bangalore, Agra, and Pune) on school children aged 9–18 years projected a high consumption pattern of sweetened food items among children and their mothers. In fact, they considered any food that was prepared hygienically and packaged properly as healthy. At the time of festivals in India, people engage themselves in purchasing clothes, jewelry, accessories, and sweets. Buying and distributing sweets is part of every festival. Start-up date for any new business or important activities are purposely kept on festival dates as they are considered to be good luck. All these important activities increase the consumption of sweets on a national level [42]. If earlier more focus was on traditional Indian sweets as gift items during festivals, the current changes in social circumstances and cultural submergence have evolved new patterns in edible gifts [43]. Sweets prepared from milk are an integral part of the culinary habits all over India [44]. However, people of young generation look at price and calorie content when selecting sweets [45]. Shifting to healthy alternatives in food choices seems to be a promising part of the solution.

Yet, Indian people of all ages indulge in sweets on both regular days and special occasions [46]. This study concentrates on developing new products by replacing sucrose with agave syrup, as well as on the sensory evaluation of some traditional Indian sweets. In addition, an attempt was made to check its nutrient profiling for the overall consumer acceptability. The study featured *rawa sheera* and *seviyan kheer* as two traditional Indian desserts.

Study objects and methods

The research objective was to evaluate the acceptability of classic Indian desserts *rawa sheera* and *seviyan kheer* produced with agave syrup against control samples with sugar. The sensory evaluation was a combination of a nine-point hedonic scale and paired comparison test on experts and semi-experts. The nine-point hedonic scale is an internationally recognized scale with nine verbal categories and a neutral category in the middle. It includes adjectives ranging from disliked extremely to like extremely and may or may not have numerical scores to indicate the strength of each term [47]. The paired comparison is one of the most popular sensory discrimination tests used in sensory science because of its simplicity. It only involves assessing two samples at a time, which significantly reduces the effect of fatigue, carry-over, and memory issues compared to assessing three or more samples [48]. The analysis of nutrients and contaminants followed the protocols established by the Food Safety and Standard Authority of India (FSSAI) and ISO 9001:2008 for examining nutrient content and contamination in accredited laboratories. Examining contaminants and residues in developed samples was the rationale. The acquired values were compared with the standards adopted in India.

a b

Figure 1. Ingredients: a – for *rawa sheera*, b – for *seviyan kheer*

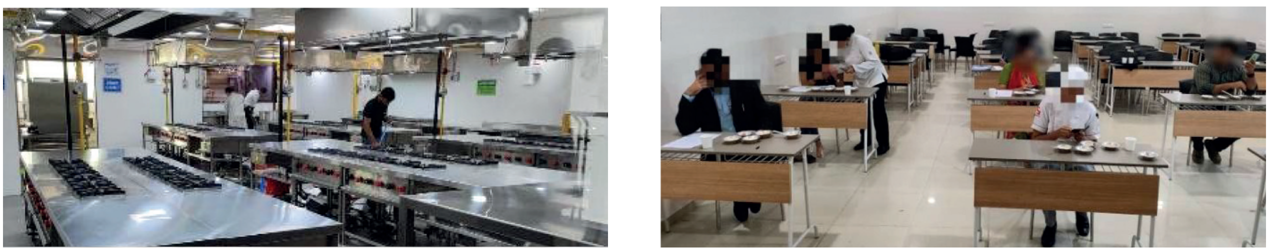
Рисунок 1. Ингредиенты: а – десерт «рава шира», б – десерт «кхир севьян»

All ingredients (Fig. 1) were purchased from a local food store in Pune City, Maharashtra: agave syrup (Mexican blue agave syrup), ghee (Govind Ghee), *seviyan* (Ganesh Seviyan Roasted), *rawa* (GSD Suji Rawa), sugar, dried fruit, milk, cardamom powder, and nutmeg.

The Foundation Training Kitchen at the Symbiosis School of Culinary Arts and Nutritional Sciences, Pune, was used to standardize the formulations with six culinary-trained volunteers who did the cooking and preparations for the sensory evaluations. The set-up for the sensory evaluation was arranged as per standard protocol, i.e., four rows of tables and chairs were set at equal distances from each other to avoid biased responses (Fig. 2).

Sensory evaluation. The sensory evaluation involved ten semi-trained experts and ten culinary experts. The semi-trained experts panel consisted of administrative employees and students (18–50 y.o.) from Symbiosis School of Culinary Arts and Nutritional Sciences, who regularly consume sweets and come from different socio-economic backgrounds. The expert participants were professional chefs and hospitality veterans with expert knowledge of the sensory attributes of sweets. Both semi-expert and expert panels were briefed about the study and the sensory evaluation procedure. The board of the classroom where the sensory evaluation took place displayed the objective of the study; hard copies of basic process on how to examine food appearance and taste were on every table along with a glass of water and a bowl of tomato wedges as palette cleanser. The same information was announced at the briefing. A 30-gram sample of *rawa sheera* with sucrose (control), *rawa sheera* with agave syrup (test sample), *seviyan kheer* with sucrose (control), and *seviyan kheer* with agave syrup (test sample) were portioned in disposables and coupled with a bowl of tomato wedges as a palette cleanser to the panelists. The blind samples were assessed using a paired comparison test and a nine-point hedonic scale ranging from 1 point (dislike extremely) to 9 points (like extremely).

The panelists were provided with written informed consent which was reviewed and signed by them before



a b

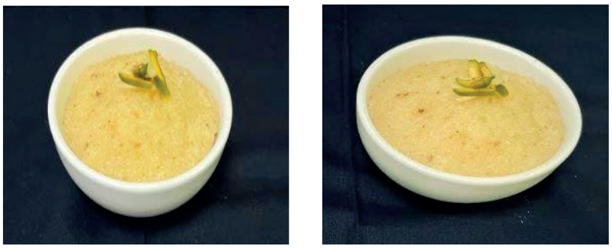
Note. All panelists provided their consent for the reprinting of their images for this research and publication.

Figure 2. Sensory evaluation procedure: a – Foundation Training Kitchen at Symbiosis School of Culinary Arts and Nutritional Sciences, b – Product tasting and response recording

Рисунок 2. Процедура органолептической оценки: а – базовая учебная кухня, отделение кулинарии Международного университета Симбиоза, б – дегустация и оценка the tasting. Ethical clearance was not required since our study focused on utility of agave as replacement with respect to sensory properties and did not involve nutritive and health-related impact.

Formulations and preparation. ***Rawa sheera*** **(control).** Semolina was gently dry-roasted at 140°C for 3 min. After that, 4 g of melted ghee and boiling water were combined to create a combination with a water-to-rawa ratio of 1:5. The toasted semolina was gradually added to this boiling mix while stirring. Then, we added sugar and more ghee, along with nutmeg and green cardamom powder to enhance the texture. A thorough mixing guaranteed that every component was distributed evenly. Finally, the finished product was adorned with almonds and pistachios that had been blanched and finely chopped.

Rawa sheera **(test sample).** The components and methods were identical to those of the control sample, but sugar was replaced with agave syrup (Fig. 3). Three pre-standardization trials made it possible to determine the proportion of agave syrup in the formulation. The share of agave syrup was gradually increased to match the sweetness to that of the control sample. The expert panel tested the sweetness during the informal trails. In the third attempt, the experts concluded it to be the closest in terms of sweetness to the control sample with sugar. The proportions of rawa and water were consistent (1:5), and other ingredients were adjusted to a common denominator of 100% (Table 1).



a b

Figure 3. *Rawa sheera*: a – with sugar, b – with agave syrup

Рисунок 3. Десерт «рава шира»: а – с сахаром, б – с сиропом агавы

Table 1. Informal trials to standardize *rawa sheera* formulation with agave syrup

Таблица 1. Стандартизация рецептуры десерта «рава шира» с сиропом агавы вместо сахара

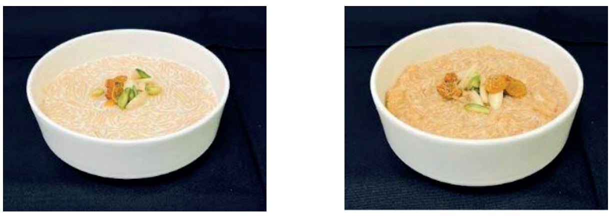
Ingredient	Trial 1 (Reference control sample), %	Trial 2, %	Trial 3 (Standardized mix), %
Rawa	16.67	16.67	16.67
Water	83.33	83.33	83.33
Ghee	6.40	6.15	5.93
Agave syrup	20.00	23.08	25.93
Green cardamom powder	1.20	1.15	1.11
Nutmeg	0.40	0.38	0.37
Pistachio	1.60	1.54	1.48
Almond	1.60	1.54	1.48
Total mass	100	100	100

Seviyan kheer **(control).** We sautéed dried fruits in 4 g of melted ghee in a skillet till they acquired a pleasant golden color. After bringing milk to a mild boil in the same pan, we added roasted vermicelli at a ratio of 1:10. Periodical stirring prevented the vermicelli from adhering to the pan. The vermicelli was cooked in the milk until it was soft and had absorbed the liquid well. It took the vermicelli about 8 min for to absorb the milk and reach the appropriate suppleness. Then, we added sugar at a ratio equal to the amount of cooked vermicelli. The kheer was vigorously stirred with the mix until all of the sugar dissolved. The sautéed dried fruits were added as a garnish to the *seviyan kheer*, giving it a palatable and visually attractive look.

Seviyan kheer **(test sample).** The components and methods were identical to the control sample, but sugar was substituted with agave syrup. In an effort to standardize the *seviyan kheer*, we experimented with various combinations and proportions of agave syrup. Three pre-standardization trials made it possible to determine the correct proportion of agave syrup in the formulation. Agave syrup was gradually increased to match the sweetness of the control sample. The expert panel tested the sweetness during the informal trails. In the third attempt, the experts concluded it to be the closest in terms of sweetness to the control sample with sugar (Fig. 4). The ingredients in Table 2 were standardized to 100% total mass, making it easier to compare between trials.

Results and discussion

Nine-point hedonic scale test. The statistical analysis involved a nine-point hedonic scale test with SPSS version 23. Student's t-test was applied to analyze the variance in the means of all the criteria (appearance, color, taste, flavor, smell, aftertaste/mouthfeel, and overall



a b

Figure 4. *Seviyan kheer*: a – with sugar, b – with agave syrup

Рисунок 4. Десерт «кхир севьян»: а – с сахаром, б – с сиропом агавы

Table 2. Informal trials to standardize *seviyan kheer* with agave syrup

Таблица 2. Стандартизация рецептуры десерта «кхир севьян» с сиропом агавы вместо сахара

Ingredient	Trial 1 (Reference control sample) %	Trial 2, %	Trial 3 (Standardized mix), %
Vermicelli	7.27	7.21	7.14
Ghee	1.45	1.44	1.43
Agave syrup	7.27	7.93	8.57
Green cardamom powder	0.44	0.43	0.4
Milk	72.67	72.05	71.43
Water	7.27	7.21	7.14
Raisin	1.45	1.44	1.43
Pistachio	1.16	1.15	1.14
Almond	1.16	1.15	1.14
Total mass	100	100	100

Table 3. Mean score for sensory attributes for *rawa sheera*: control vs. agave syrup sample

Таблица 3. Средний балл по результатам органолептической оценки десерта «рава шира»: экспериментальный образец с сиропом агавы и контрольный образец с сахаром

Characteristics	Mean ± SD		*p*-value
	Control	Agave syrup	
Appearance	7.54 ± 1.07	7.05 ± 0.80	0.08
Color	7.19 ± 1.07	7.24 ± 0.94	0.88
Taste	7.48 ± 1.56	6.81 ± 1.16	0.15
Flavor	7.52 ± 1.12	6.81 ± 1.16	0.50
Smell	7.67 ± 0.96	6.95 ± 1.11	0.03*
Overall acceptability	7.67 ± 1.11	6.76 ± 1.26	0.01*
Aftertaste/ mouthfeel	7.24 ± 1.17	6.81 ± 1.40	0.29

*Significant differences ($p < 0.05$) are marked with an asterisk.

Table 4. Mean score for sensory attributes for *seviyan kheer*: control vs. agave syrup sample

Таблица 4. Средний балл по результатам органолептической оценки десерта «кхир севьян»: экспериментальный образец с сиропом агавы и контрольный образец с сахаром

Characteristics	Mean ± SD		*p*-value
	Control	Agave syrup	
Appearance	7.52 ± 0.81	8.05 ± 0.86	0.05
Color	7.29 ± 1.05	7.90 ± 0.94	0.052
Taste	7.10 ± 1.41	7.90 ± 0.99	0.03*
Flavor	7.0 ± 1.26	7.76 ± 0.88	0.02*
Smell	7.05 ± 1.96	7.43 ± 1.24	0.45
Overall acceptability	7.19 ± 1.32	7.90 ± 0.99	0.055
Aftertaste/ mouthfeel	7.48 ± 1.47	7.67 ± 1.19	0.64

*Significant differences ($p < 0.05$) are marked with an asterisk.

Table 5. Table 5. Mean score for sensory attributes for *rawa sheera* and *seviyan kheer* with agave syrup

Таблица 5. Средний балл по результатам органолептической оценки экспериментальных образцов десертов «рава шира» и «кхир севьян» с сиропом агавы

Characteristics	Mean ± SD		*p*-value
	Rawa sheera (agave syrup)	*Seviyan kheer* (agave syrup)	
Appearance	7.05 ± 0.80	8.05 ± 0.86	0.00*
Color	7.24 ± 0.94	7.90 ± 0.94	0.02*
Taste	6.81 ± 1.16	7.90 ± 0.99	0.002*
Flavor	6.81 ± 1.16	7.76 ± 0.88	0.005*
Smell	6.95 ± 1.11	7.43 ± 1.24	0.2
Overall acceptability	6.76 ± 1.26	7.90 ± 0.99	0.002*
Aftertaste/ mouthfeel	6.81 ± 1.40	7.67 ± 1.19	0.03*

*Significant differences ($p < 0.05$) are marked with an asterisk.

acceptability). In every instance, a *p*-value of < 0.05 was regarded as significant (Table 3).

The control sample of traditional *rawa sheera* with sugar scored significantly better than the experimental sample with agave syrup in terms of smell and overall acceptability with *p*-values of 0.03 and 0.01, respectively.

The experimental sample of *seviyan kheer* with agave syrup demonstrated statistically significant higher ratings for taste and flavor (Table 4).

The comparative evaluation of *seviyan kheer* and *rawa sheera* with agave syrup showed that the *seviyan kheer* received significantly higher scores for almost all sensory attributes (Table 5).

Reliability analysis is important for product development studies. It determines the association between the scores obtained from different administrations of the scale. If the association in reliability analysis is high, it is evident that the scale yields consistent results and is therefore reliable. Our research involved a reliability test, which demonstrated a high-reliability score of 92.5% (Cronbach's alpha = 0.925) for both the products developed.

Paired comparison test. *Expert panel.* Experimental *rawa sheera* and *seviyan kheer* with agave syrup were served with their sucrose- based control variants. In the blind test performed by the expert panel, *rawa sheera* with agave showed 40% relativity in color and aftertaste, 3% in flavor, taste, and consistency, and 10% in texture. The test with *seviyan kheer* showed admirable results with 90% relativity in flavor, 80% in taste, consistency, and texture, and 70% in color and aftertaste / mouthfeel (Fig. 5).

Semi-expert panel. The same blind testing procedure was repeated with semi-trained experts. *Rawa sheera*

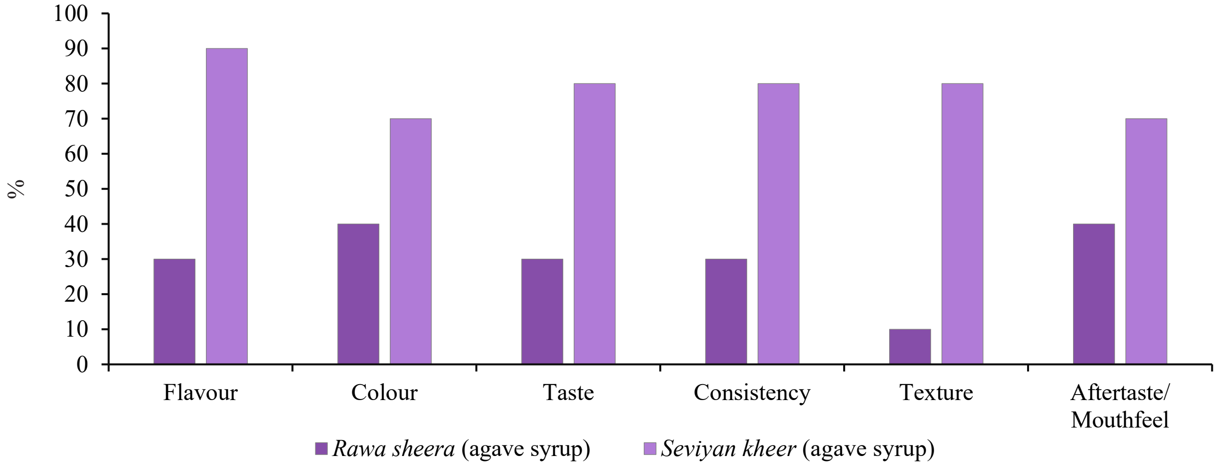


Figure 5. Paired comparison test by expert panel: *rawa sheera* and *seviyan kheer* with agave syrup vs. control samples with sugar

Рисунок 5. Результаты парного сравнительного анализа в группе экспертов: десерты «рава шира» и «кхир севьян» с сиропом агавы и контрольные образцы с сахаром

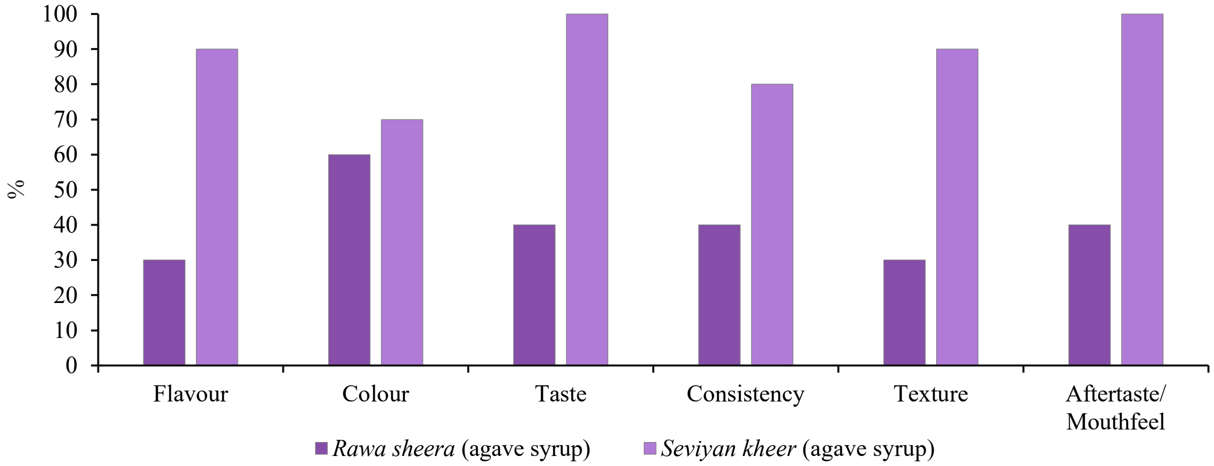


Figure 6. Paired comparison test by semi-expert panel: *rawa sheera* and *seviyan kheer* with agave syrup vs. control samples with sugar

Рисунок 6. Результаты парного сравнительного анализа в группе полуэкспертов: десерты «рава шира» и «кхир севьян» с сиропом агавы и контрольные образцы с сахаром

with agave showed 60% relativity in color, 40% in taste, consistency, and aftertaste/mouthfeel, and 30% in flavor and texture. *Seviyan kheer* with agave again showed exceptional results with 100% relativity in taste and aftertaste/mouthfeel, 90% in flavor and texture, 80% in consistency, and 70% in color (Fig. 6).

Acceptability analysis. To study and analyze the consumer acceptability of standardized formulations, the products were developed in bulk and tested among a few of the subgroup study population (n = 85). It involved four preparations: two items were sugar-free (agave syrup) and two were with sugar. Participants rated the sweets for color, sweetness, texture, aftertaste, and overall acceptability. Figures 7–11 illustrate the comparison graphs for the four preparations.

The hedonic rating scale demonstrated no significant differences between the four preparations in color, sweetness, texture, aftertaste, and overall acceptability. Therefore, the sugar-free version of traditional Indian desserts *rawa sheera* and *seviyan kheer* were equally acceptable among the participants.

Discussion. Sucrose, being a key component of sweets and bakery goods, boosts their energy content. Because of chemical processes fueled by heat and involving degraded sugar, sucrose also contributes to the change in other sensory characteristics. Sweeteners meant to replace sucrose must be water-soluble, affordable, and tasty, as well as follow national or international standards [49]. Sugar is used in thousands of foods, ranging from cured meats to preserves, frozen fruits, and confections. In terms

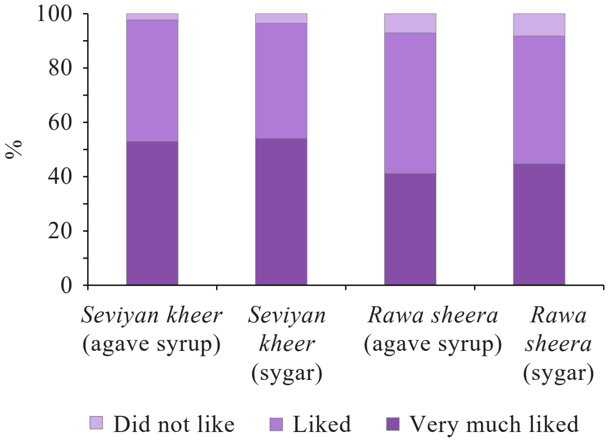


Figure 7. Color across four preparations

Рисунок 7. Результаты органолептической оценки: цвет

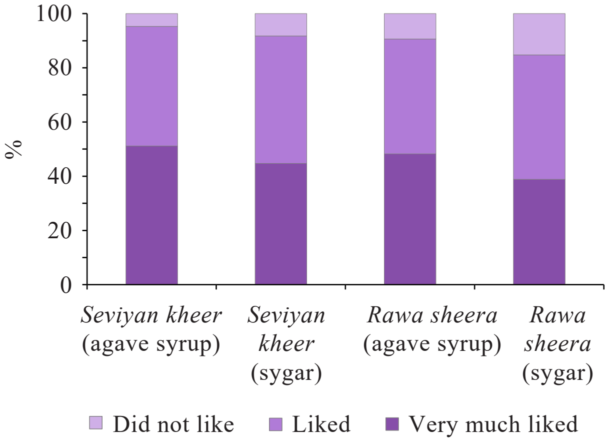


Figure 8. Sweetness across four preparations

Рисунок 8. Результаты органолептической оценки: сладость

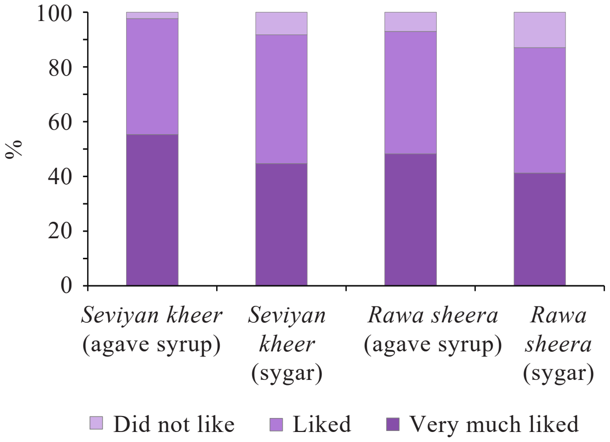


Figure 9. Texture across four preparations

Рисунок 9. Результаты органолептической оценки: консистенция

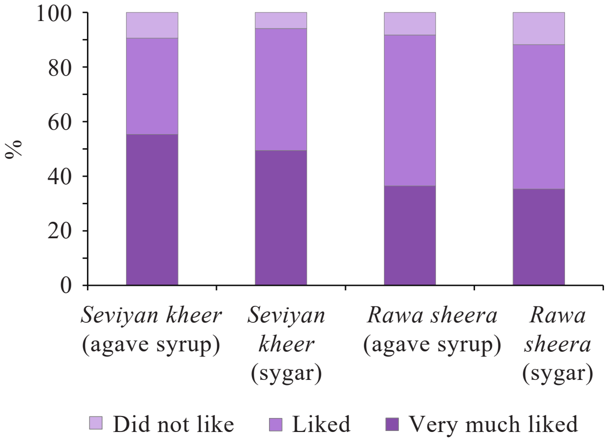


Figure 10. Aftertaste across four preparations

Рисунок 10. Результаты органолептической оценки: послевкусие

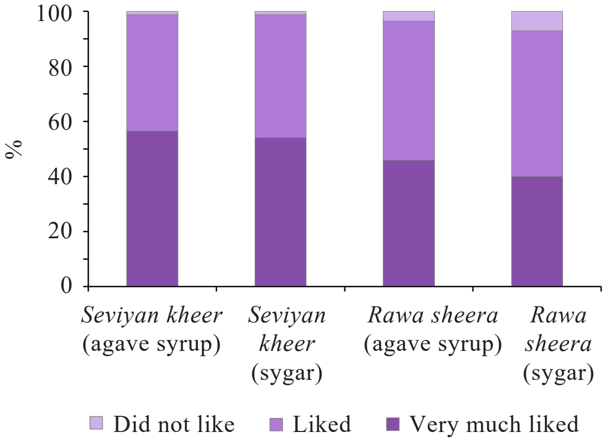


Figure 11. Overall acceptability across four preparations

Рисунок 11. Результаты органолептической оценки: общая привлекательность

of nutrition, sugar gives energy. In terms of calories, sugar is arguably the most economical food [50]. Too much added sugar intake is linked to a number of detrimental health effects. Popular indulgences, e.g., cakes and biscuits, add a substantial amount of extra sugar to people's diets. Food reformulation may make it possible to lower the amount of sugar in the diet without having to change one's eating habits [51]. The food industry has long faced the challenge of reducing the amount of sugar and energy (calories) in the diet. This challenge arises from both individual efforts to limit sugar and calorie intake, and public health policy initiatives, e.g., government reformulation programs and sugar taxes. Food producers and formulators have found it more challenging to meet this demand in recent years as consumers are looking for products with natural, clean-label ingredients. While high-potency does offer some benefits, zero-calorie sweeteners with better taste performance often present bigger issue as they replace the bulking, browning, and other qualities that sucrose, glucose, and fructose provide to many solid food products [52].

Agave syrup in sweets and bakery goods, despite concerns about high calorie content and potential health risks, attract a lot of scientific attention. Investigations focus on its technological and functional properties as a sucrose substitute. Ozuna *et al.* reduced the sucrose content in muffins by up to 75% by adding agave syrup without affecting the original quality [29]. Mata-Ramirez *et al.* developed white bread with 9% roselle flour, enhancing dietary fiber, phenolic compounds, anthocyanins, and antioxidant capacity [53]. Zamora-Gasga *et al.* developed a granola bar using agave-based ingredients and agave syrup as a sweetener, thus reducing initial sucrose content without affecting sensory qualities [31]. Čižauskaitė *et al.* demonstrated the potential of gelatin and agave syrup in functional jellies, which can be fortified with active components [54]. Belščak-Cvitanović *et al.* reported that replacing sucrose with Agave syrup in low-sugar chocolates improved sensory quality and did not affect the bioactive chemical concentration but made the product harder [55].

Modified fructans generally demonstrated better functional qualities when compared to native fructans, offering a significant chance to enhance the functionality of the food that integrate them [56]. Additional clinical and *in vivo* investigations are necessary to clarify the effects of agave syrup on human health and relate these effects to the levels of fructose, fructans, and other bioactive components in the agave syrup. More research must be done to clarify the biological attributes of agave syrup against those of the commercially available conventional sweeteners [57].

Conclusion

This study explored the possibility of replacing sugar in traditional Indian sweet treats with agave syrup. It featured such popular Indian desserts as *rawa sheera* and *seviyan kheer*. The sensory evaluation of these reformulated desserts involved a nine-point hedonic scale and a paired comparison test given to panels of experts and semi-experts. Both panels responded extremely well to the *seviyan kheer* with agave syrup. The reaction to the modified rawa sheera, while apparent, revealed a more subdued approval and less intense fervor than for *seviyan kheer*. The consumer acceptability analysis rendered *rawa sheera* and *seviyan kheer* equally acceptable.

Agave syrup proved to be an effective sucrose replacement for some traditional Indian desserts. However, the inherent limitation of the research was that it focused on these two desserts as a small portion of the wide range of traditional Indian sweets. Future studies are needed to cover a wide variety of Indian desserts, each distinguished by its unique combination of ingredients and complex cooking techniques, in order to evaluate the versatility and acceptability of agave syrup for other applications.

A thorough assessment is essential to go beyond sensory analysis. It has to take into account such practical aspects as economic viability of agave syrup and a comprehensive analysis of its nutritional makeup. Future studies should focus on these complex aspects in order to understand the viability, difficulties, and possible outcomes of including agave syrup as a substitute sweetener throughout the diverse range of customary Indian desserts.

Contribution

All authors have contributed equally to the study and are equally responsible for the information published in this article.

Conflict of interest

The authors declared no conflict of interests regarding the publication of this article.

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