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Dietetic Sweet *Boondi*: A Sugar-Free Innovation with Stevia and Polyols

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study successfully developed a dietetic version of sweet *Boondi* by replacing traditional sugar syrup with a balanced blend of natural sweeteners, including stevia and polyols like mannitol, maltitol, sorbitol, and fructooligosaccharides (FOS). Through a detailed market survey and sensory analysis of the market sweet *Boondi* samples, the *Boondi* making process was adopted and on that basis of that process dietetic sweet *Boondi* was made, in which the syrup made with the proportion consisting of mannitol (22 g), maltitol (16 g), sorbitol (22 g), FOS (15 g), and stevia (0.082 g) per

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100 g of syrup, emerged as the most favorable formulation. This combination achieved high scores across all sensory attributes scores with colour and appearance score (7.59 ± 0.09), body and texture score (7.41 ± 0.09), flavour and taste score (7.47 ± 0.10) and overall acceptability score (7.53 ± 0.10). The findings underscore the importance of balancing polyol ratios to optimize sensory qualities, addressing consumer demand for healthier sweet without compromising on sensory attributes. This research provides a promising framework for developing dietetic versions of other traditional Indian sweets, paving the way for healthier options in the market.

Keywords: Market survey; sugar substitutes; polyols; stevia; Mannitol; maltitol; fructooligosaccharides (FOS); sorbitol.

1. INTRODUCTION

India's rich cultural heritage has always embraced sweets as a significant element of celebrations and rituals. Traditional sweets like *Boondi* Ladoo are integral to various festive and religious occasions. These sweets symbolize auspiciousness and add sweetness to special moments in Indian culture [1]. *Boondi* is made by dripping a chickpea flour batter through a perforated ladle and then deep-frying the droplets [2], which are then sweetened with sugar syrup and shaped into round balls [1]. *Boondi*, a beloved sweet from Rajasthan, India, holds a special place in Hindu culture. This treat is especially popular during festivals like Diwali and Rakshabandhan and is often offered as prasad in prayer rituals.

Stevia (*Stevia rebaudiana Bertoni*), plant of the Asteraceae family and native to Paraguay, is known for its high-potency sweetness and zero-calorie content due to the presence of steviol glycosides in its leaves. This makes it an ideal sugar substitute for health conscious individuals. Its popularity as a natural sweetener has grown worldwide, with Japan as a leading consumer and China accounting for 75% of global production [3,4]. Stevia is also commercially farmed in countries like Brazil, Paraguay, Central America, Thailand, and Korea, and presents economic opportunities for Kenyan farmers as demand increases [5]. The genus Stevia comprises approximately 230 species, predominantly found in South America and Mexico [6].

Steviol glycosides, such as stevioside and rebaudioside A, are around 100-500 times sweeter than sugar and are deemed safe with a daily intake of 0-4 mg/kg body weight by the Joint FAO/WHO Expert Committee on Food Additives [7]. In addition to its sweetness and low-calorie content, stevia offers nutritional benefits like antioxidants amino acids and antimicrobials, making it a popular ingredient in food products like soft drinks and baked goods [8].

Polyols, or sugar alcohols, such as mannitol, maltitol, sorbitol, and fructooligosaccharides (FOS), are low-calorie sweeteners that mimic the functionality of sucrose. These compounds are created by modifying sugars, replacing the aldehyde or ketone group with a hydroxyl group [9]. Mannitol, a low-calorie sweetener produced by fermenting glucose with yeast, offers 50-70% of the sweetness of sucrose having only 2.4 kcal/g of energy and is known for its non-glycemic and antioxidant properties [10]. Maltitol, derived from maltose, closely mimics sucrose in sweetness (75-90%) and solubility, making it ideal for sugar-free and reduced-calorie foods [11]. Sorbitol, found naturally in fruits, serves as a sweetener and humectant due to its cooling sensation and stability having 60% of sweetness relative to sugar with calorie of 2.6 kcal/g. FOS are non-cariogenic oligosaccharides that act as prebiotics having 2 kcal/g with around 50% of sweetness relative to sugar, promoting beneficial gut bacteria and offering health benefits such as reduced blood lipid levels and improved mineral absorption [12]. These polyols are essential in creating sugar-free products like candies and baked goods while supporting oral health and catering to individuals with diabetes.

Chickpea (*Cicer arietinum* L.), also known as Bengal gram or chana, is an annual plant from the Fabaceae family is predominantly cultivated in temperate and semiarid regions worldwide [13]. The global chickpea production reached 158.71 lakh tonnes in 2022, with India as the largest producer, contributing 137.50 lakh tonnes, or 86% of the world's total production for the 2021-22 periods [14]. Chickpea known for their high protein, carbohydrate, fiber, vitamin, and mineral content, chickpeas are utilized in diverse culinary applications, from Indian "dhal" and "besan" flour to stews, soups, and salad in Asia and Africa. Chickpea-derived dietary peptides, produced through methods like acid, alkali, and enzymatic hydrolysis (with enzymatic hydrolysis being the safest), are gaining attention for their bioactive properties. These include angiotensin 1-converting enzyme inhibition, cholesterol lowering, antioxidant effects, and potential benefits in managing digestive issues, cardiovascular diseases, type 2 diabetes, inflammation, infections, and cancer [15,16].

Several studies have explored the preparation and optimization of traditional Indian sweets using alternative ingredients and techniques to improve sensory and nutritional attributes. Ravi and Susheelamma [17] found that *Boondi* made from chickpea flour batter with 40-42% solid concentration produced the best results in terms of aroma and texture. Yargatti and Muley [18] revealed that using stevia in motichoor ladoo and gulabjamun resulted in better sensory acceptance compared to agave syrup sweetener, though agave was preferred for jalebi. Ahmad and David [19] prepared rasgulla using chhana, citric acid, and aspartame syrup as a sugar substitute. They tested control samples soaked in 40% sugar syrup and others in aspartame syrups at 0.005%, 0.006%, and 0.007%. Chemical composition, microbial analysis, and organoleptic attributes were evaluated. The rasgulla soaked in 0.005% aspartame syrup was the best, though it cost ₹231.60/kg, ₹34 more than the control.

Geetha et al. [20] identified optimal conditions for making chhana jalebi with desirable sensory properties using a 3% milk fat, 1:1 chhana to maida ratio, and specific frying parameters. Kushwaha et al. [21] optimized a syrup formulation using stevia, sucralose, and maltitol for gulab jamun, achieving high acceptability with specific ratios. Chavan et al. [22] developed a dietetic rosogolla using 2% milk fat and a sorbitol solution with aspartame, which provided favorable sensory and texture attributes. Chetana [23] experimented with legume-based *Boondi* laddu, concluding that a sorbitol and mannitol blend closely matched traditional sugar syrup in quality, whereas maltodextrin and polydextrose combinations were less successful.

The increasing health concerns related to excessive sucrose consumption, such as obesity and diabetes, have driven interest in alternative sweeteners. High-intensity artificial sweeteners like acesulfame-K, aspartame, neotame, saccharin, and sucralose are commonly used as sugar substitutes, but they can have potential health risks, including unpleasant aftertastes or, in the case of saccharin, links to bladder cancer [24]. As a result, natural sweeteners have gained popularity, with stevia emerging as a leading alternative.

However, with the increasing prevalence of lifestyle diseases such as diabetes and obesity, there is a growing demand for healthier alternatives to traditional sweets. This study aims to develop a dietetic version of sweet *Boondi* by replacing sugar with natural sweeteners such as stevia and polyols like mannitol, maltitol, and sorbitol, along with FOS. The objective is to cater to health-conscious individuals, especially diabetics, without compromising on the traditional taste and texture of *Boondi*. The process involves optimizing the syrup preparation and the *Boondi*-making process to achieve the desired quality and shelf life of the dietetic sweet *Boondi*.

The main objectives of this study include market survey for the sweet *Boondi* making process, selecting and standardizing syrup preparation using sugar substitutes, formulating dietetic sweet *Boondi*, and conducting sensory analysis of the prepared product. By developing a dietetic sweet *Boondi*, this study aims to provide a healthier option for sweet lovers, particularly those who need to manage their sugar intake due to health concerns.

2. MATERIALS AND METHODS

2.1 Materials

Bengal gram flour was sourced from the local market in Anand, Gujarat, India. Amul pure ghee was used as the fat component. Stevia (rebaudioside A - 97% pure) was obtained from Herboveda India Pvt. Ltd. mannitol, maltitol and sorbitol were procured from Mirtillo International, Mumbai, while FOS were procured from Gujarat Enterprise, Ahmedabad. Stevia and polyols were chosen for their sweetness profiles, glycemic index, cooling effect and low-calorie content (Table 1).

2.2 Market Survey of *Boondi* Making Process

A market survey was conducted in Anand city to study the *Boondi*-making processes used by seven different shops. The survey included observations and interviews using pre-designed questionnaires to collect information on traditional methods, raw materials, equipment, and preparation techniques. Key parameters such as flour type, flour:water ratio, frying time and temperature, and syrup °brix were recorded with the aim of standardizing the process. Sweet *Boondi* samples were then obtained from the surveyed manufacturers for sensory analysis to determine the optimal *Boondi*-making process. A semi-trained panel used a nine-point hedonic scale to evaluate the color and appearance, body and texture, flavor and taste, and overall acceptability scores of market sweet *Boondi*.

2.3 Dietetic Sweet *Boondi* Preparation

The process for making *Boondi* was finalized through sensory analysis of commercially available sweet *Boondi*. This process was then adapted to create a dietetic version by substituting the sugar syrup with syrup made from selected polyols and stevia. Various proportions were tested to create sugar-free syrup, with the FOS level fixed at 15% in all syrups. Based on preliminary trials and sensory analysis of sweet *Boondi* made with syrup at 75 °brix, different ratios of the three polyols were tested, as shown in Table 2. Stevia was added as an intense to adjust the sweetness level of the syrup after the addition of polyols, which have different sweetness levels relative to sugar.

3. RESULTS AND DISCUSSION

3.1 Survey and Standardization of *Boondi* Making Process

A market survey conducted at seven *Boondi* manufacturing shops in Anand city, Gujarat, documented various *Boondi* making process parameters which are presented in Tables 3, 4, 5, 6, and 7. Shops surveyed included Rajbhog Sweets, Khwaja Nasta House, Famous Jalebi House, Milan Sweets & Namkeen, Jay Jalaram Farsan & Namkeen, Adarsh Farsan House, and Dwarkesh. *Boondi* samples, labeled with MSB_1 to MSB_7, were collected for sensory analysis.

A semi-trained panel used a nine-point hedonic scale to evaluate color and appearance, body and texture, flavor and taste, and overall acceptability. Each sample was assessed for sensory analysis in three replications as shown in the Table 8. This structured sensory evaluation aimed to standardize the *Boondi* making process by identifying the most acceptable practices based on panelist ratings from "dislike extremely" to "like extremely."

Table 1. Properties of different polyols

Sweeteners	Calorie content (kcal/g)	GI	Sweetness (% relative to sucrose)	Cooling effect (kcal/g)
Stevia [25]	0	0	470	-
Mannitol [25]	2.4	0	50	-19
Maltitol [25]	2.4	35	90	-18.9
Sorbitol [25]	2.4	4	60	-26
FOS [26,27]	1.5	low	50	-

GI=Glycemic Index; FOS=Fructooligosaccharides

Table 2. Experimental design for syrup making using stevia and polyols

Treatments	Mannitol (g)	Maltitol (g)	Sorbitol (g)	FOS (g)	Stevia (g)
1	60	0	0	15	0.100
2	0	60	0	15	0.038
3	0	0	60	15	0.089
4	30	30	0	15	0.072
5	30	0	30	15	0.098
6	0	30	30	15	0.064
7	20	20	20	15	0.078
8	15	20	25	15	0.077
9	18	18	24	15	0.079
10	22	16	22	15	0.082
11	25	10	25	15	0.088
12	20	5	35	15	0.091
13	10	25	25	15	0.071

Values are per 100 g of syrup, for 75 °Bx of syrup

Table 3. List of ingredients used for *Boondi* making by different manufactures

Ingredients / Samples	Besan	Sooji	Water	Sugar	Oil	Food colour
MSB_1	✓		✓	✓	✓	
MSB_2	✓	✓	✓	✓	✓	✓
MSB_3	✓	✓	✓	✓	✓	
MSB_4	✓		✓	✓	✓	
MSB_5	✓		✓	✓	✓	✓
MSB_6	✓		✓	✓	✓	✓
MSB_7	✓		✓	✓	✓	✓

Table 4. Parameters used for batter preparation for *Boondi* making

Samples / Parameters	MSB_1	MSB_2	MSB_3	MSB_4	MSB_5	MSB_6	MSB_7
Ratio (Flour: Water)	3:3:8*	4:2:3.5#	5:2.5:7#	5:6	1:1	1:1	1:1
Bulk density of batter (Kg/ m^3)	937.50	914.30	936.17	955.00	961.50	962.00	962.00
Fermentation time	0	0	0	0	0	0	0

Note:=ratio of coarse besan: fine besan: water, #=ratio of besan: sooji: water*

Table 5. Parameters used for frying operation during *Boondi* making

Samples / Parameters	MSB_1	MSB_2	MSB_3	MSB_4	MSB_5	MSB_6	MSB_7
Skimmers opening diameter (mm)	6	5	5-6	5-6	4-5	4-5	5-6
Frying temperature (°C)	185-195	182-194	190-193	190-200	185-195	195-200	200-210
Frying time (sec)	90-110	90-100	95-103	90-100	112-120	90-100	30-60
Holding time (sec)	10	10	5-10	10	10	10	8-10
Diameter of fried *Boondi* (mm)	7	6-7	6-8	6-8	6-7	6-7	6-8

Table 6. Parameters used for Syrup preparation for *Boondi* making

Parameters \ Samples	MSB 1	MSB 2	MSB 3	MSB 4	MSB 5	MSB 6	MSB 7
Ratio (Sugar : Water)	5:4	5:5	5:2.5	5:3	5:3	3:2	3:2
Cooking temperature for syrup (°C)	105-110	104	100-105	108-112	100-110	105-110	110-112
°Brix of sugar syrup	73	72.9-74.1	75	73-75	70-75	75-80	73-78
Soaking time (sec) in syrup	120-300	170-210	70-110	90-110	150-170	120-180	90-150

Table 7. Packaging material used and selling price for the market sweet *Boondi*

Packing material used for packing	PP	PP	PP	PP	PP	PP	PP
Selling price (Rs./kg) of *Boondi*	200	160	140	200	200	160	200

PP = poly propylene

Table 8. Sensory attributes scores of the market sweet *Boondi* (MSB) Samples

Sample code	Colour & Appearance	Body & Texture	Flavour & Taste	Overall acceptability
MSB_1	7.56 ± 0.31	7.29 ± 0.37	7.24 ± 0.29	7.51 ± 0.33
MSB_2	6.23 ± 0.12	6.56 ± 0.16	6.54 ± 0.11	6.43 ± 0.08
MSB_3	6.59 ± 0.40	6.43 ± 0.36	6.30 ± 0.32	6.44 ± 0.35
MSB_4	7.37 ± 0.33	7.46 ± 0.17	7.52 ± 0.35	7.55 ± 0.35
MSB_5	6.70 ± 0.48	6.47 ± 0.34	6.54 ± 0.36	6.56 ± 0.40
MSB_6	6.66 ± 0.40	6.80 ± 0.28	6.62 ± 0.32	6.71 ± 0.26
MSB_7	7.18 ± 0.10	6.92 ± 0.30	7.08 ± 0.11	7.08 ± 0.13
Sem±	0.24	0.21	0.20	0.21
CD (0.05)	0.71	0.63	0.61	0.63
CV%	5.90	5.26	5.09	5.21

Results: Each observation is mean ± SD of three replicates (n=3), CD = Critical difference; CV% = coefficient of variance; SEm = Standard error of mean

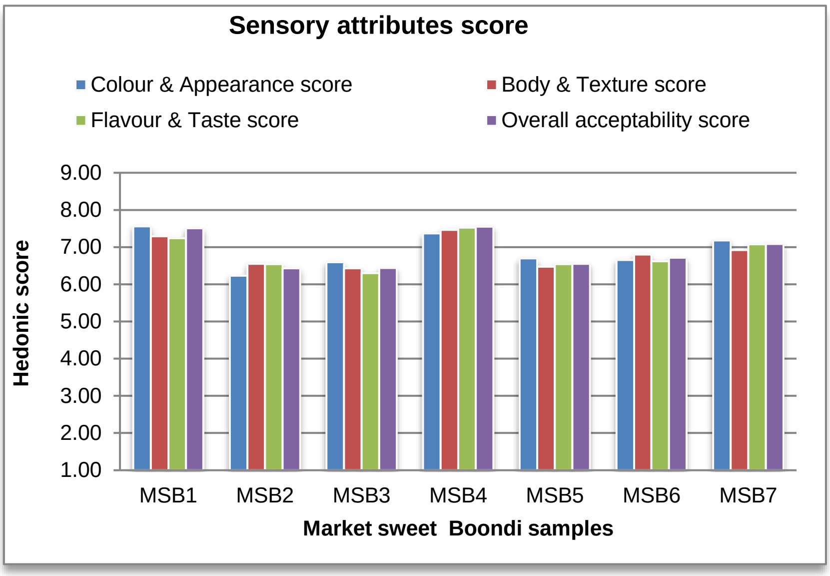

Fig. 1. Variation in sensory attributes score of MSB samples

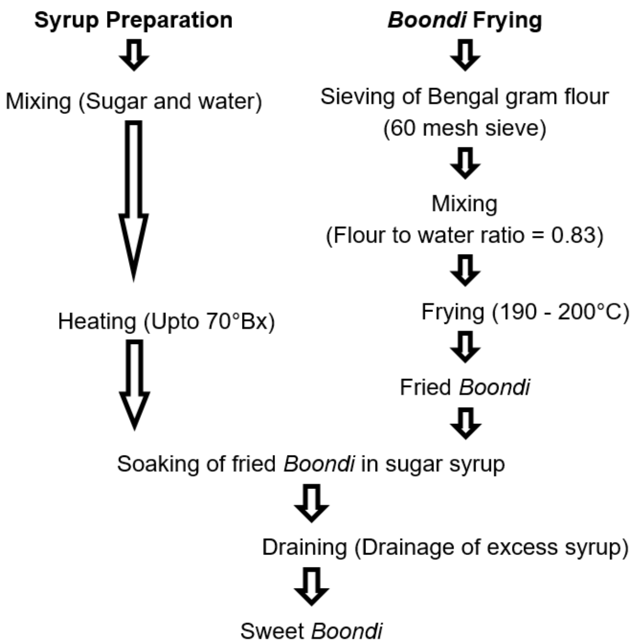

Fig. 2. Process flowchart derived from the survey for sweet *Boondi* manufacturing

Based on the data presented in Table 8 and illustrated in Fig. 1, it can be observed that shop 1 (msb_1) received the highest scores for color and appearance (7.56 ± 0.31), ranked second for body and texture (7.29 ± 0.37), and overall acceptability (7.51 ± 0.33), indicating a superior quality product. Similarly, shop 4 (msb_4) demonstrated excellent performance across all evaluated attributes, particularly excelling in body and texture score (7.46 ± 0.17), flavor and taste score (7.52 ± 0.35), and overall acceptability score (7.55 ± 0.35). The process flowchart adopted from the survey for manufacturing of sweet *boondi* is depicted in Fig. 2.

3.2 Syrup Preparation using Sugar Substitutes for Dietetic Sweet *Boondi*

The sensory evaluation of dietetic sweet *Boondi* showed significant variations in color and appearance as shown in the Fig. 3 due to the type and concentration of polyols used. Treatments with mannitol, received lower scores for color and appearance. For instance, treatment no. 1, which used 60 g of mannitol, had a score of 5.70 ± 0.17. In contrast, treatment no. 10, which featured a balanced combination of mannitol (22 g), maltitol (16 g), and sorbitol (22 g), scored the highest with 7.59 ± 0.09. This combination provided better moisture retention and stability, resulting in a more visually appealing product. These findings indicate that a balanced mix of polyols enhances the appearance of sweet *Boondi*, while a high concentration of a single polyol can negatively affect its color.

The body and texture of the sweet *Boondi* were also significantly affected by the different concentrations of polyols used as shown in the Fig. 4. Treatment no. 1, which contained a high level of mannitol (60 g), scored the lowest (6.00g ± 0.17). In contrast, treatments with balanced polyol ratios, such as treatment no. 10 (mannitol (22 g), maltitol (16 g), sorbitol (22 g)), scored the highest for body and texture (7.41 ± 0.09). The combination of maltitol and sorbitol contributed positively to the *Boondi*'s body and texture, resulting in a smooth and cohesive mouthfeel. These results highlight the importance of a balanced mix of polyols in achieving a desirable texture in sweet *Boondi*.

Flavor and taste were also influenced by the polyol composition as shown in the Fig. 5. Treatment no. 1, with high mannitol content, received the lowest scores (5.55 ± 0.10). Conversely, treatment no. 10, with a balanced mix of polyols, achieved the highest score for flavor and taste (7.47 ± 0.10). The harmonious blend of mannitol, maltitol, and sorbitol provided a more rounded flavor profile, avoiding the dominance of any single polyol's distinct characteristics. This demonstrates the importance of a balanced polyol mix in achieving a pleasant flavor and taste in sweet *Boondi*.

The overall acceptability scores reflected the trends observed in individual sensory attributes, Fig. 6 highlighting the impact of polyol composition on the overall product quality. Treatment no. 10, with a balanced mix of mannitol, maltitol, sorbitol, FOS, and stevia, achieved the highest overall acceptability score (7.53 ± 0.10). This formulation resulted in a product with a pleasing appearance, smooth texture, and balanced sweetness, leading to higher consumer satisfaction. In contrast, treatments with high concentrations of a single polyol, such as treatment no. 1 and treatment no. 2, scored lower in overall acceptability. These findings underscore the importance of optimizing polyol ratios to achieve a desirable sensory profile in sweet *Boondi*, with treatment no. 10 standing out as the most promising formulation.

Table 9. Sensory attributes scores of the dietetic sweet *Boondi* (DSB) Samples

Treatments No.	**Colour & Appearance**	**Body & Texture**	**Flavour & Taste**	**Overall acceptability**
1	$5.70^{f} \pm 0.17$	$6.00^{g} \pm 0.17$	$5.55^{g} \pm 0.10$	$5.72^{h} \pm 0.12$
2	$6.65^{e} \pm 0.13$	$6.40^{f} \pm 0.13$	$6.45^{f} \pm 0.11$	$6.45^{g} \pm 0.10$
3	$6.75^{de} \pm 0.14$	$6.80^{e} \pm 0.14$	$6.50^{f} \pm 0.11$	$6.65^{fg} \pm 0.12$
4	$6.85^{d} \pm 0.11$	$6.85^{de} \pm 0.11$	$6.80^{e} \pm 0.14$	$6.83^{ef} \pm 0.09$
5	$7.15^{bc} \pm 0.16$	$7.18^{abc} \pm 0.16$	$6.80^{e} \pm 0.09$	$7.10^{cd} \pm 0.10$
6	$6.75^{de} \pm 0.11$	$6.50^{f} \pm 0.11$	$6.50^{f} \pm 0.06$	$6.63^{fg} \pm 0.11$
7	$7.24^{b} \pm 0.12$	$7.40^{ab} \pm 0.12$	$7.38^{ab} \pm 0.16$	$7.39^{ab} \pm 0.18$
8	$7.31^{b} \pm 0.10$	$7.21^{abc} \pm 0.10$	$7.18^{bc} \pm 0.19$	$7.19^{bcd} \pm 0.15$
9	$7.32^{b} \pm 0.08$	$7.16^{abc} \pm 0.08$	$7.20^{bc} \pm 0.15$	$7.25^{bc} \pm 0.20$
10	$7.59^{a} \pm 0.09$	$7.41^{a} \pm 0.09$	$7.47^{a} \pm 0.10$	$7.53^{a} \pm 0.10$
11	$7.17^{bc} \pm 0.16$	$7.02^{cde} \pm 0.16$	$6.87^{de} \pm 0.11$	$6.80^{ef} \pm 0.11$
12	$7.17^{bc} \pm 0.08$	$7.09^{cd} \pm 0.08$	$7.04^{cd} \pm 0.10$	$7.00^{de} \pm 0.08$
13	$7.05^{c} \pm 0.16$	$7.15^{bc} \pm 0.16$	$6.75^{e} \pm 0.09$	$6.70^{f} \pm 0.09$
SEm±	0.056	0.074	0.070	0.072
CD (0.05)	0.162	0.214	0.204	0.208
CV%	1.39	1.84	1.78	1.81

Results: Mean ± SD, (n=3) superscripts (a, b, c, d, e and f) indicates critical difference between the means (P<0.05)

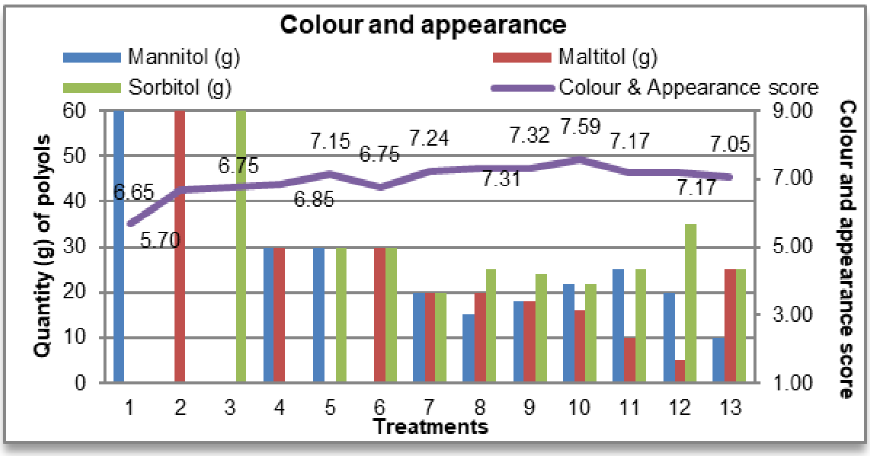

Fig. 3. Effect of different levels of polyols on colour and appearance score of DSB

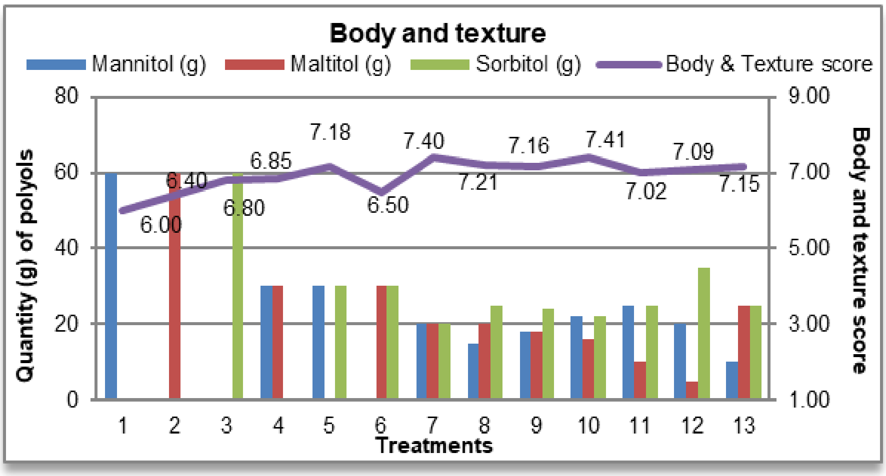

Fig. 4. Effect of different levels of polyols on body and texture score of DSB

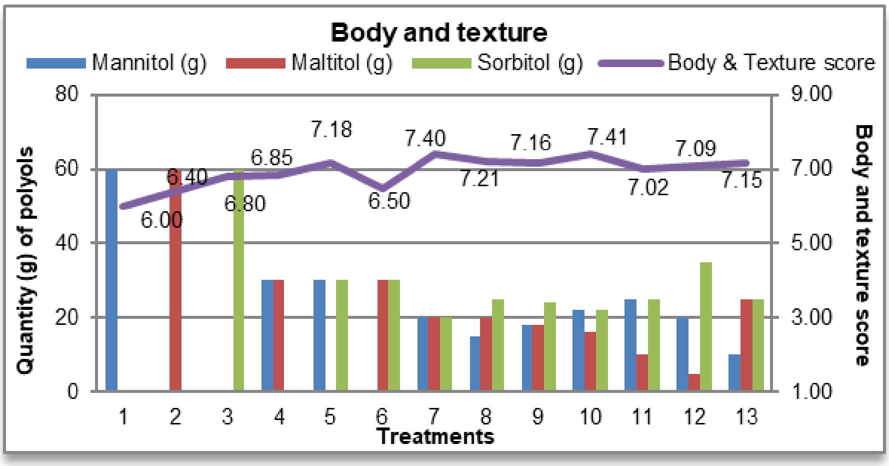

Fig. 5. Effect of different levels of polyols on flavour and taste score of DSB

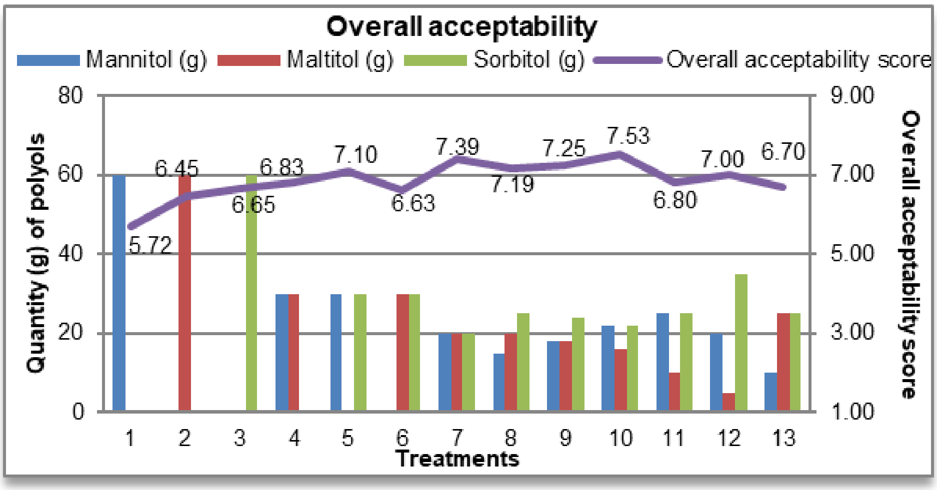

Fig. 6. Effect of different levels of polyols on overall acceptability score of DSB

4. CONCLUSION

Development of dietetic version of sweet *Boondi* includes replacement of traditional sugar syrup with a blend of stevia and polyols such as mannitol, maltitol, sorbitol, and fructooligosaccharides (FOS). The optimized formulation containing mannitol (22 g), maltitol (16 g), sorbitol (22 g), FOS (15 g), and stevia (0.082 g) per 100 g of syrup-achieved high sensory scores in color and appearance, body and texture, flavor and taste, and overall acceptability. These findings highlight the importance of balancing polyol ratios to meet consumer demand for healthier sweets without compromising sensory qualities, offering a promising framework for developing dietetic versions of other traditional Indian sweets.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. ChatGPT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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