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Development of millet, cereals and ghee residue based chocolate as a functional food

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Abstract
Chocolates act as functional food, satieties hunger and claim to prevent health problems like hypertension & coronary heart disease. To optimize the level of basic ingredients, amaranth (Rajgiro), sorghum (Juwar) & oat were added in total eight different combinations whereas ghee residue and cocoa powder was ranging from 8-10% and 3-10%, respectively. The product with amaranth, sorghum & oat in equal proportion (10%) and ghee residue & cocoa powder @ 10% & 5%, respectively, received highest score for all sensory attributes. The nutritional profile of optimized product was characterized as 5.18 g protein, 61.89 g carbohydrates, 25.09 g fat, and 2.10 g dietary fiber with iron (2.30 mg), Potassium (90.14 mg), calcium (25.14 mg) and sodium (30.15 mg) per 100 g. Microbiological testing revealed a total plate count of 210 cfu/g, while coliforms, yeast, and moulds were not detected (<10 cfu/g) in the millet & cereal based chocolate, indicating satisfactory hygienic quality. This product can be served as a good source of energy that gives 494.09 Kcal/100 g.

Keywords: Amaranth; ghee residues; functional food; nutritional analysis; sorghum; chocolate

Introduction
There has been a great interest in creating new horizons for utilization of dairy and food industry by-products throughout the world. The global shift towards health-consciousness consumer behavior has triggered food industries for development of functional foods. In particular, value-added confectionary items with enhanced nutritional profiles and guilt free features have gained much popularity. Chocolate is a globally popular food product, consumed and appreciated by people of all age groups. The primary ingredients in chocolate include cocoa solids, cocoa butter, sugar and in the case of milk chocolate milk solids (Aarthy *et al*., 2024; Chaudhary *et al*., 2026) [1, 5]. Incorporation of chocolate with millets and cereals may not only satisfy cravings but also aligns with modern values of wellness, health, sustainability, and innovative food design.

Sorghum (*Sorghum bicolor)* is a staple grain in many countries; it is gluten free and excellent sources of protein, essential vitamins (particularly B complex vitamins), and minerals such as iron, magnesium, calcium, and zinc (Prathyusha *et al*., 2021; Twinkle and Singh, 2022) [11, 17]. Incorporating millets into diets can help bridge nutrient gaps and improve overall nutritional status and health benefits like hypoglycaemic & hypolipidemic effects, prevention of cancer, etc. By adopting suitable milling and processing methods, millets offer opportunities for the development of diversified food products such as confectionary products, bakery products, ready-to-eat snacks, quick cooking cereals, weaning foods, supplementary foods, and more importantly health/fitness foods (Amin *et al*., 2026)[2]. The vital nutrients present in millets include resistant starch, oligosaccharides, lipids, antioxidants such as phenolic acids, phytosterol, flavonoids and avenanthramides which are believed to be responsible for many health benefits (Shanthala *et al*., 2018) [15].

Amaranth also known as 'Ramdana' and 'Rajgira' which is classified as gluten free starchy cereal that contains greater amount protein, dietary fibers and minerals like calcium. The oats (Avena sativa) are rich in proteins, dietary fibers, beta glucans and minerals and claimed for many health beneficiary effects including reducing cholesterol levels (Joyce *et al*., 2019) [7]. Both amaranth and oat are widely employed to replace wheat flour to develop gluten free food products.

Incorporation of dairy by product- ghee residue in the product lies in its potential to supplement valuable nutrients, enhance cost efficiency and promote sustainability drive innovation. Different researchers have tried to incorporate ghee residues in different foodstuffs such as cake and muffin (Ranjan *et al*., 2020) [11], biscuit, cookies (Sojan *et al*., 2019) [16] and other khoa based desserts (Hirpara *et al*., 2020) [6].

The key aim of the current research was to develop an enhanced macro- and micronutrients supplemented chocolate from uncommon healthy grains compared to conventional chocolate in addition to offer a more wholesome confectionery option for health-conscious consumers. It mainly involved optimization of the sorghum, amaranth and oat flour ratio followed by optimizing level of ghee residues and cocoa powder in the formulation of functional chocolate through sensory analysis followed by nutritional profiling and microbiological safety analysis.

Materials and Methods

Procurement of Raw materials

The raw materials required for preparation of chocolate procured from local market of Mehsana, Gujarat were; Amaranth, sorghum, oat, cocoa powder, sugar, dry fruits, ghee and dark compound chocolate. The ghee residues were collected from Ghee Section of Mehsana District Co-operative Milk Producer's Union Limited (DudhSagar Dairy), Gujarat, India. All the analytical grade chemicals were purchased from Merck (Mumbai, India) whereas; all the microbiological media were purchased from Hi-Media (Mumbai, India).

Preparation of chocolate and compositional analysis of the optimized product

Utilization of amaranth, sorghum and oat in various proportions are shown in Table 1. The process of preparation of millet chocolate in detail is diagrammatically represented in Figure 1. Optimized product samples were submitted at Gujarat Testing Private laboratory, Ahmedabad, Gujarat, India for compositional analysis of various macro and micro nutrients such as protein, carbohydrate, fat, minerals (iron, sodium, calcium, and potassium), dietary fiber, etc.

Optimization of the amaranth, sorghum and oat level

Amaranth, sorghum and oat were incorporated in the range of 5-20 g each wherein the final amount was fixed at 30g. The most acceptable level as determined by sensory evaluation of the product was selected and further experiments were carried out with the optimized concentration of the flours.

Optimization of the ghee residue

Three different levels of ghee residue i.e. 8%, 10%, and 12% were taken into consideration. The most acceptable level of ghee residue as determined based on sensory evaluation of the product was selected to prepare the optimized product.

Optimization of cocoa powder

The concentration of cocoa powder used to formulate millet chocolate was 3%, 5% and 10%. The optimum level was assessed based on sensory evaluation of the product.

Sensory evaluation

All the samples were evaluated for sensory attributes such as color and appearance, body and texture, flavor, and overall acceptability on a nine-point hedonic scale (9 for liking extremely and 1 for disliking extremely) by the panel of discriminative and experienced expert judges. The products were marked randomly and served as individual unit during each trial.

Microbiological analysis

Microbial contamination can stem from various stages including processing, handling and packaging of any food product and hence microbiological testing was ensured for the safety of millet chocolate. For this, Standard Plate Count (SPC), coliform count and yeast & mould count were performed SPC was performed by plating serial dilutions of the sample on Standard plate count agar using the pour plate method, followed by incubation at 37 °C for 48 h. Similarly, coliforms were enumerated using Violet Red Bile Agar (VRBA) by pour plating appropriate dilutions and incubating at 37 °C for 24 h as well as yeast and mould counts were carried out by inoculating samples onto potato dextrose agar (PDA) and incubating them at 25 °C for 3-5 days (Shah *et al*., 2025) [14]. The results were expressed as colony-forming units per gram (cfu/g) of the sample.

Statistical analysis

All experiments were carried out in triplicate (n=3). The significance was tested at five percent level using ANOVA by GraphPad Prism (Version 8.4.2).

Results and Discussion

Millets, cereals and ghee residue- a dairy by product, are underutilized despite of great nutritional profile. The fantasy for chocolate among all group of people, lead to develop a healthy as well as functional product by combining chocolate with amaranth, sorghum, oat and ghee residue. This would definitely fulfill the aim of current research work by yielding innovative healthy product.

Compositional analysis of chocolate

The optimized product and its nutritional profile are presented in Figure 3 and Table 2, respectively. The values of nutritional parameters are in line with the analysis carried out by Patel *et al*., (2026) [10]. Fat and carbohydrates content in our product was found lower compared to other studies (Santhala *et al*., 2024; Patel *et al*., 2026) [15, 10]. On the other hand, products developed by Aarthy *et al*., (2024) [1]; Santhala *et al*., (2025) [15] and Patel *et al*., (2026) [10] showed higher content of dietary fiber/crude fiber compared to fiber content of 2.10 g per 100g in our product. It is noteworthy to mention that the difference is mainly attributed to the use of different types of millet in other studies.

Optimization of the level of amaranth, sorghum and oat

The flours of amaranth, sorghum and oat were mixed in different proportion to formulate chocolate. It is evident from Figure 2 and Table 3, the maximum score of all the sensory attributes *i.e.* flavor, body & texture, color & appearance as well as overall acceptability was achieved with three different flours in equal amount. In connection to this, Aarthy *et al*., (2024) [1] has noticed the optimized product was containing 20% each of pearl millet & finger mill*et al*ong with cocoa powder and honey @ 60 g, and 50

g, respectively in millet based chocolate spread. The score for flavor was ranging from 6.5 to 7.8. The flavor score differs significantly (p <0.05) amongst treatments T1, T3 & T4; T2 & T3; T3, T4, T5, T7 & T8 and T4, T6 & T7, respectively, whereas difference between other treatments was found non-significant. Treatment T3 obtained low score of 5.1. On the other hand, T4 had received highest score of 7.8 wherein, all three ingredients are found in equal proportion. This could be attributed to the balanced taste or flavor of millet and cereals. Taste or flavor is the key element of sensory attributes. In another study conducted by Bhavani *et al*. (2018) [4], chocolate prepared with 55% popped amaranth has gained highest aroma score of 7.3. In case of color & appearance, T4 differs significantly (p <0.05) with all other treatments except T5. The panel has marked maximum score of 7.8 for T4 and least score of 5.73 for T8. The results are in line with the findings of other related studies (Shanthala *et al*., 2015; Bhavani *et al*., 2018; Ranvare *et al*., 2022) [15, 4, 13]. The millet and cereals do not have a direct impact on color & appearance as they were mixed with ghee residue and cocoa powder. However, the mixture with higher oat content has produced dull appearance to panelist. Body & texture is one of the most affected sensorial parameter due to presence of cereals or millets (Bhavani *et al*., 2018) [4]. T4 differ significantly (p <0.05) with highest score of 7.7. The millet and cereals contribute equally in producing appealing body & texture of chocolate. The increased level of amaranth causes the problem of chewiness while increase in level of oat as well as sorghum increases coarseness that affects the binding of final product. Therefore, it can be witnessed from Figure. 2 that level above 10% had resulted in lower sensory score, irrespective of type of millet and cereals. The panel of judges has marked significantly (p <0.05) higher overall acceptability score (7.83) for treatment T4.

Chocolate with equal amount of millet and cereal has provided balanced of taste, crunch and flavor. Patel and co-worker (2025) [10] had developed chocolate by incorporating millet (Finger millet, foxtail millet and kodo millet) in total of 20%. They also have not used any of the millet above 10% level which is in accordance with the outcomes of our current investigation for optimization level. In a similar study, Twinkle and Singh, (2022) [17] reported lower sensory score for chocolate containing concentration of sorghum powder above 15%. Chocolate prepared using quinoa seeds flour and sesame seeds flour has received maximum score of 8.27 for overall acceptability (Chaudhary *et al*., 2025) [5]. This observation is found in close proximity to our study.

Optimization of ghee residue level

A dairy by-product, ghee residue is rich in fat, carbohydrate and protein (Lashkare *et al*., 2024) [9]. It has been utilized in preparation of various dairy and confectionary or bakery products as it provides smooth texture which is accepted by the consumers. However, to our knowledge, this is the first study to utilize ghee residue in formulation of functional chocolate. Ghee residues were added in a range of 8 to 12% and result is illustrated in Table 4. Chocolate prepared with 10% ghee residue gained significantly (p <0.05) higher score for all attributes compared to 12%. Despite of non-significant difference for color & appearance and overall acceptability, chocolate containing 8 and 10% ghee residue differs significantly (p <0.05) for flavor and body & texture score. Significant difference (p <0.05) for all sensory attributes between chocolate with 10 & 12% ghee residue indicates that panel of judges have perceived remarkable effect of ghee residue in the product. The cooked and caramelized flavor and taste of ghee residue could be responsible for least overall acceptability score (6.3) of the product containing 12% ghee residue. No remarkable difference observed between chocolate with 8 and 10% ghee residue helped to add ghee residue @ 10% in the final product to recoup better utilization of dairy by-product.

Optimization of cocoa powder level

Cocoa powder is the key element of the chocolate composition. It is a good source of polyphenolic compounds particularly flavonoids which imparts bitterness in chocolates (Katz *et al*., 2011) [8]. Hence, the rate of addition of cocoa is vital in the product. The effect of cocoa level on sensory parameters of chocolate is demonstrated in Table 4. Chocolate with 5% cocoa powder received highest score of 7.63, 7.66, 7.7 & 7.66 for flavor, body & texture, color & appearance and overall acceptability, respectively, followed by chocolate prepared with 10% and 3% cocoa powder. The low score for C1 could be because of the presence of millet, cereals and ghee residue in higher concentrations. Treatment C2 differs significantly (p <0.05) compared to C1 for all sensory attributes. Treatment C1 and C3 did not differ significantly only for body & texture score. Likewise, C2 and C3 also showed non-significant difference for body & texture score. The combination of ghee residue with higher concentration of cocoa powder gave bitter astringent flavor to chocolate whereas the lower concentration was not found sufficient to give a typical flavor/taste of chocolate. In a recent study, Aarthy and co-workers (2024) [1] prepared chocolate spread containing 50 g cocoa powder concentration while on the contrary, Santhala *et al*., (2025) [15] optimized dark chocolate composition which was containing 60 g of cocoa powder. In both the study, the concentration of cocoa powder was 10 to 12 times higher than the concentration of cocoa powder in current study. In other studies, research workers have used various concentration of dark chocolate in combination with millets (Ranvare *et al*., 2022; Patel *et al*., 2026) [13, 10].

Microbiological analysis

The microbiological assessment of the optimized formulation indicated satisfactory microbial quality. The total plate count (TPC) was 250 cfu/g, whereas coliforms and yeast/moulds were not detected (<10 cfu/g). These results exhibit that the product maintained acceptable hygiene standards during preparation and storage. The low microbial load can be primarily attributed to the low moisture content of the product, in combination with effective processing steps such as roasting and hygienic handling during production. Similar observations have been reported by Patel *et al*., (2026) [10] and Beckett *et al*., (2017) [3]. The inherently low water activity of chocolate, coupled with proper thermal processing, restricts microbial proliferation and extends shelf stability (Beckett *et al*., 2017) [3].

Conclusion

The optimized product was formulated making use of with amaranth, sorghum, oat, ghee residue (@ 10 g each) and cocoa powder (@ 5 g). The optimized product was liked the most by the panel of judges with an average overall

acceptability score of 7.6. To the best of our knowledge, for the first time, ghee residue has been incorporated in combination with millet and cereal to develop functional chocolate. The compositional analysis found the product nutritionally relevant to support the daily requirement of vital nutrients. The future scope lies with its commercialization aspect through the shelf life study of the product using different packaging material at various temperatures.

Weighing of all the ingredients
↓
Heating ghee in a pan over medium flame
↓
Once the ghee gets hot, addition of amaranth, oat & sorghum flour to the pan and mix it well
↓
Frequent stirring while roasting until the mixture turns golden brown and a nutty aroma starts (approx.10-12 minutes).
↓
Addition of cocoa powder and ghee residue with continuous roasting
↓
Addition of warm milk to the mixture in the pan and cooking until all the milk is absorbed by the flour (1-2 minutes)
↓
Addition of sugar with continuous stirring till ghee separates from the sides
↓
Addition of roasted powdered dry fruits to the mixture
↓
Making of small size balls from mixture & put it in a chocolate moulds
↓
Pouring of melted dark/white compound chocolate on the balls
↓
Freezing below 0-1 degree Celsius for 30 min
↓
Packaging & Storage

Fig 1: Flow diagram for preparation of chocolate

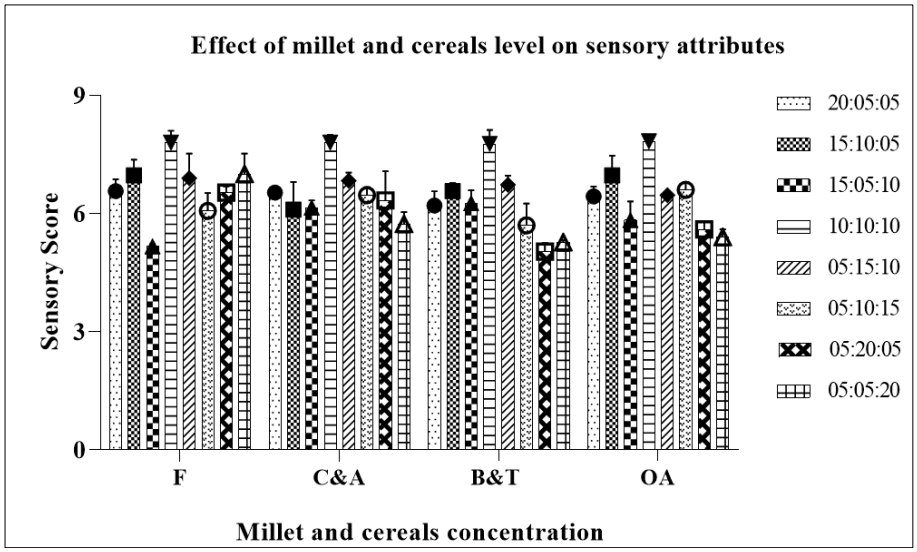

Fig 2: Effect of amaranth: sorghum: oat in various proportions on sensory score of chocolate.

n= 3 (each replicate is average score from 5 panelists).
F= Flavor, C&A= Color & Appearance, B&T= Body & Texture, OA= Overall Acceptability

Fig 3: Millet, cereal and ghee residue based functional chocolate

Table 1: Proportions of millet and cereal for preparation of chocolate

Sr. No.	Ratio of Amaranth: Sorghum: Oat	Treatment
1	20:05:05	T1
2	15:10:05	T2
3	15:05:10	T3
4	10:10:10	T4
5	05:15:10	T5
6	05:10:15	T6
7	05:20:05	T7
8	05:05:20	T8

Table 2: Nutritional composition of optimized chocolate per 100 g

Sr. No.	Particulars	Value
1.	Energy (Kcal/100 g)	494.09
2.	Total fat (g/100g)	25.09
3.	Protein (g/100g)	5.18
4.	Carbohydrate (g/100g)	61.89
5.	Sugar (g/100g)	35.10
6.	Added sugar (g/100g)	34.12
7.	Total Dietary fiber (g/100g)	2.10
8.	Saturated fat (g/100g)	23.02
9.	Iron (mg/100g)	2.30
10.	Sodium (mg/100g)	30.15
11.	Calcium (mg/100g)	25.14
12.	Potassium (mg/100g)	90.14

Table 3: Effect of amaranth: sorghum: oat in various proportions on sensory score of chocolate.

Sr. No.	Sensory attributes	Treatment (Amaranth: Sorghum: Oat)							
		20:05:05 (T1)	15:10:05 (T2)	15:05:10 (T3)	10:10:10 (T4)	05:15:10 (T5)	05:10:15 (T6)	05:20:05 (T7)	05:05:20 (T8)
		Sensory Score							
1	Flavor	6.56 ± 0.30^{a}	6.96 ± 0.40^{ad}	5.16 ± 0.05^{be}	7.8 ± 0.3^{cdf}	6.9 ± 0.62^{adgf}	6.06 ± 0.45^{adeh}	6.53 ± 0.15^{adei}	7 ± 0.51^{adef}
2	Color & Appearance	6.53 ± 0.05^{a}	6.1 ± 0.7^{a}	6.15 ± 0.18^{a}	7.8 ± 0.2^{b}	6.83 ± 0.20^{ab}	6.46 ± 0.20^{ac}	6.33 ± 0.73^{ad}	5.73 ± 0.30^{abcd}
3	Body & Texture	6.2 ± 0.36^{a}	6.56 ± 0.20^{ae}	6.26 ± 0.32^{aef}	7.76 ± 0.35^{bg}	6.73 ± 0.23^{aef}	5.7 ± 0.55^{aei}	5.03 ± 0.20^{cjl}	5.26 ± 0.05^{dkl}
4	Overall Acceptability	6.43 ± 0.25^{a}	6.96 ± 0.50^{ad}	5.83 ± 0.47^{ae}	7.83 ± 0.05^{bf}	6.46 ± 0.05^{adeg}	6.6 ± 0.2^{adeh}	5.6 ± 0.2^{ce}	5.4 ± 0.2^{ce}

Values are Means±SD for n=3 (Each replicate is average score from 5 panelists). Means with different small superscripts within raw differs significantly (p <0.05).

Table 4: Effect of various concentrations of ghee residue and cocoa powder on sensory score of chocolate.

Sr. No.	Particulars	Sensory Attributes	Treatment		
1	Ghee residue		8%	10%	12%
			Sensory Score		
		Flavor	6.76 ± 0.11^{a}	8.16 ± 0.20^{b}	6.1 ± 0.26^{c}
		Body & Texture	6.86 ± 0.11^{a}	8.16 ± 0.20^{b}	6.23 ± 0.05^{c}

		Color & Appearance	7.53±0.11[a]	8±0.2[a]	6.467±0.25[b]
		Overall Acceptability	7.66±0.15[a]	8.03±0.15[a]	6.36±0.15[b]
			Treatment		
2	**Cocoa powder**		3% (C1)	5% (C2)	10% (C3)
			Sensory Score		
		Flavor	5.7±0.26[a]	7.63±0.15[b]	7.03±0.15[c]
		Body & Texture	6.63±0.15[a]	7.66±0.15[b]	7.33±0.55[ab]
		Color & Appearance	5.66±0.12[a]	7.7±0.26[b]	6.63±0.11[c]
		Overall Acceptability	6±0.26[a]	7.66±0.11[b]	6.63±0.21[c]

Values are Means± SD for n=3 (Each replicate is average score from 5 panelists). Means with different small superscripts within raw differs significantly (p <0.05).

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