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Characterization of Popped Sorghum (*Sorghum bicolor*) Based Sports Drink Premix: Unlocking Nutritional Potential †

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Abstract: The nutritional analyses of a sports drink premix (SDP) made with sorghum flour, Bengal gram flour, seed mix, chicory root powder and a natural flavor mix, showed 66.7 g carbohydrates, 15.8 g protein, 7.43 g fat, and 14.21 g fiber per 100 g. Mineral analysis showed that the presence of electrolytes with potassium was the highest. The total phenolic content was 77.61 mg GAE/100 g, the total DPPH was 93%/100 g of sports drink premix, and the total flavonoid content was 88%/100 g of sports drink premix. The GC-MS analysis confirmed the presence of antioxidant, antibacterial, anti-inflammatory, and anti-tubercular compounds.

Keywords: popped sorghum; sports drink premix; nutrients; electrolytes; bioactive compounds

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1. Introduction

India is the largest producer of millets in the world, and sorghum production accounted for a 7.21% share in the world production of millets in 2022 [1]. In 2018, cereal grain production was 9.2 billion tons globally, due to rapid changes in demographics, economic development, and lifestyle [2]. Millets are nutritious foods loaded with energy, unsaturated fatty acids, iron, phosphorus, and alkaline phenolic phytochemicals, and can be used to combat malnutrition. They are also cheaper and affordable for everyone, regardless of the class they belong to in society [3]. Consumer demand for readily available healthy, exotic, and unique foods encourages the food industry to invest in new products and process development in functional foods and functional food ingredients [4].

Over the decades, the demand for instant beverage premixes has increased globally because of changes in lifestyle and dietary choices. These premixes have nutritional value and can be prepared with the addition of water or milk and in less time than other products [5]. Various types of sports drinks and premixes are becoming increasingly popular among athletes and those who are physically active because they contain water, electrolytes, and energy. Sports drinks are a class of beverages containing a suitable proportion of carbohydrates and electrolytes. The main motive behind the concept of sports drinks is to provide hydration and carbohydrates that can easily pass through the stomach to the small intestine for its rapid absorption. A sports drink can be used before exercise to top up glycogen levels in muscles, during exercise, and recovery, as it assists in rehydration [6]. The consumption of sports drinks has increased over time owing to increased awareness of the need for fluids and nutrients in athletes. Conventional sports drinks or premixes are characterized by high contents of added sugars (sucrose and dextrose), chemical additives, caffeine, and artificial flavors, which have raised concerns

about their potential negative effects on health and performance [7–9]. This has necessitated the development of more natural and enriched products, including millet-based SDP.

Food scientists are working relentlessly to create new generation multigrain foods and beverages, which can provide a good base for achieving the right nutritional standard and enhancing the acceptability factors. Proper formulation of mix combinations for a variety of grains, such as cereals, pseudo-cereals, legumes, and millets, can enhance appetizing, satisfactory, wholesome, and palatable products like grain-based beverages [10]. Research has particularly focused on drinks from cereals and legumes, which are known to have high contents of antioxidants, proteins, carbohydrates, vitamins, minerals, and other natural nutrition values [11–13]. Despite the fact that many researchers are studying millet-based multigrain products [5,11,12], only a few have investigated the appropriate formulation of SDP that would be beneficial in meeting the recommended dietary allowances (RDA) for moderately active women and men and according to the guidelines given by the International Olympic Committee (IOC) and Food Agriculture Organization (FAO) [13].

The major millet, *Sorghum bicolor* (L.) Moench (sorghum), is considered to be a nutrient-rich source of complex carbohydrates, protein, fiber, B vitamins, minerals, and antioxidants, which make it a perfect choice as a batter or base ingredient. Pre-processing, i.e., popping, involves heating the grains with salt until they expand in size. This process improves the bioavailability of minerals, creates a crispy texture, increases the shelf life of the grain, and finally reduces anti-nutrient factors such as phytic acid compared to raw sorghum (from 4.42 to 1.84) [3,14,15]. Popping tends to increase starch digestibility by decreasing resistant starches naturally present in sorghum grains. Sorghum protein is less digestible because of the presence of non-kafirin proteins, which glue together in the matrix. During popping, the cell wall is disrupted and kafirin is damaged, making the proteins soluble and easily digestible [16]. Additionally, *Cicer arietinum* L. (bengal gram) contains proteins, dietary fiber, and complex carbohydrates which qualify the pulse as a component to be added to sports drinks to provide energy and rehydration. Roasting, one heat treatment, promotes protein denaturation and hence improves the digestibility of grains [17]. The proper combination of carbohydrates derived from these ingredients can be useful for improving an active lifestyle, enhancing and maintaining performance, and facilitating recovery. The inclusion of seeds such as pumpkin seed powder and flax seeds also adds nutritional value to sports drinks, such as omega 3 fatty acids, which help boost the general health and performance of athletes [18].

The purpose of this study was to create a nutrient-dense SDP using popped sorghum, roasted Bengal gram, and other ingredients such as pumpkin seed powder, flax seed, chicory root powder, dehydrated carrot, beetroot, and banana powder. The main objective of including popped sorghum in SDP was to provide a source of easily digestible carbohydrates and plant-based proteins [16]. In this study, nutritional composition, antioxidant capacity, and bioactive compounds of the SDP were determined; these help in replenishing energy reserves, electrolytes, and nutrients in the body. By exploring the benefits of natural ingredients, this research will lead to the formulation of healthier and more effective sports drink alternatives for athletes and health-conscious consumers.

2. Materials and Methodology

2.1. Procurement of Raw Material

Sorghum variety CSV-23 was selected for this study because of its good popping yield and local availability. All ingredients, such as sorghum, Bengal gram, pumpkin seeds, flax seeds, chicory root powder, carrot, beetroot, and banana were procured from the local market.

2.2. Pre-Processing and Product Formulation

Popped Sorghum Flour: Sorghum grains were cleaned and popped using a traditional salt popping method at 240–250 °C. Popped grains were ground using a grain grinder

(Prestige Grain Grinder PGG01-180 Mixer Grinder) to form flour and sieved using a 3.5 mm strainer to obtain a uniform particle size.

Bengal Gram Flour: Bengal gram was continuously roasted at 180–200 °C and ground to form roasted Bengal gram flour, and sieved (3.5 mm strainer) [19].

Seed Mix Powder: Seeds (pumpkin seeds and flax seeds) were dry roasted at 70–80 °C and powdered to form seed mix, and sieved. Chicory root powder was added because of its prophylactic and phytobioactive properties [20].

Flavor Mix: Carrot, beetroot, and banana were cut into thin slices and dried using a tray dryer (Model No.MSW-216, MAC, New Delhi, India) for 72 h at 50–60 °C. Dried carrots, beetroots, and bananas were ground to obtain a fine powder. This powder is used as a flavor mix because it acts as a natural colorant and adds a flavor to the formulation.

A total of 46 trial samples were prepared using a specific amount of each powdered ingredient. All formulated samples were tested to obtain the optimized product. All prepared popped sorghum sport premix were stored in air-tight containers. Figure 1 shows the process of preparation of popped sorghum SDP.

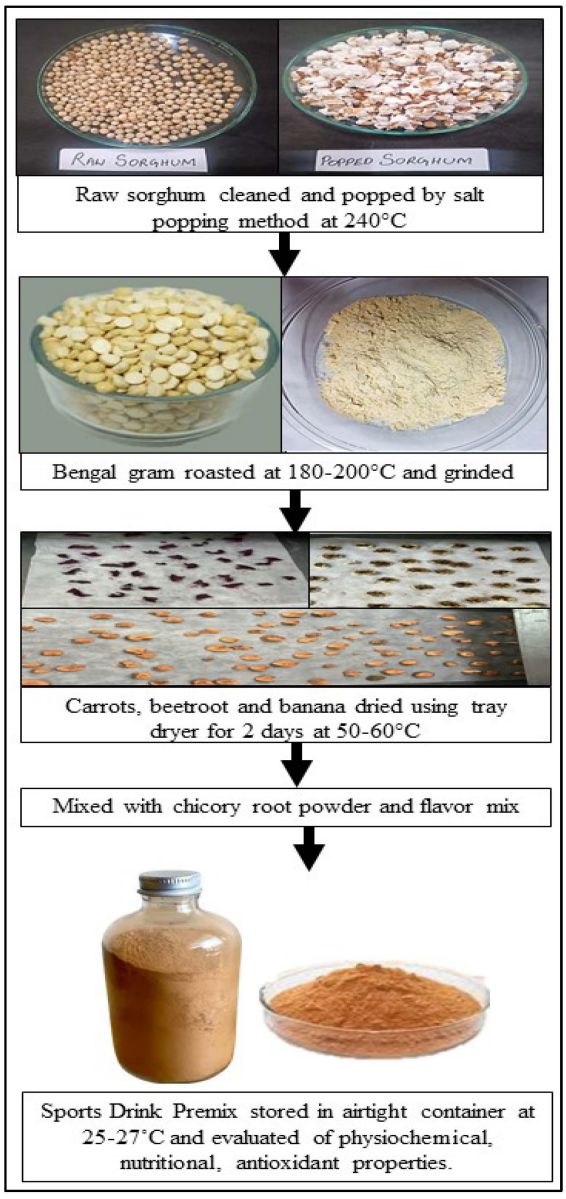


Figure 1. Method of SDP preparation.

2.3. Optimization of Sports Drink Premix (SDP)

For optimization of SDP, five independent variables viz., sorghum flour, Bengal gram flour, seed mix, chicory root powder, flavor mix and two dependent variables viz., carbohydrate and overall acceptability, were selected. According to the guidelines of the International Olympic Committee (IEC) and FAO, a sports drink premix should contain 6% carbohydrates per serving [13]. Overall acceptability is an important parameter for new product development; thus, these two parameters were selected as the dependent variables.

The Box–Behnken study design using Design Expert Software (version 13.0; StateEase 2023) was applied for the optimization. The total carbohydrate content of SDP was estimated using the anthrone reagent method [21]. Briefly, 0.1 g premix was mixed with 5 mL 2.5 N HCL. The mixture was heated for 3 h in water bath at 90 °C. The solution was left to cool, and sodium carbonate was added until effervescence stopped. The extract was filtered, and the volume was made up to 100 mL. Then, 0.5 mL of this extract was mixed with 4 mL anthrone solution (0.2% anthrone reagent was prepared with 95% conc. sulfuric acid) and absorbance was measured at 630 nm [21]. Overall acceptability was calculated using 9-point Hedonic rating scale.

2.4. Physicochemical Analysis

pH was measured using digital pH meter (Labman Scientific Instruments Pvt. Ltd., Chennai, India). A 5% solution of the SDP was prepared using distilled water and the pH was measured at 25 °C [22]. The color index of the formulated SDP was measured using a colorimeter (3nh portable spectrophotometer, Foshan, China) with a D65 illuminant and a standard observer angle of 10°. The sample brightness is represented by the symbol L*, where 100 represents flawless whiteness and 0 represents blackness. An increased L* value indicates a lighter or brighter sample. Moreover, the values a* and b* represent red–green and blue–yellow chromatically, respectively. Water activity (a_w) was measured using digital water activity meter (Rotronic 8303 Bassersdort with rortronic HW4 software). Titratable acidity was determined using the trimetric method using phenolphthalein indicator to change colorless solution to pink [23].

2.5. Nutritional Analysis of SDP

Macronutrients were estimated using AOAC methods [24]. Moisture was estimated by the hot-air oven drying method at 100 ± 1 °C for 10 h. The moisture percentage was calculated from the difference between the original and the final dried samples. A moisture-free sample was used for total ash estimation. Crude ash content was determined using a muffle furnace at 400–450 °C for 3 h. A moisture-free sample was used for fat estimation using Soxhlet extraction. The fat was extracted with 99 percent ethanol. Protein was estimated using the Kjeldahl method and the percentage protein was calculated by multiplying the percentage nitrogen by power factor. Crude fiber was estimated by acid and alkali wash method [25] and total energy was determined by summation method by following equation.

$$\text{Energy(kcal)} = 4 \times (\text{protein} + \text{carbohydrate})\text{g} + 9 \times (\text{fat})\text{g} \quad (1)$$

2.6. Micronutrient Analysis

2.6.1. Wet Digestion of SDP

A 1 g moisture-free SDP sample placed in a muffle furnace at 450 °C for 180 min to estimate the crude ash content. To the ash sample in the glass tubes, 3 mL nitric acid and 1 mL hydrochloric acid were added and heated on hot plate at 50–80 °C for 8–9 h until a colorless solution was obtained. The reagents were allowed to cool, and the volume of the contents of the tubes was adjusted to 50 mL with distilled water [26].

2.6.2. Estimation of Microminerals by Atomic Absorption Spectroscopy (AAS)

Quantitative analysis of the digested sample of SDP was performed for calcium, iron, zinc, magnesium, manganese, and phosphorous using Atomic Absorption spectroscopy (AAS-Perkin Elmer, Delhi, India). Lamps of electrodes were used for each mineral. Standard solutions of each mineral were prepared and passed through the equipment to calibrate the instrument. The dilution factors for phosphorus, magnesium, and for other minerals were 10,000, 2500, and 100 respectively. The concentrations were given as 'ppm' then converted to mg [26].

2.6.3. Estimation of Sodium and Potassium by Flame Photometry

The wet digested SDP sample solution was used for the estimation of sodium and potassium using Flame photometry (Electronic India Pvt. Ltd., Delhi, India). Working standards of 25, 50, and 100 ppm were employed for calibration. The concentrations of the elements were determined based on the degree of emission and subsequently qualified in terms of 'ppm' and then converted in terms of mg [26].

2.7. Antioxidant Potential of SDP

2.7.1. Total Phenolic Content

In a 100 mL volumetric flask, add distilled water 50:1 and 1 g of premix based at the diluted ratio of 1:5. Then, mix in 5 mL of commercially available Folin–Ciocalteu reagent and 20 mL of sodium carbonate solution (20% *w*/*v*). Distilled water was measured and added to the solution to reach capacity of 100 mL. The contents were then agitated for homogenization. After the reaction, the mixture was allowed to stabilize, and the absorbance was measured at 750 nm.

2.7.2. Diphenyl-1-Picrylhydrazyl (DPPH) Radical Scavenging Assay

A total of 0.0125 g of DPPH was mixed with methanol (5 mL). Aliquots (1 mL) were mixed with 100 mL of a methanol solution and covered with silver foil. For extraction, 0.3 g of sample was mixed with 100 mL of methanol, followed by maceration and centrifugation at 5000 RPM for 10 min. The sample was then filtered, and the supernatant was collected. The mixture was then incubated for 30 min at 25–30 °C in the dark. The absorbance was measured at 517 nm [27]. The extract concentrations yielding IC_{50} inhibition values were determined from the percentage of scavenging effect against extract concentration by plotting the graph using nonlinear regression. IC_{50} values were expressed in µg/g of sample extracts based on the potency of the sample extract.

2.7.3. Flavonoid Content

The flavonoid aluminum chloride colorimetric method was applied for flavonoid determination. The SDP extract was prepared (0.5 mL of 1:10 *w*/*v*), and methanol was added to 1.5 mL of methanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1 M potassium acetate and 2.8 mL and distilled water. Incubated at 25 °C for 30 min. The absorbance of the reaction mixture was determined at 415 nm using a double beam UV/Visible spectrophotometer (Perkin Elmer, Waltham, MA, USA) [27].

2.8. Gas Chromatography Mass Spectrometry (GC-MS)

An ethanolic extract of SDP was prepared using a Soxhlet apparatus. The solvent used for this process was 99.9% ethanol. The complete extraction process required 6 hrs at 60 °C. The 5 mg ethanolic extract was dissolved in 1 mL of ethanol (99%), followed by shaking in vertex until dissolved [28]. The GC system (8860, Agilent Technologies, Hyderabad, India) linked to a single quadrupole (stainless steel source) mass spectrometer and DB-5 capillary column (30 m × 0.25 mm ID, 0.25 µm film thickness) (J and W Scientific, New York, NY, USA) was used to identify bioactive compounds. The intake was maintained in venting mode, and helium was used as the carrier gas at a rate of 1 mL/min. The temperature was then maintained at 220 °C for five minutes. The relative percentage of the sample

constituents was computed using the peak area normalization method, and unknown compounds were identified using the NIST Library [28].

2.9. Statistical Analysis

All analytical methods were performed in triplicates. The overall analysis of all results is expressed in mean and standard deviation. To optimize the degree of significance of the model terms and model fitting, State-ease software was used to perform regression analysis and analysis of variance (ANOVA). The adequacy of the models was assessed using the lack-of-fit test, model, and R^2 (coefficient of determination) analysis. The measure of the degree of fit is the R^2, which is the ratio of the explained variance to total variation. The coefficient of variation (CV) displays the relative deviation of the experimental points from the model's forecast.

3. Results and Discussion

3.1. Pre-Processing and Formulation

The total popping yield of sorghum was found to be 88%, and the expansion ratio was 0.82 to 0.95. During popping of sorghum, the Maillard reaction takes place where amino proteins within the aleurone layer interact with sugars, imparting a nutty flavor to the popped product, and improving the overall digestibility of the product [29]. All ingredients were added and the sports drink premix was prepared using popped sorghum flour along with other ingredients mentioned in Table 1. The purpose of choosing popped sorghum flour was to add an adequate amount of carbohydrates and improve the flavor and overall digestibility.

Table 1. Ingredient of SDP.

Ingredients	Amount (g)
Popped sorghum flour	10–20
Roasted Bengal gram flour	30–40
Seed mix (pumpkin seeds, flax seeds)	8–12
Chicory root powder	8–12
Flavor mix (Beetroot, carrot and Banana powder)	25–35

3.2. Product Optimization

Response surface methodology was used to optimize the response variables viz., carbohydrate content and overall acceptability for the formulation of SDP. As shown in Table 2, a total of 46 formulations were prepared based on varying quantities of five factors: sorghum flour (Factor 1) ranged from 10 g to 20 g, roasted Bengal gram flour (Factor 2) ranged from 30 g to 40 g, seed mix (Factor 3) ranged from 8 g to 12 g, Chicory root powder (Factor 4) ranged from 8 g to 12 g, flavor mix (Factor 5) ranged from 25 g to 35 g. The impact of these factors on the response variables was studied through optimization. The central point was repeated six times at 2, 3, 21, 28, 33 and 36. Figure 2 illustrates the 3D graphical representation of response surface contours of the effect of independent variables (sorghum flour, Bengal gram roasted flour, seed mix, chicory seed powder and flavor mix) on dependent variables (carbohydrate and overall acceptability).

The goodness-of-fit statistics analysis of the dependent variables (carbohydrate and overall acceptability) are depicted in Table 3. For carbohydrate content, the statistics revealed a remarkably precise model with a standard deviation of 0.01, indicating consistent values around the mean of 66.77. The coefficient of determination (R^2), adjusted R^2 and predicted R^2 values were all 1, indicating a perfect fit of the model. Additionally, the low lack of fit value and significant *p*-value of 0.00 underscore the model's statistical significance and robustness. Similarly, the analysis of overall acceptability demonstrated a strong model, capturing 88.75% of the variability with an R^2 of 0.88. An adjusted R^2 of 0.79 suggests a good fit. This value was used to test the model fit. A lower value indicated a better fit. Here, the lack of fit was relatively low, suggesting that the model fits the data well.

Overall, the fit statistics table provides a detailed insight into the predictive capabilities and statistical significance of the models developed for the SDP, highlighting their effectiveness in understanding and optimizing the dependent variables.

Table 2. Trials for the optimization of SDP.

	Independent Variables					Dependent Variables	
Run	**Factor 1: Sorghum Flour (g)**	**Factor 2: Bengal Gram Flour (g)**	**Factor 3: Seed Mix (g)**	**Factor 4: Chicory Seed Powder (g)**	**Factor 5: Flavor Powder Mix (g)**	**Response 1: Total Carbohydrate (g)**	**Response 2: Overall Acceptability**
1	15	35	10	8	25	61.09	7
2	15	35	10	10	30	66.78	8.2
3	15	35	10	10	30	66.78	8.2
4	15	40	12	10	30	69.94	6
5	20	35	10	12	30	72.42	5
6	10	35	10	10	35	66.83	7.3
7	10	35	10	12	30	64.42	5.1
8	10	35	10	10	25	58.73	6.6
9	20	35	12	10	30	71.03	4.8
10	20	35	10	8	30	69.1	5.9
11	20	30	10	10	30	67.87	6.7
12	10	40	10	10	30	65.68	5.6
13	10	30	10	10	30	59.78	7.1
14	15	35	8	8	30	64.88	6.8
15	15	40	10	12	30	71.32	4.3
16	15	35	10	12	25	64.37	5.8
17	15	35	8	10	25	62.47	6.4
18	10	35	8	10	30	62.52	5.2
19	15	40	10	10	35	73.73	7.3
20	15	35	8	12	30	68.16	4.9
21	15	35	10	10	30	66.78	8.2
22	15	30	8	10	30	63.61	5.7
23	10	35	12	10	30	63.03	7.6
24	15	35	10	12	35	72.46	3.9
25	15	30	10	8	30	62.23	5.9
26	15	35	12	10	25	62.98	6.5
27	15	30	10	12	30	65.51	6
28	15	35	10	10	30	66.78	8.2
29	15	30	10	10	35	67.92	7.1
30	15	35	10	8	35	69.18	5.9
31	15	35	12	10	35	71.08	6.8
32	15	35	12	8	30	65.39	7.5
33	15	35	10	10	30	66.78	8.2
34	20	35	10	10	35	74.82	5.3
35	15	30	12	10	30	64.13	6.7
36	15	35	10	10	30	66.78	8.2
37	15	40	10	8	30	68.04	7.7
38	15	40	10	10	25	65.63	7.2
39	15	40	8	10	30	69.42	6.9
40	15	35	8	10	35	70.57	6.1
41	15	30	10	10	25	59.82	5.8
42	20	35	10	10	25	66.73	7
43	20	40	10	10	30	73.68	5.8
44	15	35	12	12	30	68.67	4.3
45	10	35	10	8	30	61.14	7.4
46	20	35	8	10	30	70.52	6.8

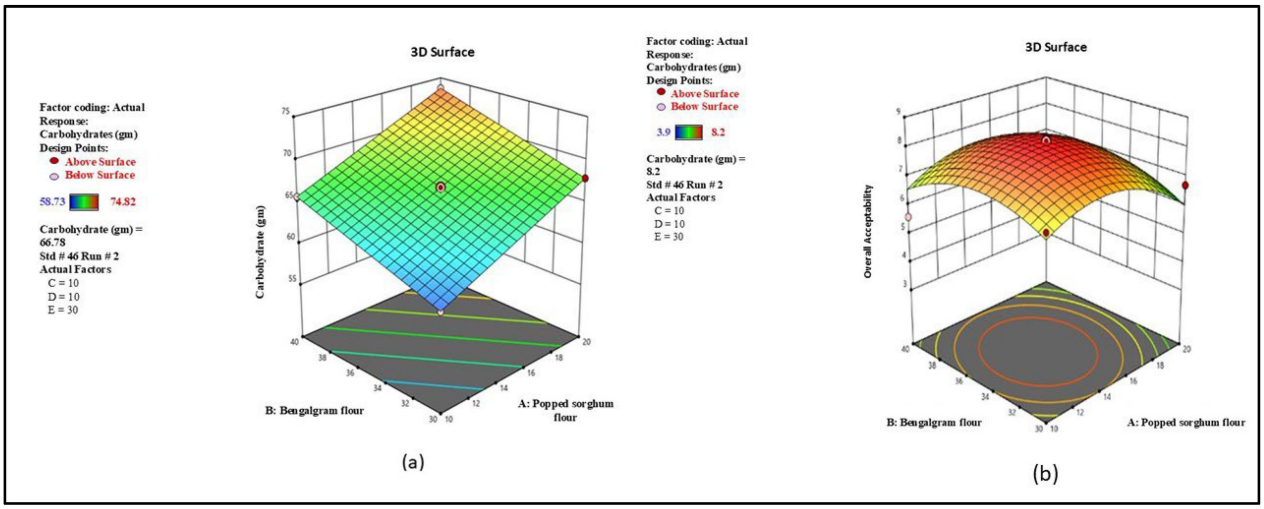


Figure 2. Response surface effects of dependent variables on (**a**) carbohydrates, (**b**) overall acceptability.

Table 3. Fit statistics of the dependent variables of SDP.

Model Parameter	Carbohydrate	Overall Acceptability
Std. Deviation	0.01	0.51
Mean	66.77	6.45
C.V.%	0.02	7.99
R^2	1.00	0.88
Adjusted R^2	1.00	0.79
Predicted R^2	1.00	0.54
Adequate Precision	2979.45	11.66
lack of fit	0.00	0.33
p value *	0.00	0.00

* $p < 0.01$ is highly significant.

3.3. Optimization of Dependent Variable

The best formulated SDP was produced after optimization to reach the levels of the independent variables. SDP made with 15 g (*w*/*w*) popped sorghum flour, 35 g (*w*/*w*) roasted Bengal gram flour, 10 g *w*/*w* seed mix, 10 g *w*/*w* chicory root powder, and 30 g *w*/*w* flavor mix showed the desired acceptability and carbohydrate content. An ideal mixture was prepared in triplicate to verify the accuracy of the generated model. Table 4 illustrates that the overall carbohydrate content per 100 g, which is 6% per serving aa per IOC and FAO [6], and the overall acceptability of optimized drink, which was high (8.2) among 46 trials.

Table 4. Predicted and experimental outcomes of response variables.

Response Variables	Experimental Values	Predicted Values
Carbohydrates (g)	66.70	66.80
Overall Acceptability (score)	8.20	7.05

3.4. Physicochemical Analysis

The titratable acidity was found to be 0.23 ± 0.04 g (Table 5) which measures the total acidity of the premix, influencing the taste and preservation of the product. The titratable acidity was in the range given in the literature 0.25 ± 0.04% [5]. The pH value of the SDP was 8.4 ± 0.1, indicating its slightly alkaline nature. The alkaline nature is a good attribute of SDP [5]. The color measurement revealed a light brown color with a low lightness value (l*), mild redness value (a*), and mild yellowness value (b*). Additionally, SDP showed

lower water activity (a_w), indicating that the product could be stored for a longer duration and improved stability [30].

Table 5. Physicochemical analysis of SDP.

Parameters	Results
Titratable Acidity (g)	0.23 ± 0.04
pH	8.40 ± 0.12
Color	
L*	26.99 ± 0.2
a*	1.04 ± 0.01
b*	1.17 ± 0.03
Water activity (a_w)	0.53 ± 0.01

3.5. Nutritional Analysis

As depicted in Table 6, the moisture content of the SDP was 2.74 ± 0.52% which is crucial for the product's shelf life, texture, and stability, with lower moisture content generally indicating a longer shelf life and reduced microbial growth risk. Ash content represents the total mineral content in the premix, with a total ash content of 3.36 ± 0. The SDP contains 66.7 ± 3.5 g of carbohydrates per 100 g, providing 14.95 g per serving which fulfils the 6.28% per serving of carbohydrates as per IOC guidelines [13]. Similar carbohydrate values were observed in various studies [5,31].

Table 6. Nutritional analysis of the SDP.

Variables	Values per 100 g	* %RDA Fufilled
Moisture (%)	2.74 ± 0.5	-
Ash (%)	3.36 ± 0.6	-
Carbohydrate (g/100 g)	66.70 ± 3.5	51.30
Calories (kcal/100 g) #	396.92 ± 1.1	18.82
Protein (g/100 g)	15.80 ± 1.2	29.25
Fat (g/100 g)	7.43 ± 0.67	24.76
Crude fiber (g/100 g)	14.21 ± 0.5	40.83
Calcium (mg/100 g)	61.23 ± 0.5	6.12
Iron (mg/100 g)	4.72 ± 0.4	24.84
Zinc (mg/100 g)	9.91 ± 0.6	58.29
Magnesium (mg/100 g)	201.80 ± 2.7	57.65
Manganese (mg/100 g)	2.47 ± 0.2	61.75
Phosphorous (mg/100 g)	283 ± 2.7	28.30
Potassium (mg/100 g)	534.94 ± 4.4	15.28
Sodium (mg/100 g)	97.90± 0.4	4.89

* %RDA fulfilled established by ICMR 2020, moderately active male. # %EAR fulfilled (Estimated Average Requirement) values established by ICMR 2020.

Table 6 also depicts the comparative analysis of variables per 100 g and per serving (23 g) with percentage RDA/100 g and percentage RDA per serving as per RDA 2020 given by ICMR-FSSAI [32,33]. The protein content is 15.8 ± 1.2 g per 100 g, classifying the SDP as high in protein (≥10.8 g as per FSSAI/SP/2021) [32]. A high protein content in the SDP will help in tissue repair and muscle recovery, making it beneficial for athletes and active individuals. Similar results were observed in studies providing higher protein content [6,34]. The total fat content is 7.43 ± 0.67 g, providing essential fatty acids and aiding in the absorption of fat-soluble vitamins. The fat content of the formulated SDP was attributed to the seed mix powder, which is a source of essential fatty acids. Flax and pumpkin seeds are rich in omega-3 fatty acids [35]. The mineral content included zinc (9.91 ± 0.6 mg), magnesium (201.8 ± 2.7 mg), manganese (2.47 ± 0.2 mg), and phosphorus (283 ± 2.7 mg), which each provide more than 30% of the RDA and hence the drink is

considered as high in minerals [32]. Iron (4.72 ± 0.4 mg, potassium (534.94 ± 4.4 mg) and sodium (97.9 ± 0.4 mg/100 g) provide more than 15% of the RDA [32]. These minerals found in SDP are essential for various bodily functions including enzyme activity, bone health, oxygen transport, and electrolyte balance [36].

3.6. Antioxidant Potential of SDP

The total antioxidant potentials are shown in Table 7 and Figure 3. The DPPH radical scavenging activity is 93% and the IC_{50} value 5.86 µg/g is low, indicating strong antioxidant activity, which is can be helpful for neutralizing free radicals and protecting the body from oxidative stress and related diseases [37]. The total phenolic content is 77.61 ± 1.5 mg GAE/100 g. Phenolic compounds are known for their antioxidant properties, and can help in reducing inflammation and preventing chronic diseases [38]. The total flavonoid content is 88%, which can play a significant role in protecting cells from oxidative damage, and which provide anti-inflammatory and cardioprotective effects [39].

Table 7. Antioxidant potential of SDP.

Parameters	Results
DPPH radical scavenging activity (%)	93.01 ± 2.3
IC_{50} (µg/g)	5.86 ± 0.06
Total phenolic content (mg GAE/100 g)	77.61 ± 1.5
Total flavonoid content (%)	88.00 ± 1.7

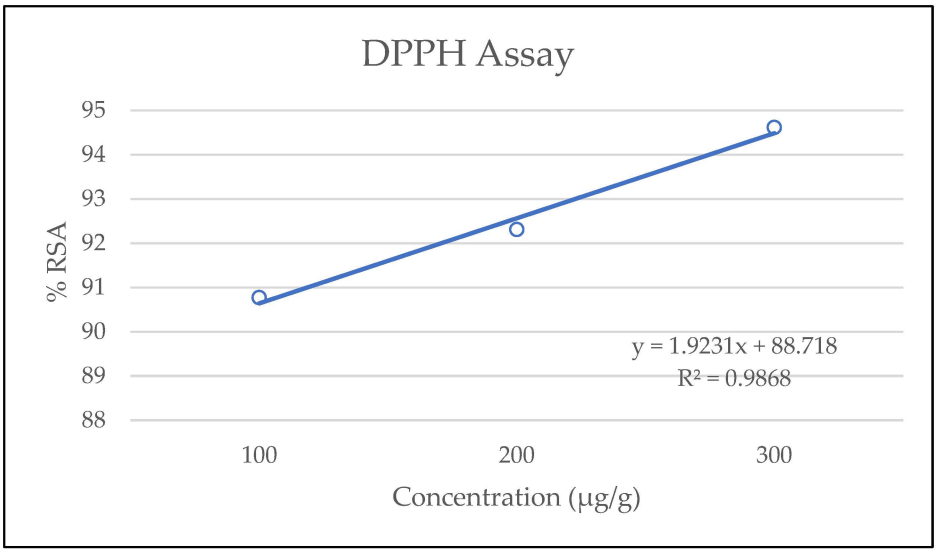


Figure 3. Radical scavenging activity percentage of SDP.

3.7. GC-MS Analysis of SDP

The GC-MS analysis of the SDP ethanolic extract confirmed the presence of various bioactive compounds. Seven compounds were identified, which are listed in Table 8 along with the name, retention time, percentage area, bioactivity and molecular formula of each compound. Figure 4 depicts the GC-MS chromatogram depicting the peaks of the seven compounds that could contribute to the medicinal/phytochemical properties of SDP. The predominant compound, ethane, 2-chloro-1,1-dimethoxy-, exhibits antioxidant properties, crucial for combating free radicals and preventing cellular damage. Additionally, 2-propen-1-ol, 3,3-difluoro-, acetate showed promising antiviral activity, which is essential for the inhibition of viral replication. Methanone, 1,3-dithian- 2-yIphenyI- and silanediol, dimethyl both possess antimicrobial properties [40], making them effective against a broad spectrum of microorganisms, including bacteria, fungi, and viruses. The low area percentage suggests that they are minor components but still contribute to the overall antimicrobial activity of

the premix. The presence of 4H-[1,2,5]Oxadiazolo [3,4-b][1,2,3]triazolo[4,5-E]pyrazine indicates potential anti-tubercular and anticancer activities [41], which are crucial for treating tuberculosis and inhibiting cancer cell growth. Furthermore, Benzenpropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy is known for its anti-inflammatory properties [42], crucial in reducing inflammation and associated symptoms in various conditions, such as arthritis, asthma, and inflammatory bowel disease. Even compounds with lower concentrations like 1,1,1,3,5,5,5-Heptamethyltrisiloxane contribute to the overall antimicrobial potential. Analysis of the ethanolic extract revealed the presence of compounds that exhibit antioxidant, antiviral, antimicrobial, anti-tubercular, anticancer and anti-inflammatory properties.

Table 8. Compounds identified by GC-MS analysis.

Peak No.	Retention Time	Area%	Compound Name	Activity	Molecular Formula
1	1.57	98.63	Ethane, 2-chIoro-1,1-dimethoxy-	Antioxidant	$C_4H_9ClO_2$
2	1.76	0.04	2-Propen-1-oI, 3,3- difluoro-, acetate	Antiviral	$CH_6F_2O_2$
3	1.99	0.03	Methanone, 1,3-dithian- 2-yIphenyI-	Antimicrobial	$C_5H_6OS_2$
4	2.16	0.27	Silanediol, dimethyl-	Antimicrobial	$C_6H_{12}O_4Si$
5	2.9	0.01	4H-[1,2,5] OxadiazoIo [3,4-b][1,2,3]triazoIo [4,5-E]pyrazine,	Anti tubercular, anticancer	$C_6H_8N_6O_3$
6	7.752	0.11	Benzenepropanoic acid, 3,5-bis(1,1-dimethyIethyI)-4-hydroxy	Anti inflammatory	$C_{18}H_{28}O_3$
7	12.05	0.04	1,1,1,3,5,5,5-Heptamethyltrisiloxane	Antimicrobial	$C_7H_{22}O_2Si_3$

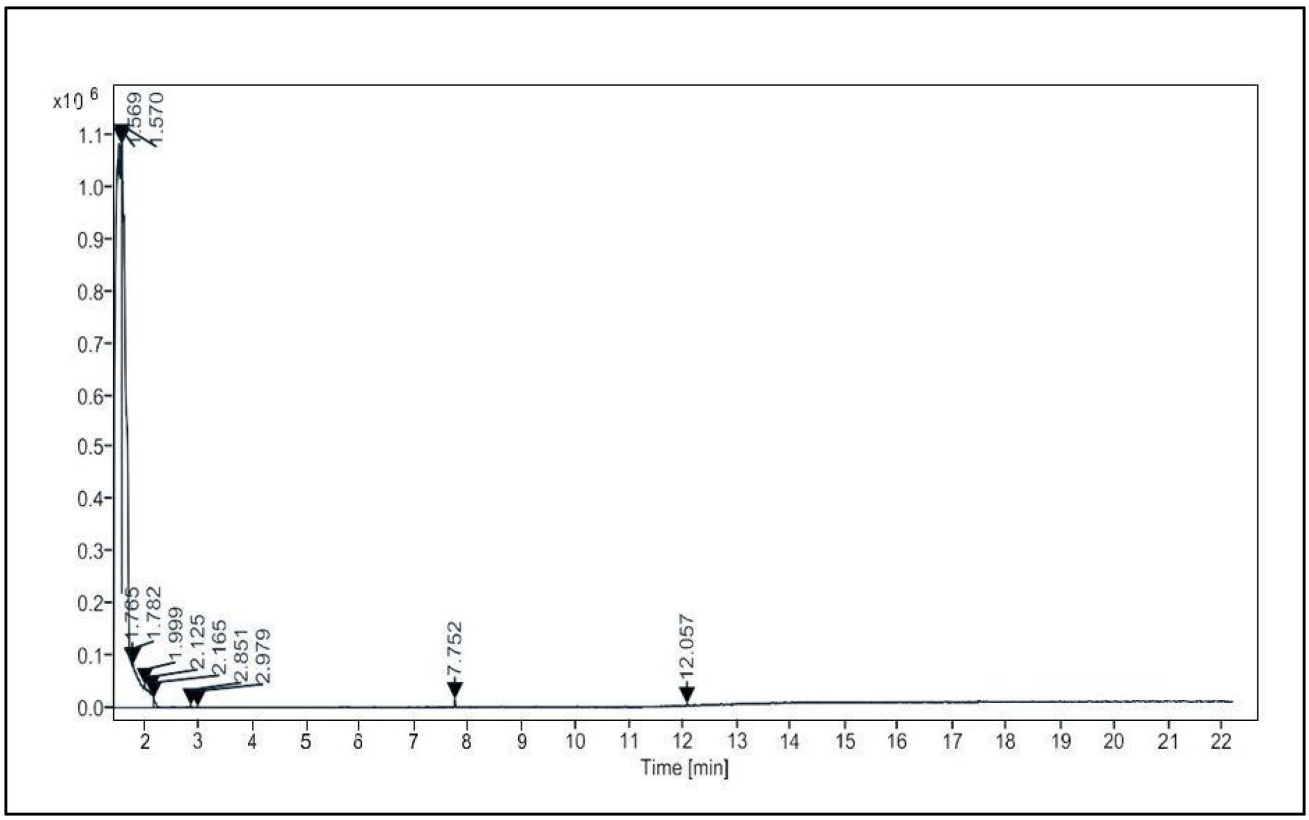


Figure 4. GC-MS chromatograms of ethanolic extract of SDP.

4. Conclusions

The present study successfully developed and characterized a nutrient-rich SDP formulated using popped sorghum and chickpea, meeting the 6% carbohydrates per serving guidelines by IOC and FAO as well as high overall acceptability. Nutritional analysis of the optimized SDP revealed that it was an excellent source of proteins, carbohydrates, essential

fats and minerals. SDP exhibits significant physicochemical stability and robust antioxidant potential. GC-MS analysis identified several bioactive compounds with significant antioxidant, antiviral, antimicrobial, anticancer, and anti-inflammatory activities. These attributes collectively contribute to a promising product for supporting athletic performance and overall human health and wellbeing. Further new developments in creating natural and cereal-based premixes can be utilized for pharmaceutical and therapeutic applications.

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