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Healthy, Dietary Fiber-Rich, and Low Glycemic Sevaiyyan Developed from *Cucumis sativus* and Buckwheat Flour for Diabetic and Obese Patients, and Ranking of the Product by MAHP and TOPSIS Method

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ABSTRACT

Today, the goal of obtaining good health is a very difficult task for all people, especially those suffering from metabolic disease. In general, refined wheat and rice flour are used in the preparation of a vegetable (sevaiyyan) that is not healthy for diabetes and obese patients, because it contains high calories and increases the glucose level in the blood. Cucumber's glycemic index is only 14, and it belongs to the low GI category. The high concentration of nutritional fibers ensures that cucumbers are slowly digested and do not increase blood glucose levels. Germination is one of the most widely accepted methods in cereals to help decompose and leach antinutrients such as protein and protein inhibitors and to activate the enzyme system that catalyzes the hydrolysis of reserve compounds such as proteins, starch, and mineral solubility to improve the bioavailability of nutrients. Therefore, the research idea was to develop food products (sevaiyyan) that everyone liked, but to make them healthier by replacing unhealthy ingredients with healthy ones to avoid harmful health effects. The A, B, C, and D samples of sevaiyyan were prepared in the ratio of 10:20:70, 15:25:60, 20:30:50, and25:35:40, using dried cucumber powder, germinated buckwheat flour, and wheat flour. Sensory evaluations of all products were conducted by 20 panel members based on taste, color, texture, firmness, stickiness, and general acceptance. Sample A (10:20:70) was strongly accepted by the panel members, while the least accepted sample D (25:35:40) included dry cucumber powder, germinated buckwheat dry flour, and wheat flour. The developed sevaiyyan has energy (318.1 Kcal), carbohydrate (63.22 g), protein (10.88 g), fat (1.48 g), and dietary fiber (9.48 g), and also has a low price as prepared from locally available product such as Cucumber.

Key words: Dietary Fiber-Rich, buckwheat, diabetic, obese, TOPSIS

INTRODUCTION

Diabetes is a chronic metabolic disorder caused by high blood glucose levels, insulin resistance, and relative deficiency of insulin. The International Diabetes Federation's 2019 Diabetes Atlas reported that 463 million adults worldwide are suffering from diabetes, and that the number will have increased to 700 million by 2045 (Saeedi et al., 2019; Sharma & Sharma, 2024). The inclusion of dietary fiber would help to regulate the blood glucose level and has a beneficial impact on serum cholesterol level in patients with type 2 diabetes (Nitzke et al., 2024). Soluble fibers are characterized by the inability to dissolve into water and form viscous gels, reducing the passage time of the intestinal tract and retarding the absorption and complete digestion of nutrients (Giuntini et al., 2022). The main soluble fiber types are—glucans, inulin, fructo-oligosaccharides, arabinoxylans, and pectins. Apart from this, insoluble fiber consumption can also serve as a physical barrier, reducing the speed of food through the enterocyte brush border (Guan et al., 2021). Additionally, Dietary fibers and prebiotics have one mechanism of action which is colonic fermentation and intestinal microbiological changes. Non-digestible foods that selectively stimulate the growth and activity of some colon bacteria and improve host health are called prebiotics (Slavin, 2013). Thus, for patients with Type 2 diabetes, it is recommended to consume 20–35 g fiber daily. Currently, everyone is having a difficult time maintaining good health, especially if one is suffering from metabolic disease (Nitzke et al., 2024). A sevaiyyan is a recipe that everyone liked, containing sugar, high-calorie food that is unhealthy for diabetes and obesity and is generally prepared from refined wheat or rice flour. Thus, the aim of the study was to develop a food product (sevaiyyan), by replacing unhealthy ingredients with healthy ones to avoid any harmful effects on health.

Cucumber (Cucumis sativus)

Cucumis sativus is a melon fruit in the Cucurbitaceae family. Its nutritional value, ease of use, and ease of supply of raw materials make it a potential food source. However, due to a lack of efficient storage technologies, a large amount of these fruits is likely to be wasted. The presence of high levels of potassium in dried cucumbers and the addition of vitamins K, B, magnesium, and phosphorus make it a promising snack despite its light compression structure (Mallick, 2022). Raw cucumbers are composed of approximately 95% water, 4% carbohydrates, 1% protein, and a negligible amount of fat. A 100-gram serving provides about 16 kilocalories of energy. While low in most micronutrients, cucumbers are a notable source of vitamin K, providing around 16% of the recommended daily value (Uthpala et al., 2020). *C. sativus* is considered a safe and suitable candidate for reducing oxidative and carbonyl stress associated with diabetes, and it may help protect against diabetes-related complications (Heidari et al., 2016).

C sativus L. fruits may be used to manage diabetes and reduce postprandial glucose. Moreover, fruit extracts (including Kaempferol) can be used as plant chemicals for the treatment of diabetes and its complications such as dyslipidemia and oxidative stress (Ibitoye et al., 2018).

Cucumbers have a low glycemic index (GI) of just 14, placing them in the lowest GI category. One cup of chopped cucumber contains only about 0.87 grams of sugar. Their high dietary fiber content slows digestion, helping to prevent spikes in blood sugar levels. The nutritional value of raw and dried cucumber is elaborated in Table 1. The review of literature is detailed in the Table 3.

Table 1. Nutritional value of raw and dried cucumber per 100g (Syakira et al., 2012).

Principles	Raw cucumber/100g	Dried cucumber/100g
Moisture (g)	95.20	36.65
Ash (g)	0.38	8.73
Crude Protein (g)	0.57	10.51
Total Fat (g)	0.00	0.00
Dietary Fiber (g)	0.5	15.29
Carbohydrates (g)	3.6	44.11
Energy (Kcal)	0.02	249.06

Buckwheat (*Fagopyrum esculentum Moench*)

Pseudocereals are seeds similar in function and composition to cereals. Amaranth, Quinoa and Buckwheat are commonly used pseudocereals. Of the nine most important buckwheat species, common buckwheat and Tartary buckwheat are the most widely cultivated and utilized (Gimenez-Bastida and Zielinski, 2015).

Buckwheat grains contain various nutrients such as proteins, polysaccharides, lipids, foodstuffs, rutins, polyphenols, and microelements. It is a balanced amino acid and contains sufficient lysine, are strictive amino acid in wheat and barley (Sofi et al., 2023). Especially high minerals such as zinc, copper, and potassium from wheat play an important role in the prevention of hypertension and anemia (Chiu et al., 2021).

Germination is one of the most widely accepted methods for cereal grains, helping to decompose and leach antinutrients such as protein and protein inhibitors, activating enzyme systems that catalyze the hydrolysis of reserve compounds such as proteins, starch, and mineral solubility, and enhancing the bioavailability of nutritional value (Nkhata et al., 2018). The nutritive value of the raw buckwheat and germinated buckwheat is elaborated in Table 2.

Table 2. Nutritional value of raw and germinated buckwheat per 100g (Shreeja et al., 2021).

Principle	Buckwheat/100g	Germinated buckwheat/100g
Moisture (g)	11.03	12.77
Ash (g)	2.05	1.53
Carbohydrates (g)	72.63	69.49
Protein (g)	10.22	12.14
Fat (g)	3.13	2.05
Crude Fiber (g)	0.92	1.44
Energy (Kcal)	359.64	345.06
Sodium (mg)	3.1	5.13
Potassium (mg)	427.6	517

Table 3. Literature Search.

Author and year	Journal	Aims of the study	Study description	Result and conclusion
Heidari et al., (2016).	*BioImpacts: BI*	Defensive mechanisms of *Cucumis sativus* in diabetes-associated models oxidative stress and carbonyl stress	Water extracts of *C. sativus* fruits (40 g/mL) prevented all cytotoxic markers associated with oxidative stress and carbonyl stress models, including cell lysis, ROS formation, membrane lipid peroxidation, glutathione depletion, mitochondrial membrane potential depletion, lysosomal lipidation, and proteolysis.	This extract also protects hepatocytes from protein carbonylation caused by glyoxal. The results showed that *C. sativus* could prevent oxidative stress and carbon stress in isolated hepatocytes.
Karthiyayini, et al., (2015).	*Biomedical and Pharmacology Journal*	Assessment of antidiabetic and hypolipidemic outcome of *Cucumis sativus* fruit in streptozotocin-induced-diabetic rats	Different doses of ethanol extract have been tested for effects on glucose levels in the serum of rats induced by streptozotocin, and blood lipid profiles (biochemical parameters) have also been observed by histological studies.	The oral administration of 200 and 400 mg/kg of Cucumis sativus powder ethanol extract showed significant anti-inflammatory effects in rats induced by streptozotocin compared to standard drugs.
Ibitoye et al., (2018).	*Journal of Food Biochemistry*	Bioactivity-directed separation of kaempferol as the antidiabetic principle from *Cucumis sativus L.* fruits.	The active principle is isolated by column chromatography and identified by high-performance liquid chromatography. The extract and chromatographic fraction B of *C. sativus* fruit reduces blood glucose in diabetes rats inducing alloxan. The extract inhibits theIC50 values of-amylase and -glucosidase to652.43 and 540.42g/mL.	The data gained in this study indicated that Caempferol separated from *C. sativus* was responsible for its-amylase and-glucosidase inhibition, low glucose, anti-dyslipidemic and antioxidant activity.

AIMS AND OBJECTIVES

- To create novel food products from available food sources, such as fibers, proteins, carbohydrates, and low-energy food.
- To assess the organoleptic evaluation of the product developed by standardizing variation.
- Statistical examination of products formulated using the MAHP and TOPSIS methodologies.
- To identify the nutrients (dietary fibres, proteins, fats, and energy) of the final product (Sevaiyyan).

MATERIALS AND METHODS

Procurement of Raw Materials

The raw materials (Cucumber, Buckwheat) were bought from a local store in Panchgaon and the Amity University Manesar departmental store. The preparation was done in the Nutrition Lab of Amity University Gurugram. An electronic balance was used to weigh the appropriate amount of the ingredients, and they were stored carefully.

Standardization of Food Products

The recipe for sevaiyyan was standardized using the following ingredients:

Cucumber powder

Germinated Buckwheat flour

Development of the Product (Sevaiyyan)

This product is very common in India. The development of this sevaiyyan was started by using powder of dry cucumber, and germinated buckwheat dry powder. The development of sevaiyyan was proportioned of 100 g by using cucumber dry powder, germinated buckwheat flour and wheat flour in four variations. Table 4 mentions the ingredients used in the preparation of sevaiyyan and the flow chart of preparation and schematic diagram is depicted in Figures 1 and 2.

Table 4. Ingredient used in the preparation of newly developed fiber-rich sevaiyyan (sample variation).

	Cucumber dry powder (g)	Germinated buckwheat flour (g)	Wheat flour (g)
Sample A	10	20	70
Sample B	15	25	60
Sample C	20	30	50
Sample D	25	35	40

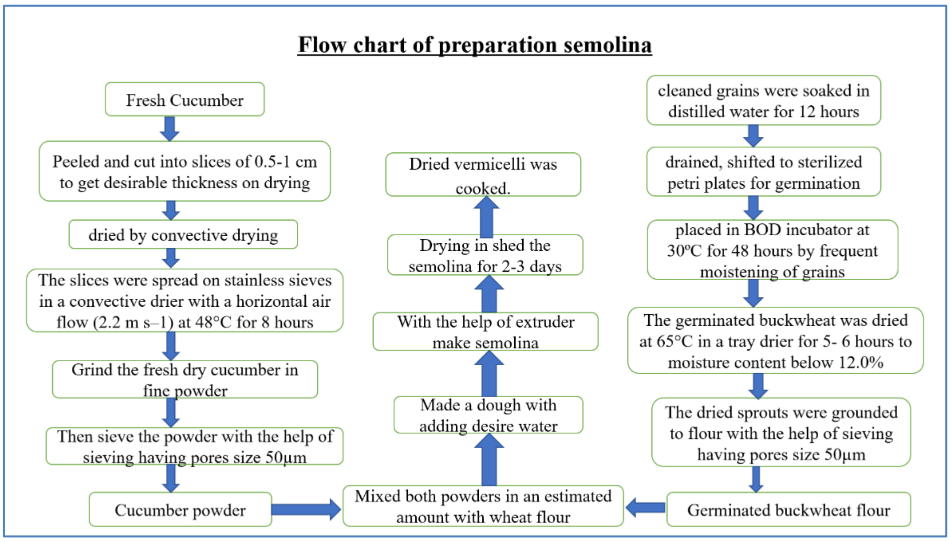

Fig. 1. Flow chart of the preparation of sevaiyyan.

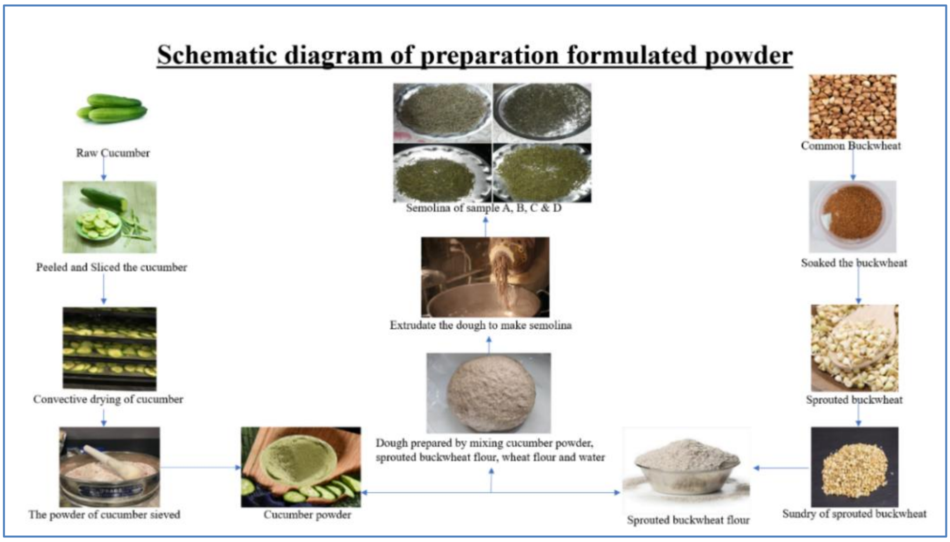

Fig. 2. Schematic diagram of the preparation of sevaiyyan.

Sensory Evaluation

The four samples were evaluated sensorially using a hedonic scale. Twenty panelists, each with expertise in diet and applied nutrition, conducted 20 tastings of each variation. Sensory attributes assessed included taste, color, texture, firmness, stickiness, and overall acceptability. Each rating reflected the individual panelist's preferences or dislikes. Statistical analysis was performed following the sensory evaluation. The results of the sensory evaluation will be described in (Table 5) and (Figure 3).

Table 5. Sensory evaluation result of the four different samples of sevaiyyan.

Attributes	Sample A	Sample B	Sample C	Sample D	*P*-value
Taste	9.1 ± 1.2	9.1 ± 1.10	8.8 ± 0.91	7.8±1.68	<0.001*
Colour	9.7 ± 0.67	8.4 ± 1.68	8.7 ± 0.94	7.2±1.54	<0.001*
Texture	9.4 ± 0.51	9.4 ± 0.69	9.4 ± 0.69	7.5±1.84	<0.001*
Firmness	9.5 ± 2.91	8.8 ± 1.13	8.5 ± 1.50	8±2.05	<0.001*
Stickiness	9.5 ± 0.52	8.5 ± 1.26	9.1 ± 0.99	7.3±1.94	<0.001*
Overall Acceptability	9.4 ± 0.51	9.1 ± 0.99	8.9 ± 1.19	7.8±1.81	<0.001*

* = Significant at <0.05

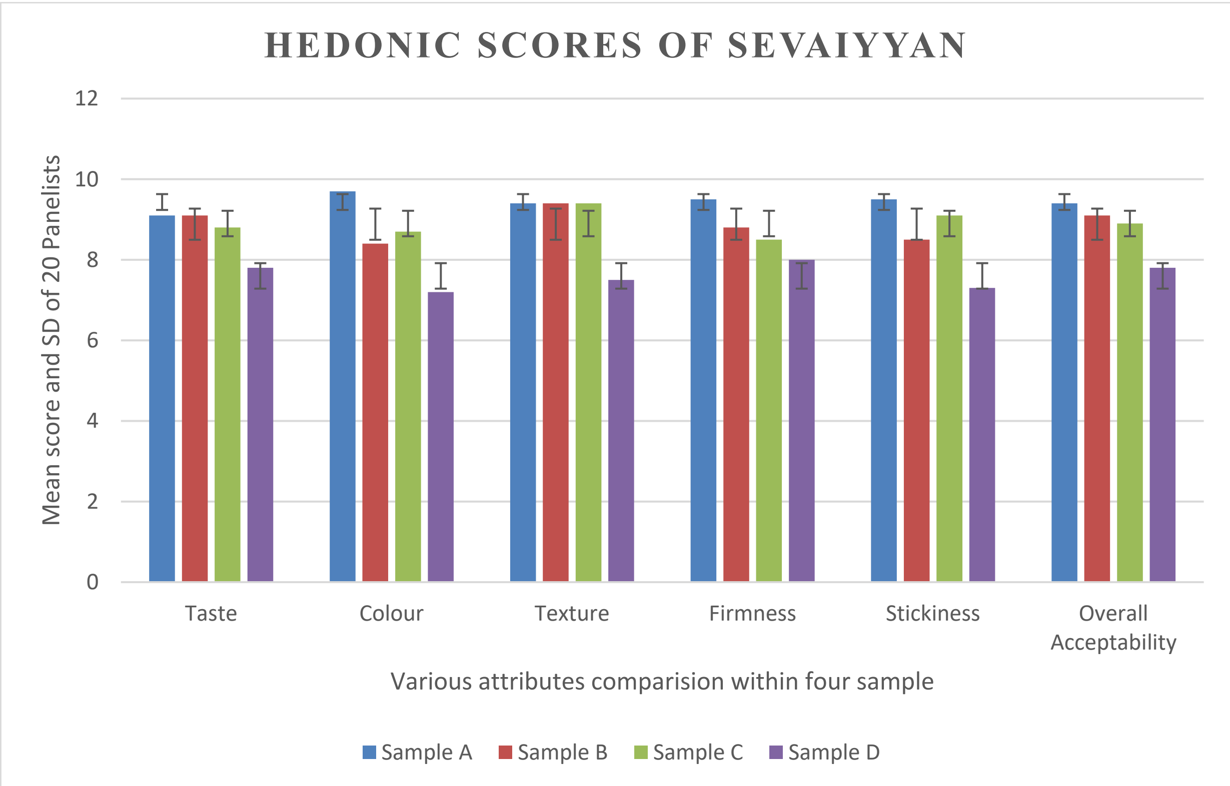

Fig. 3. Mean Sensory Evaluation (9-point Hedonic) scores of developed samples of sevaiyyan.

RESULTS

After sensory assessment, the product was statistically analysed using mean, standard deviation, and one sample t-test was performed on the sensory data to determine the statistical significance between samples, thereby addressing concerns associated with the reproducibility and reliability of the product as above.

Calculation of Weights by MAHP (Means of Analytical Hierarchy Process)

MAHP was applied for the best product/option out of a list of different available options. A pairwise comparison scale has been utilized for the ranking process (Forman et al., 2001; Sharma et al., 2024).

Analytical Hierarchy Process Technique

Allowing the set of the criteria to be A = {Aj}, such that j = 1, 2, 3 .... n. Pair-wise comparison of a matrix Z of 'n' numbers of criteria can be represented as (n × n) matrix. Every element in (n × n) matrix is 'ij', where i, j = 1, 2, 3 .... n. The pair-wise comparison matrix has been described in Table 6.

Table 6. Pair-wise comparison matrix for n number of criteria.

K	A_1	A_2	A_3	...	A_n
A1	1	a_{12}	a_{13}	...	a_{1n}
A2	a_{21}	1	a_{23}	...	a_{2n}
A3	a_{31}	a_{32}	1	...	a_{3n}
.	.	.	.	...	.
An	a_{n1}	a_{n2}	a_{n3}	...	1

AHP Calculation

Step 1: The first step is to draw a '4 × 4' matrix for four different samples, and calculations were done. The '4 × 4' matrix calculation has been described in Table 7.

Table 7. 4 × 4′ matrix for four different samples.

	Sample A	Sample B	Sample C	Sample D	4th. Root	PV (Priority Vectors) Weights
Sample A	1.00	2.00	3.00	4.00	2.21	0.47
Sample B	0.50	1.00	2.00	3.00	1.32	0.28
Sample C	0.33	0.50	1.00	2.00	0.76	0.16
Sample D	0.25	0.33	0.50	1.00	0.45	0.10
SUM	2.08	3.83	6.50	10.00	4.74	
SUMPV	0.97	1.06	1.04	0.95	4.03	

Step 2: After drawing the matrix, the 4th root of A = (1×2×3×4)1/4 = 2.21 was calculated, and the steps were repeated for all four variables.
Step 3: The Individual 4th root was calculated, and then the sum of all the 4th roots was done, and it was found to be 4.74.
Step 4: The calculation of PV for each group was then done. To calculate PV, divide the 4th root for each sample by the sum of the 4th root (eg, 2.21/4.74=0.60). Do the same for all four variables.
Step 5: The sum PV for each variable was calculated. Repeat the steps for all the four variables and sum PV for A = 0.47 × 2.08= 0.97.
Step 6: The calculation of Total for Sum PV= λ(max) {Lambda-max} was then done, where λ(max)= ∑(PV (A, B, C, D) = 4.03
Step 7: The next step is to calculate the CI value (Consistency Index). The formula is given below to calculate it.
Consistency Index = 4.03 − n / (n − 1) = 0.01046
Step 8: The CR (Consistency Ratio) value was calculated by dividing CI (Consistency Index) by the RI value, where RI is the Random Index. Table 8 below gives values of RI.

Table 8. Values of RI.

N	1	2	3	4	5	6	7	8	9	10
RANDOM INDEX (RI)	0.000	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Random Consistency Index

In our study, a total of 6 criteria were compared, so n = 6. RI for 6 is used to calculate the CR value. CR= 0.01046/ 1.24= 0.008435

- The CR is the measure of consistency of the different samples. Less than 0.1 consistency ratio is fine. A matrix is consistent and suitable if the consistency ratio is less than 0.1. If the Consistency ratio reaches more than 0.1, then the sample is corrected with different correction measures.
- The calculated Consistency Ratio of the study was 0.008435, which was less than 0.1, so our pair-wise comparison test was found to be consistent, and no corrective actions were required for the comparison.

TOPSIS for Ranking the Samples

- Mean scores of all 6 attributes of every sample were employed in the TOPSIS procedure, coupled with the calculated weight value using the AHP procedure. 6 different attributes used were Appearance, taste, color, flavor, consistency, and overall acceptability has been provided in below Table 9.

Table 9. Six diverse characteristics of sensory evaluation.

	Taste	Color	Texture	Firmness	Stickness	Overall
Sample A	9.1	9.7	9.4	9.5	9.5	9.4
Sample B	9.1	8.4	9.4	8.8	8.5	9.1
Sample C	8.8	8.7	9.4	8.5	9.1	8.9
Sample D	7.8	7.2	7.5	8	7.3	7.8

Mean scores derived from sensory evaluation and computed weights from the AHP method. Then, the test scores of the 9-scale Hedonic rating were analyzed, and the mean and standard deviation were computed. TOPSIS was ranked for all four samples.

m= varieties of sample= 4; n= number of attributes= 6

Step 1: Calculation of $(\Sigma x^2{}_{ij})^{1/2}$ for each row: Table 10 below describes each step involved in the $(\Sigma x^2{}_{ij})^{1/2}$ calculation.

Table 10. Calculation of $(\Sigma x^2{}_{ij})^{1/2}$ for each row.

	Appearance	Taste	Colour	Flavour	Consistency	Overall
Sample A	0.522006658	0.56747468	0.52438736	0.544916145	0.549767046	0.532836669
Sample B	0.522006658	0.49142138	0.52438736	0.504764429	0.49189683	0.515831243
Sample C	0.504797647	0.50897214	0.52438736	0.487556551	0.526618959	0.504494293
Sample D	0.447434278	0.42121832	0.41839417	0.458876754	0.422452572	0.442141066

Calculation of $(\Sigma x^2{}_{ij})^{1/2}$ for Each Row

Step 2: Calculation of r_{ij}:

To calculate r_{ij} for each attribute, divide the mean score for every attribute by (Σx2 ij) 1/2 for every sample, described in Table 11.

Table 11. r_{ij} Values.

	Appearance	Taste	Colour	Flavour	Consistency	Overall
Sample A	0.245343129	0.2667131	0.24646206	0.256110588	0.258390511	0.250433234
Sample B	0.146161864	0.13759799	0.14682846	0.14133404	0.137731112	0.144432748
Sample C	0.080767624	0.08143554	0.08390198	0.078009048	0.084259034	0.080719087
Sample D	0.044743428	0.04212183	0.04183942	0.045887675	0.042245257	0.044214107

Table 12. Positive and Negative Ideal Situation.

V+	0.245343129	0.2667131	0.24646206	0.256110588	0.258390511	0.250433234
V−	0.044743428	0.04212183	0.04183942	0.045887675	0.042245257	0.044214107

Positive and Negative Ideal Situation. V+ is the Positive Ideal Solution, and V− is the Negative Ideal Solution.

Step 3: The Positive and Negative Ideal Solutions are then determined.

The Positive Ideal Solution is the highest value for each attribute, and the Negative Ideal Solution is the lowest value for each attribute, the calculation is described in Table 12.

Step 4: The separation from Positive Ideal Solution and Negative Ideal Solution is then determined.

All the samples were calculated to have Si = [S(vj* – vij*)2] 1/2 Si+ and Si− negative values. The separation from the Positive Ideal Solution is Si+, and the separation from the Negative Ideal Solution is Si−, the calculation for Si+ and Si− value has been described in Table 13.

Step 5: The relative closeness to the ideal solution was then taken out using the formula-

$$Ci = (Si-)/\{(Si+) + (Si-)\}$$

Table 13. Si values and Ci values for each sample. Ranks of different samples.

Si+	Si−	Pi	Rank
0	0.515743	1	1
0.274596	0.242271	0.46873	2
0.42271	0.093499	0.181127	3
0.515743	0	0	4

Ranking

Sample A was found to be the best sample, then Sample B and Sample C, and Sample D was ranked last. Figure 4 shows that sample A was the most accepted and sample D was the least accepted.

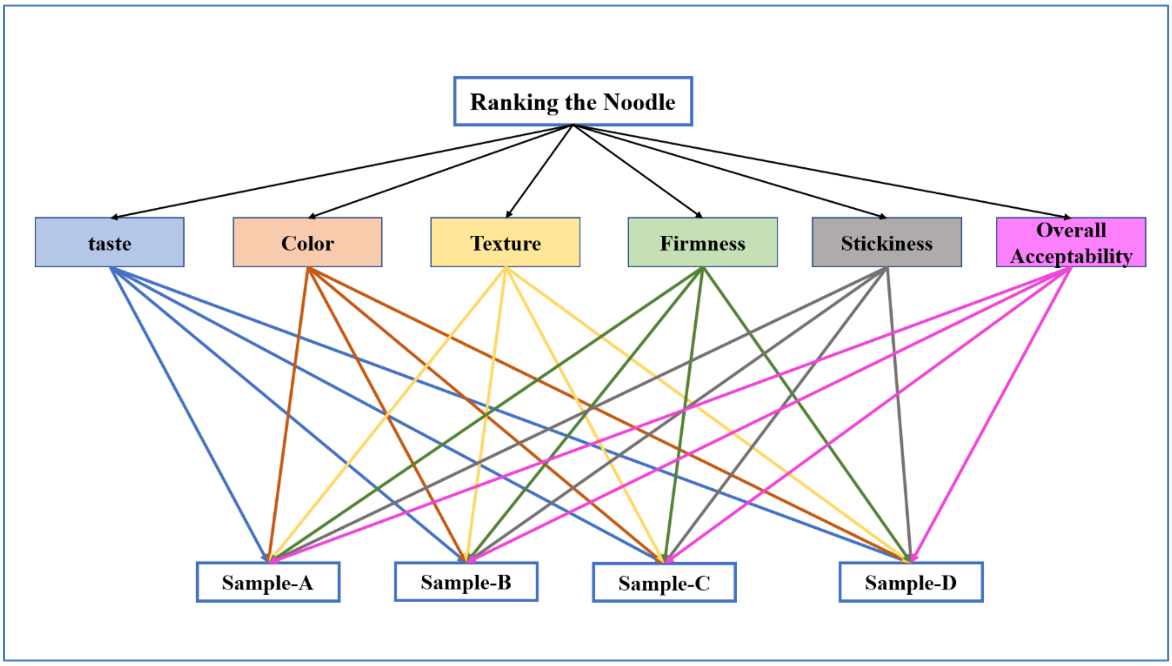

Fig. 4. Hierarchical Structure of the four samples of sevaiyyan.

Hierarchical Structure

The hierarchical structure for the ranking evaluates the macaroni samples systematically based on the various sensory qualities. The ranking system split it based on the nine parameters such as taste, color, texture, firmness, stickiness, and overall acceptability (Figure 4). The parameter assessment is related to the sevaiyaan samples of A, B, C, and D, and was analysed in many dimensions. The interwoven lines frame the comparison assessment process, highlighting the mechanism for selecting the best option.

Nutritive Composition & Values of Newly Developed Fiber-Rich Sevaiyyan

The food we eat should be known for its nutritional composition. The nutritional analysis of the developed product was calculated using the AOAC 2000 method (AOAC, 2000). For 100 g samples, the food product was calculated for carbohydrates, protein, fats, dietary fiber, and energy. Table 14 describes the results of the nutritive value of newly developed sevaiyyan.

Carbohydrate—The Antrone method was used for carbohydrate analysis, the Micro-Kjeldahl method was used for the estimation of proteins, and the Soxhlet apparatus method was used in the product for the estimation of fats (AOAC, 2000).

Energy—Proteins and carbohydrates were multiplied by four, fats by nine, and the values of three were added up.

Dietary fiber—Dietary fiber content was calculated using the Enzymatic-Gravimetric method [18].

Crude Fat—AOAC (2000) was followed by the method of fat extraction (AOAC, 2000).

Protein Content—Estimation of various flours was done by the Micro Kjeldahl method as described in A.O.A.C. (2000) (AOAC, 2000).

The following formula was used: N (%) = 1.4(V2 − V2) Normality of HCI × 250 (dilution)/weight of Sample Where, (V2 − V1) = Volume made of the digest

Protein % = N% × Conversion factor (6.25)

Table 14. Nutritive composition & values of newly developed product sevaiyyan.

100 gm of cucumber sevaiyyan contains	
Nutrient	Amount (g)
Energy (Kcal)	318.1
Carbohydrate (g)	63.22
Protein (g)	10.88
Fat (g)	1.48
Dietary Fiber (g)	9.78

CONCLUSIONS

Sample A has 70 g wheat flour, 20 g wheat flour, and 10 g dry cucumber powder, and is the best in taste, color, texture, firmness, stickiness, and overall acceptability as shown. From the 9-scale Hedonic test results, developed sample A of Cucumber sevaiyyan was found to be the most acceptable sample. As per the results of MAHP & TOPSIS, sample A of Cucumber sevaiyyan was ranked first. From the Proximate analysis results, sample A was found to be the richest source of fibre. The sevaiyyan developed has energy (318.1 Kcal), carbohydrate (63.22 g), protein (10.88 g), fat (1.48 g), dietary fiber (9.48 g), and a low price as it is prepared from locally available ingredients such as Cucumber.

AUTHOR CONTRIBUTIONS

D.S., L.S., D.P., K.D. and D.B.: conceived the design, Methodology, Food Development, analysis, planning, review, and writing. L.S. and D.S.: critical analysis, review, and supervision. All authors provided their critical feedback and approved the final manuscript for publication.

FUNDING

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AVAILABILITY OF DATA AND MATERIAL

All datasets for the study are available in the manuscript.

CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest.

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