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Formulation,Characterization and Evaluation of Plant-based Synbiotic Food Products Derived from Buckwheat

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ABSTRACT

Background: The rising prevalence of gluten-related diseases (GRDs), including celiac disease and non-celiac gluten sensitivity, underscores the need for functional, gluten-free alternatives. This study aimed to formulate and assess innovative buckwheat-based synbiotic compositions augmented with Ayurvedic prebiotics integrated with probiotic strains *Lactobacillus plantarum* (MTCC 13002), *L. rhamnosus* (MTCC 13028) and *Streptococcus salivarius* (MTCC 13009). The incorporation of buckwheat with conventional Ayurvedic prebiotics offers a viable non-dairy synbiotic substrate for improving gut health.

Methods: Buckwheat was subjected to blanching and germination to reduce anti-nutritional elements before fermenting. The resultant synbiotic buckwheat milk was used to formulate three products: jelly, chocolate and thandai. Sensory assessment was conducted using a 9-point hedonic scale, while product optimization was done following the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach/methods. Nutritional profile, pH analysis and microbial viability were evaluated, with statistical significance established by ANOVA and Tukey's HSD test.

Result: All documented product variants have sensory ratings over 6, indicating overall acceptance. The optimal formulations-sample 102 (jelly), 202 (chocolate) and 302 (thandai)-demonstrated favourable flavour, texture and overall acceptance. Probiotic viability remained above 7 log CFU/g during 21 days of refrigeration without encapsulation. Nutritional analyses indicated moderate protein levels (4.5-7.9%), low to moderate fat content (2.3-17%) and significant phenolic concentration (182-480 mg GAE/100 g), indicating antioxidative potential.

Key words: Ayurvedic prebiotics, Buckwheat, Gluten-related disorders, Probiotic viability, Synbiotic foods, Sensory optimization.

INTRODUCTION

Gluten-related disorders (GRDs) have garnered considerable attention recently due to increased awareness, improved diagnoses and changing dietary preferences. People often refrain from consuming foods that contain gluten because they have symptoms such bloating, malabsorption and gastrointestinal distress (Dinu *et al*., 2017). Furthermore, numerous consumers consider gluten-free diets (GFDs) as preferable options for improving digestive and metabolic health, which has led in a notable demographic shift towards gluten-free lifestyles.

The gluten-free food market has grown quickly because more people want it. It is expected to be worth $36 billion by 2026 (CAGR of 10%) gluten (Gluten-Free Products Market Size | Industry Report, 2030). However, removing gluten, which is an important structural protein, sometimes results in a less-than-ideal texture, lower protein quality, less fiber and less appealing sensory properties (Foschia *et al*., 2016; Melini and Melini, 2019).

An innovative gluten-free ingredient that can circumvent these limitations is buckwheat (*Fagopyrum esculentum*), a pseudocereal with a high nutritional value. It consists of high-quality protein with a balanced amino acid profile, notably rich in lysine-an essential amino acid deficient in cereal-based diets (Bhinder *et al*., 2020; Jin *et al*., 2022). Additionally, buckwheat provides bioavailable minerals, resistant starch and dietary fiber, which enhance metabolic results and promote satiety (Yilmaz *et al*., 2018; Zhou *et al*., 2019). It is different from other gluten-free foods since it has a unique polyphenolic content (Simranpreet and Katyal, 2022; Sucheta and Arora, 2018). Due to these compounds' anti-inflammatory, anti-hypertensive, antidiabetic and antioxidant effects, buckwheat is established as a functional food.

Buckwheat's natural prebiotic fibers help the growth of good bacteria and the production of short-chain fatty acids good for the gluten free users who might be at risk of high glycemic load diets (Dinu *et al*., 2017; Yao *et al*., 2022). From a technological perspective, buckwheat demonstrates satisfactory sensory properties, effective gelation potential and inherent emulsifying characteristics in applications

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pertaining to confectionery and beverage industries (Ahmed *et al*., 2014; Sofi *et al*., 2023).

Nonetheless, anti-nutritional components including tannins and protease inhibitors may restrict protein digestion in buckwheat.Though protein availability and quantities of bioactive compounds can both be enhanced by processing techniques (Mattila *et al*., 2018).

Synbiotic formulations demonstrated evidence in improving gut health resulted in the recent shift for development of synbiotic foods (Chaturvedi and Chakraborty, 2024; Singh and Prasad, 2022; Tiwari *et al*., 2013). Probiotic strains that can improve nutritional absorption, strengthen mucosal immunity and restore microbial equilibrium include *Lactobacillus plantarum, Lactobacillus rhamnosus* and *Streptococcus salivarius* (Mirsalami and Mirsalami, 2024; Tanwar *et al*., 2019; Yang *et al*., 2024). Ayurvedic herbal preparations such as Bilvadi Lehyam, which contains Aegle marmelos and Dadimastaka Churna, which have high polyphenol content from pomegranate peels, have long been used for their gastrointestinal effects and as natural prebiotics (Benguiar *et al*., 2020; Sawale *et al*., 2019).

This study aimed to develop gluten-free synbiotic buckwheat products enhanced with probiotics and Ayurvedic prebiotic formulations, determine the optimal formulations through AHP-TOPSIS approach, probiotic viability. sensory, nutritional and functional assessments.

MATERIALS AND METHODS

Raw materials

Buckwheat (*Fagopyrum esculentum* Moench; cultivar FC-114) was obtained from the Rajasthan Agricultural Research Institute (RARI) in Jaipur, India.Herbal components for Dadimastaka Churna and Bilvadi Lehyam were obtained from AIIA Pharmacy.Food-grade probiotics- Lactobacillus plantarum (MTCC 13002), *Lactobacillus rhamnosus* (MTCC 13028) and Streptococcus salivarius (MTCC 13009) were sourced from the Microbial Type Culture Collection (MTCC) in Chandigarh, India. The work was carried out at All India Institute of Ayurveda, Delhi during the period from 2023-2025.

Development of potential synbiotic buckwheat based products

Removal of anti-nutritional factors and extraction of buckwheat milk

The processing of buckwheat included blanching 500 g of seeds at 80-100°C for 5±2 minutes, soaking in water at 23±2°C for 12±4 hours, surface sterilization with 0.07% sodium hypochlorite and germination for 48 hours at 20°C in darkness. The germinated seeds were wet milled with warm water (40-50°C) for 5-10 minutes and the resultant slurry was filtered through a 0.5 mm sieve to yield buckwheat milk. The milk was heated at 121°C for 15 minutes, then cooled to 4°C and stored for later use (Altıkardeş and Güzel, 2024) shown in Fig 1.

Preparation of prebiotic formulations

Preparation of bilvadi lehyam formulation

According to classical sources (Shilpa and Rajesh, 2023), a proportion of Agele roots was boiled with jaggery and blended with the other ingredients listed in Table 1.

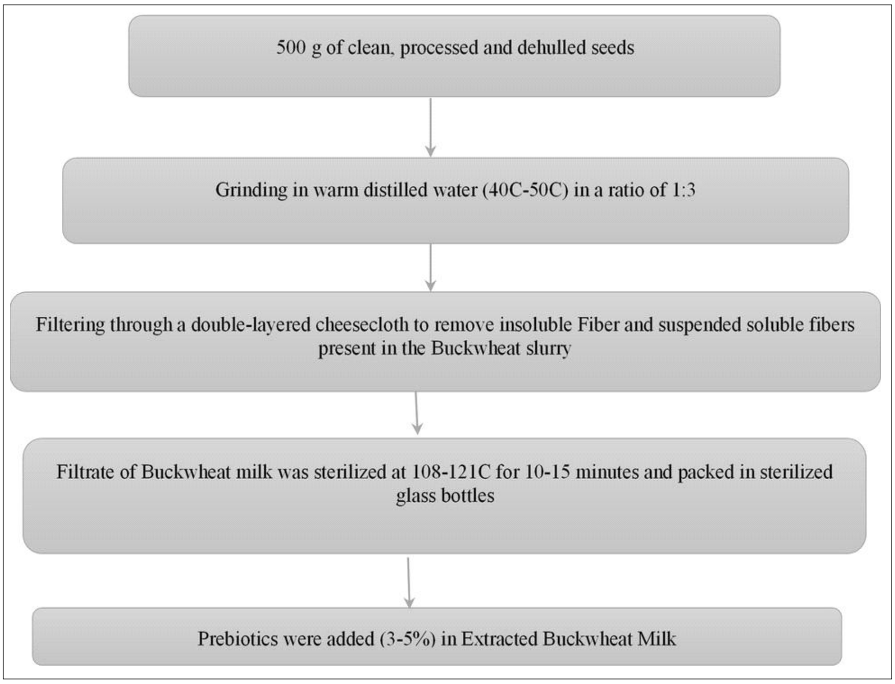

Fig 1: Extraction process of buckwheat milk.

Preparation of dadimashtaka formulation

The components, in amounts specified in traditional texts and shown in Table 2, were ground, mixed and filtered to make the prebiotic formulation (Dwivedi *et al.*, 2015).

The extracted buckwheat milk was mixed with prebiotic formulations. Dadimastaka Churna and Bilvadi Lehyam were added at concentrations between 3% and 4% and licorice was consistently maintained between 3% and 5% in all formulations.

The formulation of synbiotic buckwheat products

Revival of probiotic strains

Bacterial isolates stored at -80°C were revived in 10 mL of MRS broth. Streptococcus salivarius (MTCC 13009) and Lactobacillus plantarum (MTCC 13002) were incubated aerobically at 37°C for 24 hours, whereas Lactobacillus rhamnosus (MTCC 13028) was incubated at 30°C. After incubation, cells were harvested by centrifugation at 10,000 rpm for 5 minutes, washed three times and resuspended in 0.85% saline for further use (Rajput *et al.*, 2025).

Inoculation and fermentation of buckwheat beverages

A probiotic concentration of 7-8 $\log_{10}$ CFU/mL has been recognized as beneficial for health. As a result, cultures of Streptococcus salivarius, *L. rhamnosus* and *L. plantarum* (8-9 $\log_{10}$ CFU/mL) were added to processed buckwheat milk to get a final concentration of about 7 $\log_{10}$ CFU/mL. The samples were fermented at 37°C for 5 hours, subsequently transferred into sterile containers and maintained at 6±0.5°C. Over the course of 15 days, the pH levels and the viability of the probiotics were monitored periodically.

Changes in pH

A calibrated pH meter (Elico LI-127) was used to measure pH. Hourly measurements were made during the first five hours of incubation and subsequently at 0, 7 and 21 hours during storage.

Microbiological viability assessment

Viable probiotic counts were determined by homogenizing 1 mL of each beverage in 9 mL of sterile peptone water, followed by serial dilution. The appropriate dilutions were inoculated onto MRS agar and incubated at 37°C for 48 hours, following which colonies were counted and reported as CFU/mL (Davis, 2014).

Development of synbiotic products

Synbiotic jelly preparation

The mixture was heated to 70°C with stirring for 2-3 minutes, thereafter cooled and blended with agar dissolved in distilled water, along with buckwheat milk, sugar, sodium citrate and citric acid. The agar-based mixture was subsequently combined with the synbiotic buckwheat beverage (BLR-B) at 6°C and heated to 40°C. The jelly was formed at 27-30°C, thereafter chilled at 5°C for 30 minutes, wrapped in plastic bags and stored at 5°C (Domínguez-Murillo and Urías-Silvas, 2023) (Fig 2).

Synbiotic milk chocolate preperation

Synbiotic milk chocolates were produced in conformity with Aragon-Alegro *et al.* (2007) with a few modifications. Chocolate was melted and homogenized at 50°C (40 rpm) and thereafter blended with the synbiotic buckwheat beverage (BLP-D) kept at 6°C. After being molded and homogenized at 27 to 30°C, the mixture was demolded, chilled for 30 minutes at 5°C and kept at 4±1°C for storage. Four synbiotic chocolate variants were formulated (Aragon-Alegro *et al.*, 2007) (Fig 3).

Synbiotic thandai preparation

After soaking for 45 minutes, the peel was removed and the seeds and nuts (almonds,poppy seeds and melon seeds) were added to the synbiotic buckwheat drink (BSS-L). The entire mixture was stirred at 37°C. Following that, sugar, black pepper, cardamom powder were added to the mixture (Fig 4). It was then refrigerated to 5°C for 30 minutes, poured into sterilized glass bottles and kept at 5°C (Mousavi *et al.*, 2022).

Table 1: Bilwadi lehyam composition.

Ingredients	Quantity
Stone apple root (*Aegle marmelos*)	4.8 gm
Jaggery	4.8 gm
Honey	1.5 gm
Ginger (*Zingiber officinale*)	0.5 gm
Chitraka (*Plumbago zeylanica*)	0.2 gm
Maricha (*Piper nigrum*)	0.6 gm
Pippali (*Piper longum*)	0.5 gm
Chavya (*Piper cubeba*)	0.2 gm
Kesar (*Crocus sativa*)	0.1 gm
Pipplimola(piper longum)	0.5 gm
Jeeraka (*Cuminum cyminum*)	0.5 gm
Cinnamon (*Cinnamomum zeylanicum*)	0.1 gm
Ellachi (*Elettaria cardamomum*)	0.1 gm
Tejpata (*Cinnamomum tamala*)	0-1 g

Table 2: Dadimastaka composition.

Ingredients	Quantity
Rocksugar	4 gm
Pomegranate (*Punica granatum*)	32 gm
Cinnamon (*Cinnamomum zeylanicum*)	2 gm
Carom seeds (Trachyspermumammi)	4 gm
Coriander (*Coriandrum sativum*)	4 gm
Triaktu-concoction of ginger (*Zingiber officinale*), long pepper (*Piper longum*) and pepper (*Piper nigrum*)	12 gm
White cumin seeds (*Cuminum cyminum*)	4 gm
Ellachi (*Elettaria cardamomum*)	2 gm
Tejpata (*Cinnamomum tamala*)	2 gm

Preparation of synbiotic variations

Four samples of each product were made by altering the ratios of the ingredients as specified in Table 3.

Organoleptic evaluation by semi-skilled panelists

A sensory assessment was done to assess the acceptability of gluten-free synbiotic formulations, that

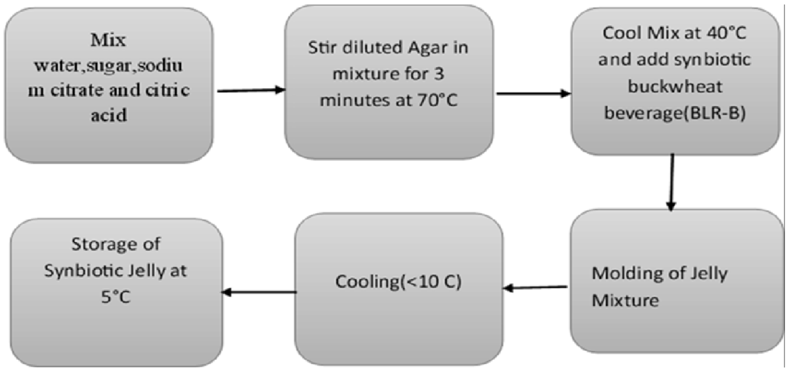

Fig 2: Flowchart of preparation of synbiotic jelly.

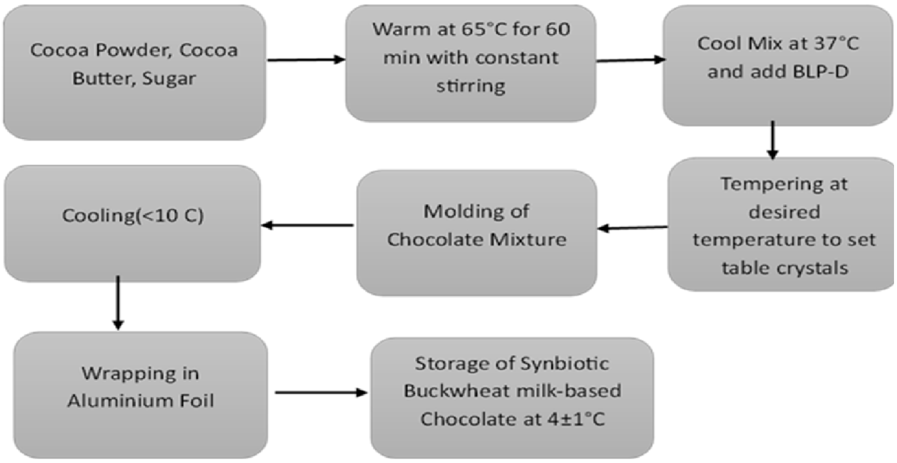

Fig 3: Flowchart of preparation of synbiotic chocolate.

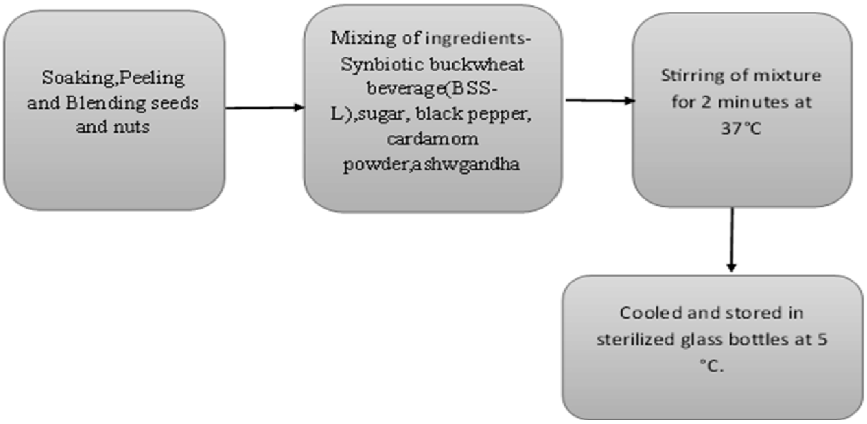

Fig 4: Flowchart of preparation of synbiotic thandai.

involved fifteen semi-trained panelists aged 22 to 35 years. Samples were assigned randomized three-digit codes and evaluated concurrently utilizing a 9-point hedonic scale, wherein scores of 5 or greater indicated suitability (Wichchukit and O'Mahony, 2015).

Proximate analysis

The moisture, dry matter, ash, lipid, crude fiber and protein levels of the selected gluten-free synbiotic items were measured using standard AOAC methods. According to AOAC 934.01, moisture was measured; according to AOAC 922.06, fat was measured; and according to the SP:18 (Part XI, 1981) composite approach, total carbohydrates were quantified. Protein content was quantified using the Kjeldahl method (IS 7219:1961), crude fiber was evaluated via acid-alkali digestion and ash content was determined by furnace incineration (Helrich, 1990; Horwitz, 1980, 2005).

Statistical analysis

Statistical evaluations were conducted using Microsoft Excel 2013, with results expressed as mean±standard deviation. One-way ANOVA was performed to analyze at sensory data, followed by Tukey's post-hoc test ($p<0.05$). The Mean AHP (MAHP) method was employed to assign weights to sensory attributes (Spice-Logic v4.2.7), while TOPSIS was applied in Excel to rank the formulations (Forman and Gass, 2001; Wang *et al*., 2017). The statistical significance ($p<0.05$) was assessed for sensory analysis, probiotic viability and pH measurements.

RESULTS AND DISCUSSION

Proximate composition analysis of various synbiotic formulations

As per nutrition composition depicted in Fig 5, the moisture content of the synbiotic formulations differed significantly ($p<0.05$), with chocolate exhibiting lower moisture (24.97%), which enhances microbial stability, while jelly (88.82%) and thandai (86.11%) demonstrated higher moisture levels due to their aqueous herbal matrix compositions. The protein content ranged from 4.51% to 7.95%, indicating a significant nutritional advantage for individuals adhering to gluten-free diets. Chocolate had the most fat (17.01%) because it has cocoa butter in it, which helps protects germs by forming a lipid matrix. Jelly and thandai had 3.0% and 2.3% fat, respectively. Carbohydrate levels that stayed mostly the same (10-13.23%) contributed to maintaining both the structure and the overall flavor of the food.As illustrated in Fig 5, chocolate exhibited the highest total phenolic content (480 mg GAE/100 g), succeeded by thandai (233 mg GAE/100 g) and jelly (182 mg GAE/100 g), thereby suggesting a favorable impact from the Ayurvedic

Table 3: Formulations various combinations.

Variations	Synbiotic products		
Variation codes (Jelly, chocolate and thandai respectively)	Jelly (Code-100)	Chocolate (Code-200)	Thandai (Code-300)
	BLR-B+Agar+sugar	BLP-D+Cocoa+Butter	BSS-L+Sugar
101,201,301	140 ml+3 gms+40 gms	150 ml+135 gms+75 gms	200 ml+15 gms+10 gms
102,202,302	120 ml+2 gms+30 gms	130 ml+110 gms+55 gms	150 ml+10 gms+8 gms
103,203,303	10 ml+1.2 gms+25 gms	110 ml+85 gms+40 gms	120 ml+ 7 gms+5 gms
104,204,304	80 ml+1 gms+15 gms	90 ml+ 60 gms+30 gms	110 ml+5 gms+4 gms

Abbreviations:

BLR-B-Buckwheat *L. rhamnosus*-bilwadilehyam beverage.

BLP-D: Buckwheat *L. plantarum*-dadimastak beverage.

BSS-L: Buckwheat streptococcus salivarius-licorice beverage.

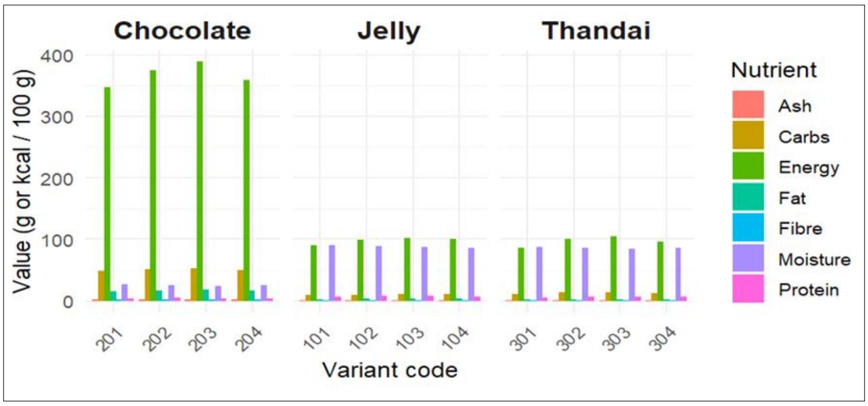

Fig 5: Variant-wise nutrient composition of synbiotic products.

herbal components. These phenolics enhance antioxidant capacity and may mitigate inflammation associated with gluten-free dietary practices (Benguiar *et al*., 2020; Zyżelewicz *et al*., 2021).

The optimized synbiotic formulations' nutritional content and bioactive properties indicate their potential as functional gluten-free foods.

pH

Before fermentation, the buckwheat drinks had a pH of about 6.4-6.5. After 5 hours of fermentation at 37°C, the pH dropped significantly to 4.5-4.7, which means that the bacteria were thriving well. After 3 to 4 hours, the pH of the BLP-D and BLR-B samples dropped considerably, however the BSS-L formulation exhibited the fastest and most effective acidification Fig 5.

During refrigerated storage, the pH levels remained relatively stable, ranging from 4.5 to 5.01, thereby supporting probiotic viability. Thandai samples had a slightly lower pH (≤4.7), which is probably because licorice is acidic. Jelly samples, on the contrary, had a pH around 5.0 since they did not contain any acidic flavoring ingredients. Synbiotic chocolates showed a slightly higher pH (~4.8), suggesting that the chocolate matrix is pH balanced. The results (Table 4) demonstrate that the selection of prebiotic components affects the acidity of the food, which consequently impacts the stability of the probiotics. Keeping the environment slightly acidic helps probiotics survive, which has been demonstrated by previous studies (Yang *et al*., 2024).

The viability of probiotics in synbiotic products

Synbiotic formulations have been developed with *Lactobacillus plantarum* (MTCC 13002), *Lactobacillus rhamnosus* (MTCC 13028) and *Streptococcus salivarius* (MTCC 13009), in conjunction with Ayurvedic prebiotics (Punica granatum peel, Aegle marmelos and licorice) to enhance the survival of probiotics. Viable counts in chocolate, jelly and thandai products commenced at 7.61 to 7.83 log CFU/g and increased up to 7.91 to 8.12 log CFU/g by day 7. By day 21, than dropped slightly to 7.20 to 7.79 log CFU/g (Fig 6).

All of the samples were stable enough to be stored and stayed above the recommended therapeutic level of roughly 7 log CFU/g. The research results suggest that plant-based matrices helped maintain probiotics viable without encapsulation. It illustrates that various prebiotic components regulate microbial viability (Koh *et al*., 2016; Morrison and Preston, 2016).

Sensory assessment of gluten-free synbiotic buckwheat-based products

A sensory evaluation of the synbiotic jelly, chocolate and thandai formulations was conducted, measuring

Table 4: pH of fermented buckwheat beverages during fermentation and storage.

Time	Parameter	BLP-D	BLR-B	BSS-L
0 h	pH	6.550±0.212^{a}	6.550±0.212^{a}	6.410±0.46^{a}
1 h	pH	5.501±0.262^{b}	5.750±0.21^{ab}	5.610±0.481^{b}
2 h	pH	4.860±0.160^{b}	5.085±0.262^{b}	5.200±0.389^{b}
3 h	pH	4.825±0.850^{b}	4.912±0.050^{b}	4.730±0.113^{b}
4 h	pH	4.790±0.156^{b}	4.780±0.000^{b}	4.610±0.212^{b}
5 h	pH	4.695±0.175^{b}	4.795±0.145^{b}	4.475±0.271^{b}
0 day	pH	4.695±0.276^{a}	4.790±0.156^{a}	4.595±0.271^{b}
7 day	pH	4.875±0.035^{a}	4.900±0.000^{a}	4.850±0.071^{ab}
21 day	pH	4.845±0.075^{a}	5.000±0.050^{a}	4.742±0.075^{ab}
28 day	pH	4.915±0.035^{a}	5.000±0.000^{a}	4.975±0.016^{a}

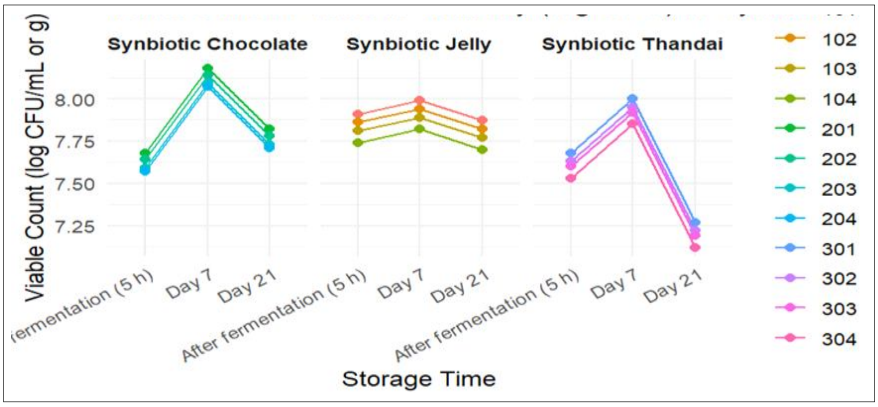

Fig 6: Variant-wise probiotic viability (log CFU/g) of synbiotic products.

appearance, color, texture, flavor, taste and overall acceptability on a 9-point hedonic scale. Tukey's HSD test revealed statistically significant differences among samples within each product category ($p<0.05$). Subsequently, AHP-TOPSIS was employed to determine the weighting of sensory attributes and to provide an objective assessment of the formulations. Tables 5 and 6 summarize the mean sensory assessments and rankings. Among the jelly samples, formulation 102 demonstrated the highest overall acceptance (4.26±0.45), along with superior texture (4.23±0.52) and flavor (4.33±0.48), indicating favorable consistency and taste. Sample 104 scored a significantly lower value (3.60±0.50), suggesting that it might have related to taste and texture.

Owing to its optimal distribution of cocoa fat, formulation 202 of the chocolates received the most favorable scores for color (4.63±0.48), flavor (4.56±0.50) and overall acceptability (4.36±0.49). Conversely, formulation 204 received the lowest evaluation across all criteria.

In thandai formulations, sample 302 received the greatest acceptance (4.36±0.49), corroborated by a favorable flavor (4.56±0.50) and consistency (4.43±0.50), suggesting a well-balanced spice-nut combination. Scores for Sample 401 were significantly lower ($p < 0.05$). The AHP study revealed that taste is the primary attribute across all categories, with overall acceptability ranking next for jelly and chocolate and consistency being prominent for thandai consistent with consumer expectations.

The TOPSIS ranking was generated based on these weights.In the chocolate group, formulation 202 had the highest P*b" score (0.7342), which is consistent with its favorable ratings for color and flavor. Formulations 201 and 204 were rated second, while 203 got the lowest score, probably because it wasn't perceived adequately, according to findings by the sensory post-hoc analysis.

Table 5: Organoleptic evaluation scores of formulations.

Product	Attribute	Mean+SE	Mean+SE	Mean+SE	Mean+SE	F-value	p-value
Jelly	Appearance	8.07±0.68^{a}	8.33±0.67^{a}	7.67±0.88^{b}	7.47±0.99^{b}	3.425	0.023159
Jelly	Colour	8.27±0.65^{a}	8.40±0.66^{a}	7.47±0.61^{b}	7.53±0.81^{b}	7.455	0.000276
Jelly	Consistency	8.20±0.56^{a}	8.30±0.53^{a}	7.60±0.43^{b}	7.43±0.46^{b}	11.267	6.9E-06
Jelly	Taste	8.13±0.72^{a}	8.33±0.67^{a}	7.43±0.86^{b}	7.67±0.77^{b}	4.453	0.0071
Jelly	After taste	7.43±0.59^{b}	7.27±0.68^{a}	8.07±0.68^{a}	7.97±0.61^{a}	5.632	0.001908
Jelly	Overall accept.	7.97±0.97^{a}	8.20±0.59^{a}	7.40±0.87^{ab}	7.53±0.97^{b}	2.778	0.049489
Chocolate	Appearance	8.07±0.88^{a}	7.97±0.74^{a}	7.67±1.01^{a}	7.83±0.79^{a}	0.602	0.616
Chocolate	Colour	7.97±0.69^{ab}	8.17±0.75^{a}	7.63±0.61^{ab}	7.33±0.49^{b}	4.905	0.0043
Chocolate	Consistency	8.20±0.65^{a}	8.47±0.48^{a}	7.80±0.56^{b}	7.53±0.58^{b}	7.903	0.00017
Chocolate	Taste	8.20±0.82^{a}	8.40±0.51^{a}	8.03±0.64^{ab}	7.67±0.77^{b}	2.997	0.038
Chocolate	After taste	7.77±0.73^{b}	7.20±0.41^{c}	8.00±0.63^{ab}	8.07±0.46^{a}	7.132	0.0004
Chocolate	Overall acceptability	8.03±0.85^{a}	8.20±0.68^{a}	7.63±0.52^{b}	7.20±0.46^{c}	7.194	0.0004
Thandai	Appearance	8.10±0.66^{a}	8.27±0.68^{a}	7.67±0.88^{a}	8.07±0.68^{a}	1.824	0.153
Thandai	Colour	7.97±0.48^{a}	8.10±0.54^{a}	7.33±0.59^{b}	7.50±0.57^{b}	6.771	0.0006
Thandai	Consistency	8.27±0.56^{a}	8.37±0.48^{a}	7.80±0.59^{ab}	7.77±0.42^{b}	5.413	0.0024
Thandai	Taste	8.07±0.59^{ab}	8.47±0.67^{a}	7.73±0.78^{b}	7.93±0.59^{ab}	3.284	0.027
Thandai	After Taste	7.80±0.65^{a}	7.57±0.70^{a}	7.87±0.61^{a}	8.07±0.68^{a}	1.457	0.24
Thandai	Overall accept.	8.13±0.97^{a}	8.00±0.65^{a}	7.30±0.90^{b}	7.67±0.70^{b}	3.112	0.033

Table 6: TOPSIS ranking of formulations.

Product	Variation	Si+	Si-	Pi	Rank
Jelly	101	0.00773	0.01695	0.68675	3
Jelly	102	0.00671	0.02449	0.78481	1
Jelly	103	0.02320	0.00718	0.23647	4
Jelly	104	0.02127	0.00720	0.68981	2
Chocolate	201	0.00540	0.01440	0.72780	2
Chocolate	202	0.00730	0.02030	0.73420	1
Chocolate	203	0.01290	0.01050	0.44810	4
Chocolate	204	0.02020	0.00740	0.55780	3
Thandai	301	0.00590	0.01260	0.68210	2
Thandai	302	0.00530	0.01660	0.75690	1
Thandai	303	0.01710	0.00310	0.15460	4
Thandai	304	0.01260	0.00770	0.46120	3

In the thandai formulations,formulation 302 achieved the highest rating (P*ä = 0.7569), ascribed to its favorable flavor and texture attributes, thereby establishing it as the preferred formulation.

Formulations 102, 202 and 302 were identified as the most preferred options through the integrated use of ANOVA, AHP and TOPSIS. This selection indicates substantial customer acceptance and warrants further investigation for potential development.

CONCLUSION AND RECOMMENDATIONS

This study efficiently developed gluten-free synbiotic food products utilizing buckwheat as the primary constituent, offering balanced nutrition, substantial polyphenol content and notable sensory appeal. During storage, the probiotic viability remained above the therapeutic threshold (>7 log CFU/g) and usage of Ayurvedic prebiotics significantly enhanced functional attributes. Variants 102 (jelly), 202 (chocolate) and 302 (thandai) attained the highest ratings from AHP-TOPSIS, suggesting that these products proved more favored among consumers as well as more probable to be acceptable.

These results may offer plant-based, clean-label options suitable for consumers with lactose and gluten intolerances, while also addressing nutritional deficiencies in gluten-free diets. The Ayurvedic synbiotic approach presents substantial commercial prospects and confers supplementary advantages for intestinal well-being.

Further research is required to validate clinical efficacy, improve probiotic stability (*e.g.*, *via* encapsulation) and expand consumer testing to support scalability and wider market adoption.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript. Informed consent. All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

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