Development Of Gluten-Free Superfood Pasta

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Abstract — This study focuses on the development of gluten-free superfood pasta to address the growing demand for nutritious and sustainable food options. Motivated by the increasing prevalence of gluten intolerance and the popularity of health-conscious diets, this project leverages locally sourced, nutrient-rich ingredients such as banana flour, amaranth flour, and horse gram flour. The goal is to create a product that combines nutritional adequacy with sensory appeal, overcoming challenges associated with the absence of gluten in pasta formulations. The scope of this work involves optimizing ingredient ratios to enhance the texture, flavor, and nutritional value of gluten-free pasta. Response Surface Methodology (RSM) was employed to systematically refine the formulation. Key methods included sensory evaluation by semi-trained panels, nutritional analysis, and shelf-life studies under varying storage conditions. The research aims to balance health benefits with consumer preferences for gluten-free pasta products. The findings reveal that the use of flaxseed gel and wheatgrass powder significantly improved the pasta's nutritional profile and texture. Enhanced protein, fiber, and mineral content were observed, aligning with market trends and consumer demands. This study concludes that gluten-free superfood pasta is a viable and appealing alternative to traditional wheat-based pasta, providing both health benefits and sensory satisfaction. Future research can explore scaling production and integrating additional plant-based ingredients for further innovation.

Keywords: Gluten-Free Pasta, Superfood Ingredients, Nutritional Optimization, Banana Flour, Amaranth Flour, Horse Gram Flour, Flaxseed Gel, Wheatgrass Powder, Sensory Evaluation, Response Surface Methodology (RSM)

I. INTRODUCTION

The rising prevalence of gluten intolerance and celiac disease has driven significant growth in the gluten-free food industry, with a projected CAGR of 9.2% from 2022 to 2030. Traditional wheat-based pasta, though widely consumed, is unsuitable for individuals with gluten sensitivity, creating a demand for alternatives that match its texture, taste, and nutritional value. However, many gluten-free pasta options lack essential nutrients like protein, fiber, and iron, necessitating innovative formulations. Researchers are exploring nutrient-rich ingredients such as banana flour, amaranth, horse gram, and wheatgrass to enhance the nutritional profile of gluten-free pasta while maintaining desirable cooking properties.

Advancements in food processing, including hydrocolloid incorporation, enzyme modification, and high-pressure processing, have improved the texture and structural integrity of gluten-free products. Consumer trends indicate a preference for clean-label, high-protein, and fortified gluten-free foods, further driving innovation. This study aims to develop a gluten-free superfood pasta using functional ingredients to offer approximately 10-12% protein, enhanced fiber, and antioxidants, addressing nutritional gaps in existing gluten-free options. By leveraging ingredient optimization and advanced processing techniques, this research contributes to the growing field of gluten-free product development, providing a nutritious and palatable alternative to conventional pasta.

II. LITERATURE REVIEW AND PROBLEM FORMULATION

A. Background Theory

The rise in gluten intolerance and celiac disease has driven demand for gluten-free products. Gluten, found in wheat, barley, and rye, provides elasticity and structure to pasta. Replacing it with hydrocolloids, plant proteins, and resistant starches can improve texture and nutrition. Superfoods like banana flour, amaranth, horse gram, and wheatgrass offer protein, fiber, and antioxidants, but their combined effects in gluten-free pasta remain underexplored.

B. Reviewed Literature

1) Importance of Gluten-Free Diets

Celiac disease affects ~1% of the population, while many experience gluten sensitivity. A gluten-free diet helps prevent inflammation and other health issues. Growing awareness of gut health has increased demand beyond medical necessity.

2) Rising Demand for Gluten-Free Pasta

The market is projected to reach $6.43 billion by 2027. Traditional pasta relies on durum wheat, whereas gluten-free versions use alternative flours but struggle with texture and elasticity. Research suggests optimizing ingredients and processing can enhance product quality.

3) Nutritional and Functional Properties

- Banana flour: High in resistant starch, promotes digestion, and enhances texture.
- Amaranth: Rich in protein and amino acids, improves texture and mineral bioavailability.
- Horse gram: High in protein and fiber, supports glycemic control.
- Flaxseed gel: Binds dough, enhances elasticity, and adds omega-3s.

4) Challenges in Gluten-Free Pasta Development

Gluten-free dough lacks structure, affecting texture and chewability. Hydrocolloids and proteins can improve elasticity. Processing challenges like hydration, extrusion, and drying impact quality and shelf-life.

5) Processing Techniques

Optimized mixing, extrusion, and controlled drying enhance pasta texture and structure. High-temperature, short-time extrusion improves firmness and cooking resistance.

6) Shelf-Life and Storage Stability

Moisture retention, oxidation, and microbial growth impact shelf-life. Modified atmosphere packaging (MAP) and natural preservatives can enhance stability.

7) Quality Evaluation

Texture analysis assesses firmness and chewiness. Cooking loss, water absorption, and swelling index affect sensory properties. Fortification with legumes and pseudocereals improves nutrition.

8) Future Trends and Innovations

Advancements include enzyme treatments, protein fortification, and prebiotic fiber integration. Research aims to optimize texture, nutrient bioavailability, and consumer appeal.

C. Problem Formulation

Despite growing gluten-free pasta options, many lack nutritional value. Superfoods can enhance these formulations, but maintaining sensory appeal, texture, and stability remains a challenge. This study aims to develop a nutrient-rich gluten-free pasta that meets dietary needs without compromising quality.

III. Materials and Methods

Pasta was made using banana, amaranth, horse gram flours, wheatgrass powder, and xanthan gum. Steps included mixing, dough formation, extrusion, and drying. Functional, sensory (9-point scale), and nutritional analyses were done. Shelf-life studies ensured stability.

A. Materials:

Chemicals: Analytical-grade; glassware sterilized.
Ingredients:

- Banana flour: Airtight at 25°C
- Amaranth flour: Vacuum-sealed, room temp
- Horse gram flour: Moisture-proof pouches
- Wheatgrass powder: 4°C in amber jars
- Xanthan gum: Cool, dry, sealed

B. Methodology

Preparation of Gluten-Free Pasta
The flour blend was mixed, sifted, and kneaded with water into a firm dough using industrial equipment. After 30 minutes of resting, it was shaped, dusted with banana flour, and dried at 45–50°C for 6–8 hours (moisture <10%).
Cooled pasta was packed in 50g PET pouches to maintain freshness and shelf life.

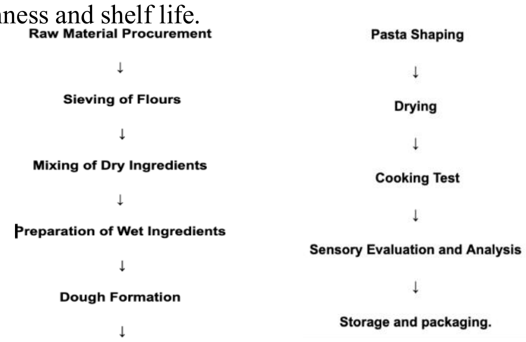

Fig. 3.1: Flow chart for the method of preparation of Gluten-Free Pasta

a)

b)

b) Sieving flour
c) Mixing of ingredients

c) Dough formation

d) Pasta shaping

e) Pasta drying using tray dryer

f) Storage and packaging

1) Wheatgrass Powder Incorporation:

Wheatgrass powder, rich in nutrients and antioxidants, was blended into the dry mix for uniform distribution, enhancing nutrition and color.

2) Proportion Standardization & Trials:

Flour ratios were optimized through trials, keeping xanthan gum fixed at 1.5g.
Trial 1: Varied proportions of banana, amaranth, and horse gram flours (see Table 4.1).

Ingredients	Trial 1	Trial 2	Trial 3	Trial 4
Banana Flour	60	50	40	30
Amaranth Flour	30	35	40	45
Horse Gram	10	15	20	25

*Note: 1.5g of Xanthan gum is added to all samples.
Table 3.1: Standardization of proportions- Trial 1

Trial 1: Dough had good elasticity; pasta was slightly brittle after drying with moderate cooking loss and firm texture.
Trial 2: Used new flour ratios (see Table 4.2).

Ingredients	Trial 1	Trial 2	Trial 3
Banana Flour	50	40	30
Amaranth Flour	35	40	45
Horse Gram	15	20	25

Note: 1.5g of Xanthan gum is added to all samples.
Table 3.2: Standardization of proportions- Trial 2

Trial 2: Better elasticity and firmness, but cooking loss remained slightly high.
Trial 3: Tested new flour ratios (see Table 3).

Ingredients	TRIAL 1	TRIAL 2	TRIAL 3
Banana Flour	50	40	30
Amaranth Flour	35	40	45
Horse Gram	15	20	25

Note: 4g Wheat grass powder and 1.5g Xanthan gum is added for all samples.
Table 3.3: Standardization of proportions- Trial 3

Trial 3: Ratios (B: A:H = 50:35:15, 40:40:20, 30:45:25) with 4g wheatgrass powder showed best acceptability—good firmness, elasticity, and low cooking loss.
Trial 4: Used new flour ratios (see Table 4).

Trial	BaseCompositio (B:A:H))	Sample	Wheat Grass Powder (g)	Xanthan gum
Trial 4	30:45:25	Sample 1 (Control)	0	2.5
		Sample 1 + WG	2.5	2.5
		Sample 2 + WG	5	2.5
		Sample 3 + WG	7.5	2.5

*Note: 1.5g of Xanthan gum is added to all samples. WG- Wheat Grass

Table 3.4: Standardization of proportions- Trial 4

Trial 4: Tested 2.5g, 5g, and 7.5g wheatgrass; 2.5g had highest acceptability—higher doses caused bitterness.
Trial 5: Bulk production using optimized blend (B:A:H = 30:45:25 + 2.5g WG); tested for microbial stability.
Trial 6: Shelf-life study over 2 months in PET packs with periodic microbial and sensory checks.

C. *Functional Properties of Flour*

1) *Swelling Power*

Indicates flour's water absorption and expansion during heating, impacting texture. Measured by heating 1g flour in 10mL water at 90°C for 30 mins, then centrifuging at 3000 rpm for 10 mins. Sediment weight is used to calculate swelling power.

Swelling Power (g/g) =Weight of sediment/Weight of dry sample

Important for understanding flour behavior during cooking, especially in pasta and bread.

2) *Oil Absorption Capacity*

Indicates flour's ability to retain oil, crucial for texture in snacks. Measured by mixing 1g flour with 10mL oil, resting 30 mins, centrifuging at 3000 rpm, then weighing absorbed oil.

Oil Absorption Capacity (g/g) = Weight of absorbed oil/ Weight of dry sample

3) *Water Absorption Capacity*

Shows how much water flour absorbs for dough. 1g flour is mixed with 10mL water, rested 30 mins, centrifuged at 3000 rpm, and absorbed water is measured.

Water Absorption Capacity (g/g) = Weight of absorbed water/Weight of dry sample

D. *Proximate Analysis*

Measures moisture, protein, fat, fiber, ash, and carbs to assess food's nutrition and quality. Uses standard methods (e.g., oven drying, Kjeldahl, Soxhlet). Carbs are calculated by difference. Essential for labeling and product development.

1) *Moisture Content*

Assessed by drying 5g pasta at 105°C (AOAC 925.10) until constant weight. Calculated from weight loss; affects shelf life and texture.

Moisture (%) =Final weight (g) – Initial weight (g) x 100/ Sample weight

2) *Crude Protein*

Estimates protein via total nitrogen (AOAC 984.13) using digestion, neutralization, distillation, and titration.

Kjeldahl Method Steps:
Digestion: Sulfuric acid converts nitrogen to ammonium sulfate.
Distillation: NaOH releases ammonia, absorbed in boric acid.
Titration: Ammonia is titrated with standard acid to measure nitrogen.

$$Protein\ (\%) = \frac{(Titer\ value - blank)\ x\ Normality\ of\ H2SO4\ x\ 14.007x6.25}{Sample\ weight\ (g)} \times 100$$

This method is widely used for protein estimation due to its accuracy and ability to measure total nitrogen.

3) *Fat Content*

Soxhlet Extraction Method (AOAC 954.02):
Sample in a thimble is repeatedly washed with heated solvent; fat is extracted, solvent evaporated, and fat weighed.

Crude fat (%) = Initial weight (g) - weight after extraction / Sample weight (g) x100

Crude Fiber Determination (AOAC 962.09):
Sample is treated with acid and alkali, then dried, weighed, and ashed. Fiber is calculated from weight difference
Crude Fiber (%)=(WW1−W2)×100

4) *Ash Content*

Ash Content (AOAC 923.03):
Sample is incinerated at 550°C for 5 hrs. Residue (ash) is weighed to calculate mineral content.

Formula:

Ash (%) = (Weight of crucible with ash / Weight of crucible with sample) × 100

5) *Carbohydrate Content*

Carbohydrates by Difference:
Calculated as:

Carb (%) = 100 - (Moisture + Protein + Fat + Ash + Fiber)

Used when direct testing isn't feasible.

6) *Energy Content:*

Energy (AOAC 920.87):

Calculated using:

Energy (kcal) = (Protein × 4) + (Fat × 9) + (Carbs × 4)

Indicates caloric value and diet suitability.

7) *Calcium Content:*

Measured by atomic absorption spectrophotometer after sample prep. Indicates calcium levels, important for bone health.

8) *Iron and Vitamin C*

Iron (AOAC 944.02): Sample is digested with nitric acid and analyzed via AAS. Vitamin C (AOAC 967.21): Measured by DCPIP titration based on dye decolorization. Both are key for nutritional evaluation.

Nutrient	AOAC Method	Chemicals Used	Quantity of Chemicals
Moisture	925.10	None (hot air oven)	Not Applicable
Crude Protein	984.13	H2SO4, NaOH, Boric acid	5 mL (H2SO4), 40 mL (NaOH)
Fat Content	954.02	Petroleum Ether	200 mL
Crude Fiber	962.09	H2SO4, NaOH	100 mL (each solution)

Carbohydrates	Difference	Not Applicable	Not Applicable
Energy Content	920.87	None (caloric calculation)	Not Applicable

*Note: AOAC method 2023.

Table 3.5: Chemicals used for macronutrients analysis

Nutrient	AOAC Method	Chemical Used	Quantity of Chemicas
Ash Content	923.03	None (mufle furnace)	Not Applicable
Calcium Content	984.27	Atomic absorption reagents	As per AAS protocol
Iron Content	944.02	Nitric acid	5 mL
Vitamin C	967.21	DCPIP solution, Metaphosphoric acid	20 mL (DCPIP), 40 mL (HMPA)

*Note: AOAC method 2023.

Table 3.6: Chemicals used for macronutrients analysis

E. *Shelf-Life Stability Studies*

Gluten-free pasta was stored in PET packs at 25°C, <55% RH for 2 months, tested every 10 days for:

- Microbes: Total bacteria, fungi, coliforms (using agar media).
- Moisture: Oven drying; rise indicated spoilage.
- Texture/Color: Via texture analyzer and spectrophotometer.
- Rancidity: Assessed using TBA assay.

1) *Sensory Evaluation*

Sensory evaluation used a 9-point hedonic scale for appearance, texture, taste, aroma, and overall acceptability.

- Panel: 15 trained members (Food Nutrition & Dietetics).
- Conditions: Warm samples; palate cleansing between tests.
- Analysis: ANOVA to identify significant sensory differences over time

IV. RESULTS AND DISCUSSION

A. *Optimization of Gluten-Free Superfood Pasta Formulation*

1) *Trial 1: Base Proportions of Flours*

- Tested: B: A:H = 30:45:25, 50:35:15, 40:40:20
- 50:35:15 & 40:40:20 rejected (brittle, high cooking loss)
- 30:45:25 chosen for ideal firmness & elasticity

2) *Trial 2: Wheatgrass Powder Incorporation (4g)*

- 4g wheatgrass added to all formulations
- 30:45:25 + wheatgrass accepted (score: 7.53)
- Others rejected for brittle texture

3) *Trial 3: Validation of Proportions*

- Sensory tests confirmed 30:45:25 + 4g wheatgrass as best.
- Significant differences found ($p = 0.002$).
- 50:35:15 and 40:40:20 rejected due to lower scores.

4) *Trial 4: Variation in Wheatgrass Powder Levels*

- 30:45:25 tested with 2.5g, 5g, and 7.5g wheatgrass.
- 5g and 7.5g rejected for green tint, bitterness, and coarse texture.
- 2.5g wheatgrass had highest acceptability (score: 7.10).

5) *Trial 5: Bulk Production and Microbial Stability*

- Bulk prepared: 30:45:25 + 2.5g wheatgrass (10 × 50g, PET packed).
- Minimal microbial growth observed.
- 5g & 7.5g wheatgrass samples excluded due to poor sensory scores.

6) *Trial 6: Shelf-Life Evaluation*

- Stored (30:45:25 + 2.5g wheatgrass) for 2 months at room temp in PET.
- Maintained color, texture, flavor; minimal fungal growth.
- Shelf-stable and commercially viable.

B. *Sensory Evaluation*

A 9-point hedonic scale was used to evaluate sensory attributes. The control scored highest, followed closely by 30:45:25 + 2.5g wheatgrass. Higher wheatgrass levels reduced color, taste, and texture acceptability.

1) *Sensory Attributes Analysis*

The control sample had the best appearance, color, taste, and texture, with 2.5g wheatgrass closely matching. Higher wheatgrass levels caused bitterness, grassy flavor, and coarse texture. The optimized 30:45:25 + 2.5g wheatgrass showed good sensory and nutritional quality, suitable for commercial use.

Proportion (B:A:H)	Appearance	Colour	Taste	Flavour	Texture	Overall acceptability
Control	7.67	7.93	7.76	7.63	7.13	7.70
60:30:10	6.48	6.33	6.75	6.32	6.30	6.54
50:35:15	7.30	7.26	7.36	7.13	7.26	7.03
40:40:20	6.83	6.90	6.93	6.66	6.76	6.86
30:45:25	7.60	7.66	7.63	7.40	7.56	7.53
P Value	0.034	0.003	0.008	0.04	0.27	0.003
Standard Deviation	0.75	0.68	0.87	1.09	0.67	1.02

*Note: Anova is used for statistical analysis. Banana flour (B): Amaranth flour (A): Horse gram flour (H).

Table 4.1: Trial 1 - Organoleptic evaluation of pasta using varied proportions

2) *Sensory Evaluation of Control and Varied Formulations*

Table 5.1 shows that the 30:45:25 blend had the best sensory scores, similar to the control in appearance, taste, texture, and flavor. Higher fiber gave firmer texture, while lower protein made others dry. Statistical analysis ($p < 0.05$) confirmed its sensory superiority.

Proportion (B:A:H)	Appearance	Colour	Taste	Flavour	Texture	Overall acceptability
Control	7.76	7.39	7.66	7.83	7.38	7.80
50:35:15	7.50	7.26	7.36	7.13	7.26	7.43
40:40:20	6.83	6.90	6.93	6.66	6.76	6.86
30:45:25	7.60	7.86	7.69	7.44	7.32	7.53
P Value	0.003	0.04	0.04	0.002	0.17	0.003
Standard Deviation	1.02	0.84	0.68	0.73	0.81	0.75

*Note: Anova is used for statistical analysis. Banana flour (B): Amaranth flour (A): Horse gram flour (H)

Table 4.2: Trial 2 - Organoleptic evaluation of pasta using varied proportions of flours.

3) Sensory Evaluation of Control and Wheatgrass Powder Samples

Proportion (B:A:H)	Appearance	Colour	Taste	Flavour	Texture	Overall acceptability
50:35:15	7.67	7.54	7.98	7.14	7.36	7.53
40:40:20	6.73	6.93	6.23	6.99	6.16	6.83
30:45:25	7.80	7.46	7.59	7.47	7.54	7.33
P Value	0.004	0.02	0.03	0.003	0.14	0.002
Standard Deviation	1.01	0.84	0.92	0.61	0.88	1.02

Wheatgrass at 2.5g per 100g pasta had sensory scores close to the control. Higher levels (5g, 7.5g) caused bitterness, darker color, and coarse texture, reducing acceptability.

Table 4.3: Trial 3 - Organoleptic evaluation of pasta using varied proportions of flours.

*Note: Anova is used for statistical analysis. Banana flour (B): Amaranth flour (A): Horse gram flour (H)

4) Statistical Significance and Interpretation

Sample 1 (30:45:25 + 2.5g wheatgrass) matched the control in sensory quality. Stats ($p < 0.05$) support its suitability. Higher wheatgrass (5g, 7.5g) reduced acceptability due to bitterness, coarse texture, and color. Balancing ingredients is key.

Proportion (B:A:H)	Appearance	Colour	Taste	Flavour	Texture	Overall acceptability
C: (30:45:25)	7.42	7.52	7.47	7.42	7.42	7.31
C + WG (2.5)	7.31	7.26	7.21	7.15	6.94	7.10
C + WG (5)	6.94	6.89	6.63	6.68	6.78	6.84
C + WG (7.5)	7.05	6.89	6.57	6.63	6.57	6.57
P Value	0.32	0.06	0.005	0.02	0.10	0.007
SD	0.69	0.88	1.02	0.61	0.86	1.01

*Note: Anova is used for statistical analysis. Banana flour (B): Amaranth flour (A): Horse gram flour (H) + Wheat grass (WG)

Table 4.4: Trial 4 - Organoleptic evaluation of pasta using varied proportions of wheat grass.

5) Result of the Sensory Evaluation of Control and Wheatgrass Powder Samples

Sample 1 (30:45:25 + 2.5g wheatgrass) was most acceptable, resembling the control with good sensory traits. Moderate wheatgrass use is feasible. Further studies can confirm its commercial potential.

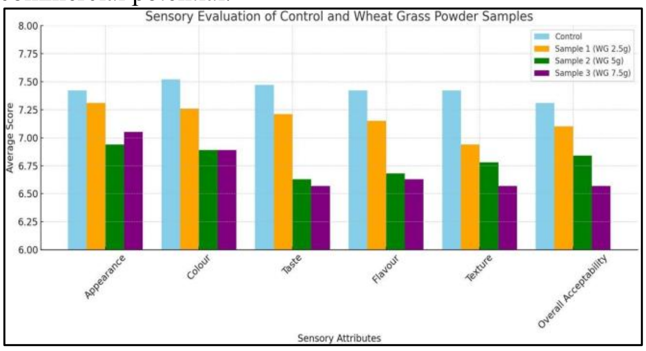

Fig. 4.1: Graphical Representation of the sensory evaluation of control and control with varied proportions of wheat grass powders.

C. Functional Properties of Flours and Their Contribution to Pasta Formulation

Swelling power, OAC, and WAC of banana, amaranth, and horse gram flours were studied to improve pasta texture, elasticity, and stability.

1) Swelling Power (SP):

Swelling power affects pasta texture by indicating water absorption during heating. Banana flour (6.0) improved cohesiveness, amaranth (4.5) added elasticity, and horse gram (3.5) gave structure.

2) Oil Absorption Capacity (OAC):

OAC affects pasta's texture and flavor. Horse gram (2.0 g/g) added richness, amaranth (1.4) balanced it, and banana flour (1.2) kept it light.

3) Water Absorption Capacity (WAC):

WAC impacts dough and elasticity. Horse gram (2.5 g/g) gave strength, amaranth (1.8) added pliability, and banana flour (1.5) reduced stickiness.

Integration of Functional Properties in the Final Formulation

The 30:45:25 blend gave firm, cohesive pasta with minimal cooking loss. Adding 2.5g wheatgrass improved nutrition and taste. Higher levels reduced acceptability. Final product showed 2-month shelf stability, supporting its commercial potential.

Parameter	Banana Flour	Amaranth Flour	Horse Gram Flour
Swelling Power	6.0	4.5	3.5
Oil Absorption Capacity (OAC)	1.2 g/g	1.4 g/g	2.0 g/g

Water Absorption Capacity (WAC)	1.5 g/g	1.8 g/g	2.5 g/g

Table 4.5: Physical Properties of Flour

D. Nutritional Composition Analysis

The nutritional composition of gluten-free superfood pasta was analyzed to ensure a balanced macronutrient and micronutrient profile while maintaining sensory acceptability.

1) Macronutrient Composition

The gluten-free pasta offers 351.52 Kcal/100g, with 13.61g protein, 67.33g carbs, 2.74g fat, and 8.4g fiber. Low moisture (8.92%) and ash (0.56%) indicate good shelf life and mineral content. It suits gluten-sensitive, health-focused consumers.

2) Micronutrient Composition

The pasta delivers 7.35 mg iron, 155.3 mg calcium, and 4.29 mcg vitamin C. Wheatgrass boosts these, adding functional value.

Nutrients	Per 100 g	AOAC Method
Energy (Kcal)	351.52	AOAC 920.87
Protein (g)	13.61	AOAC 984.13
Carbohydrate (g)	67.33	AOAC 986.25
Fat (g)	2.74	AOAC 954.02
Crude Fiber (g)	8.4	AOAC 962.09
Moisture (%)	8.92	AOAC 925.10
Ash Insoluble (%)	0.56	AOAC 923.03
Iron (mg)	7.35	AOAC 944.02
Vitamin C (mcg)	4.29	AOAC 967.21
Calcium (mg)	155.3	AOAC 984.27

Table 4.6: Nutritional Composition per 100g: AOAC Method 2023.

E. Role of Individual Ingredients in Nutritional Enhancement

Legume protein (30%) gives amino acids, carbs (45%) offer energy, and 2.5g wheatgrass adds nutrients. Higher wheatgrass (5–7.5g) lowers taste, needing balance.

F. Nutritional Significance and Health Benefits:

The pasta fits modern diets—high fiber aids digestion, vitamin C boosts iron absorption, calcium/magnesium support bones and nerves, and zinc with vitamin C strengthens immunity.

Nutrients	Per 100 g	RDA (Sedentary Male)	RDA (Sedentary Female)
Energy (Kcal)	351.52	2320 Kcal	1900 Kcal
Protein (g)	13.61	60 g	55 g
Carbohydrate (g)	67.33	130 g	130 g
Fat (g)	2.74	25 g	20 g
Crude Fiber (g)	8.4	30 g	25 g
Moisture (%)	8.92	-	-
Ash Insoluble (%)	0.56	-	-
Iron (mg)	7.35	17 mg	21 mg
Vitamin C (mcg)	4.29	40 mg	40 mg
Calcium (mg)	155.3	1000 mg	1000 mg

Table 4.7: Gives the Recommended Dietary Allowance (RDA) for sedentary male and female:

G. Future Research Considerations for Nutritional Optimization

Future studies can refine ingredients for better nutrition and taste, test new plant proteins for amino acid balance, explore fortification, and assess nutrient stability. This supports the pasta's role as a functional, gluten-free option for health-conscious users.

1) Cost analysis of ingredients and final product pricing

The 100g pasta costs ₹21.95: Banana and Amaranth Flour ₹9.00 each, Horse Gram ₹1.25, Wheatgrass ₹1.20, Xanthan Gum ₹1.50. At 500g, cost is ₹109.75. This supports pricing, planning, and feasibility.

2) Pricing, Profit, and Return on Investment (ROI) Analysis with 25 per cent Profit Margin

With a 25% margin, 100g sells at ₹27.44 (₹5.49 profit) and 500g at ₹137.19 (₹27.44 profit). ROI is 25%, supporting profitability and sustainability.

3) Projected ROI by 2026:

By 2026, ROI may rise to 30–35% due to bulk buying, efficient production, and growing demand for functional foods. Retail, e-commerce, and bulk supply expansion will boost sales, supporting long-term growth and profitability.

H. Discussion

This chapter summarizes the development of gluten-free superfood pasta, focusing on ingredient optimization, processing, sensory and nutritional evaluation, and market potential, with comparisons to existing studies.

1) Optimization of Ingredient Ratios

The optimized gluten-free pasta (30:45:25) balanced nutrition and sensory appeal. Banana flour aided gut health (Ovando-Martínez et al., 2020), amaranth improved protein and texture (Alvarez-Jubete et al., 2019), and horse gram added fiber and glycemic benefits (Rao et al., 2021). Wheatgrass (2.5g) boosted antioxidants, but higher doses affected taste (Stevenson et al., 2020).

2) Processing Techniques and Their Impact

Gluten-free pasta development used xanthan gum for structure, supporting Gularte et al. (2019). Extrusion ensured consistent texture (Petitot et al., 2019). Drying at 45–50°C for 6–8 hrs reduced moisture <10%, aiding shelf life (Bustos et al., 2020). Wheatgrass was blended evenly to avoid taste/color issues. Hydrocolloids improved texture and cooking resistance (Martinez et al., 2021).

3) Sensory Evaluation

Sensory evaluation using a 9-point hedonic scale showed that the 30:45:25 blend with 2.5g wheatgrass scored highest, resembling the control ($p < 0.05$). It had good texture, taste, and color, supporting Almeida et al. (2021). Higher wheatgrass (5g–7.5g) reduced scores, confirming Stevenson et al. (2020) on the need to balance nutrition and sensory appeal.

4) Nutritional Assessment

The gluten-free pasta offers 351.52 kcal/100g, with 13.61g protein, 67.33g carbs, 8.4g fiber, and 2.74g fat—ideal for nutrient-dense diets. Iron (7.35mg), calcium (155.3mg), and vitamin C (4.29mcg) boost its value. These results align with Capriles & Arêas (2019), Rosell et al. (2019), and Zannini et al. (2020) on fortified, high-protein gluten-free foods.

5) Shelf-Life Stability Studies

Two-month shelf-life tests showed the pasta remained stable in PET packaging. Moisture and nutrients stayed consistent, with no spoilage. Color and texture changed minimally. PET packaging protected against moisture, oxygen, and light—supporting Mastromatteo et al. (2019) and Guiné et al. (2021). Results confirm the product's commercial viability.

6) Implications for Gluten-Free Product Development

This study shows gluten-free pasta can be a protein- and fiber-rich option. Adding 2.5g wheatgrass gave nutrition without harming taste. Higher levels affected texture, needing careful balance. As interest in functional foods rises, market potential grows, though consumer familiarity with wheatgrass matters. Tech upgrades like better extrusion may improve texture. More research is needed on storage and nutrient retention.

7) Commercialization and Market Potential

Gluten-free superfood pasta fits today's health trends. It's rich in nutrients, gluten-free, and tasty—great for those avoiding gluten. To sell well, focus on its health benefits and eco-friendly angle. Selling through health stores, online sites, and with dietitians can help. As demand grows for clean, healthy foods (Market Research Insights, 2023), this pasta has real market value. Using better machines and bulk-making can also cut costs and boost quality.

8) Cost analysis of ingredients and final product pricing

Cost analysis shows a 100g batch costs ₹21.95 using Banana Flour, Amaranth Flour, Horse Gram, Wheatgrass, and Xanthan Gum. At 500g, the cost is ₹109.75. This helps balance pricing and profit.

9) Pricing Strategy and Profit Margin Considerations

A 25% profit margin sets selling prices at ₹27.44 (100g) and ₹137.19 (500g), ensuring affordability and sustainability. Bulk buying, automation, and direct sales can boost profits. Nutritional value and clean-label appeal support pricing and build brand trust.

10) Projected Return on Investment (ROI) and Future Market Trends

A 25% ROI ensures financial sustainability, with projections of 30–35% by 2026 due to cost optimization, growing demand for functional foods, expanded sales channels, and product innovation. These factors support scale, market reach, and long-term profitability.

V. Conclusions and Future Directions

A. Conclusion

This study developed a nutritionally enhanced gluten-free pasta using banana, amaranth, horse gram flours, and wheatgrass powder. The optimized formulation improved protein (13.61 g/100 g), fiber (8.4 g/100 g), iron (7.35 mg/100 g), and calcium (155.3 mg/100 g), with strong sensory acceptability. It offers functional benefits, market potential, and promotes sustainability by using underutilized crops. Future work may focus on scaling, fortification, and processing improvements to boost shelf life and market viability.

B. Future Directions

Marketing will focus on health benefits, digital outreach, retail partnerships, and influencer collaborations. Shelf life will be improved through MAP, biodegradable, and smart packaging. Scaling will involve automation, training, and process refinement. Regular consumer feedback will guide product tweaks. Expansion includes new flavors, fortified versions, and complementary gluten-free products. Ethical sourcing and sustainability through fair trade, alternative proteins, and LCAs will further strengthen market positioning.

References

[1] Lee AR, Newman J. Celiac disease: Pathogenesis and clinical management. Clin Rev Food Allergies, 34(6), 2003. [1]

[2] Tonutti L, Bizzaro G. Gluten-free diet in celiac disease: What we know and what we still need to learn. Clin Rev Allergy Immunol, 47(1), 2014. [2]

[3] Ivarsson A, Myleus A, Norström F, et al. Celiac disease diagnosed in Swedish children: Epidemiology and implications. Pediatr Gastroenterol Nutr, 56(4), 2013. [3]

[4] Catassi C, Fasano A. Celiac disease. Lancet, 383(9936), 2014. [4]

[5] Ludvigsson JF, Green PH. Clinical management of celiac disease. JAMA, 306(15), 2011. [5]

[6] Mearin ML, Catassi C. Gluten-free diet in children with celiac disease. Dig Liver Dis, 49(4), 2017. [6]

[7] Macdonald D, Miele E. Celiac disease and gluten-free diet: An overview. J Clin Gastroenterol, 51(5), 2017. [7]

[8] Meyer D, Vogel R. Trends in the gluten-free diet. J Nutr, 149(7), 2019. [8]

[9] Petroni M, Zampetti C. The gluten-free diet: Challenges and benefits. Nutr Rev, 78(9), 2020. [9]

[10] Granfeldt Y, Bjorck I. Health implications of gluten-free diets. J Nutr Health, 18(2), 2019. [10]

[11] Miele E, Macdonald D. Gluten-free food: Market dynamics. J Am Diet Assoc, 118(9), 2017. [11]

[12] Repo-Carrasco-Valencia R, Hellström JK, Pihlava JM, Mattila PH. Flour from quinoa, kañiwa, and amaranth. Food Chem, 120(1), 2010. [12]

[13] Alvarez-Jubete L, Arendt EK, Gallagher E. Nutritive value of pseudocereals. Trends Food Sci Technol, 20(11-12), 2009. [13]

[14] Tosi EA, Ré MI, Masciarelli R. Gluten-free flatbread with pseudocereals. J Food Sci Technol, 57(9), 2020. [14]

[15] Martínez MM, Gómez M. Nutritional quality of gluten-free bread. Food Sci Technol Int, 23(3), 2017. [15]

[16] Rastogi A, Shukla S. Amaranth: A crop of nutraceutical values. Crit Rev Food Sci Nutr, 53(2), 2013. [16]

[17] Foschia M, Horstmann S, Arendt EK, Zannini E. Nutritional therapy in coeliac disease. Int J Food Microbiol, 239, 2016. [17]

[18] Astrup A, Dyerberg J, Selleck M, Stender S. Dietary guidelines and evidence. Public Health Nutr, 7(1a), 2004. [18]

[19] Hu FB. Impact of low-carb, high-fat diets. Lancet Diabetes Endocrinol, 1(1), 2013. [19]

[20] Jones JM, Peña RJ, Korczak R. Carbohydrates, obesity, and health. Nutr Rev, 78(8), 2020. [20]

[21] WHO. Obesity and overweight fact sheet. World Health Organization, 2022. [21]

[22] Ludwig DS, Ebbeling CB, Heymsfield SB. Dietary carbohydrates in health. JAMA, 320(23), 2018. [22]
[23] Slavin JL. Fiber and prebiotics: Health benefits. Nutrients, 5(4), 2013. [23]
[24] McKeown NM, Meigs JB, Liu S, et al. Whole-grain intake and insulin sensitivity. Am J Clin Nutr, 86(6), 2009. [24]
[25] Moore RJ, et al. Celiac disease in children. Pediatrics, 113(3), 2004. [25]
[26] Fasano A, Catassi C, Araya M. Challenges in gluten-free diets. Nat Rev Gastroenterol Hepatol, 11(11), 2014. [26]
[27] Augustin LSA, Kendall CW, Jenkins DJ, et al. Glycemic index and response. Nutr Metab Cardiovasc Dis, 25(9), 2015. [27]
[28] Padhi EMT, Blewett HJ, Duncan AM, Nagodawithana T. Nutritional properties of pulses. J Agric Food Chem, 65(5), 2017. [28]
[29] Lassaletta L, Billen G, Garnier J, Bouwman L. Sustainability of European agriculture. Environ Res Lett, 9(9), 2014. [29]
[30] Blekkenhorst LC, Prince RL, Devine A, et al. Vegetables and cardiovascular health. Eur J Clin Nutr, 72(9), 2018. [30]
[31] Gebremariam MM, Zarnkow M, Becker T. Teff as gluten-free raw material. J Food Sci Technol, 51(11), 2014. [31]
[32] Matos ME, Rosell CM. Quality of gluten-free bread. Food Rev Int, 31(3), 2015. [32]
[33] Schoenlechner R, Drausinger J, Ottenschlaeger V, et al. Properties of gluten-free pasta. Plant Foods Hum Nutr, 65(4), 2010. [33]
[34] Susanna S, Prabhasankar P. Gluten-free pasta validation. LWT - Food Sci Technol, 50(2), 2013. [34]
[35] Lemmens E, De Brier N, Celus I, et al. Shelf life of gluten-free pasta. J Cereal Sci, 87, 2019. [35]
[36] Marco C, Mancebo CM, León AE. Gluten-free pasta under refrigeration. Food Sci Technol Int, 28(4), 2022. [36]
[37] Hutchings JB, Carter P, Webb N. Consumer preferences for gluten-free pasta. Int J Consum Stud, 44(3), 2020. [37]
[38] Marco C, et al. Effect of refrigerated storage on pasta. Food Sci Technol J, 25(5), 2022. [38]
[39] Tola A, et al. Scaling gluten-free pasta production. J Culinary Sci Technol, 19(4), 2021. [39]
[40] Hutchings B, et al. Market analysis of gluten-free pasta. Int J Food Mark, 8(2), 2020. [40]
[41] Singh N, et al. Optimization of gluten-free dough. J Food Process Eng, 32(6), 2018. [41]
[42] Yousefi A, et al. Drying techniques for gluten-free pasta. J Food Eng, 98(7), 2020. [42]

