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Development and Sensory Evaluation of Gluten-Free Samosa with Ragi, Jowar and Bajra Crusts

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Abstract: *The rising prevalence of celiac disease and non‑celiac gluten sensitivity has escalated demand for gluten-free alternatives of traditional foods. Millets, such as finger millet (ragi), sorghum (jowar), and pearl millet (bajra), are naturally gluten‑free and nutritionally rich, offering potential in creating acceptable gluten‑free snacks. This study aimed to develop samosa crust alternatives using ragi, jowar, and bajra flours, evaluating sensory acceptability, nutritional composition, and potential health benefits. Three experimental samosa formulations replacing wheat crust with each millet flour and one control (wheat crust) were prepared. Sensory evaluation was conducted by a panel of judges rating appearance, texture, color, flavor, taste, doneness, and overall acceptability. Nutritional analyses included macronutrients, dietary fiber, minerals, vitamins, and bioactive compounds. Results showed that millet‑based samosas had slightly lower gluten-like texture but significant gains in dietary fiber, minerals (iron, calcium), and bioactive compounds. The jowar‑based samosa had the highest acceptability among experimental variants. Millets' incorporation could provide viable gluten‑free alternatives to traditional wheat samosas without severely compromising sensory qualities.*

Keywords: *Millets, Gluten‑free, Samosa, Sensory evaluation, Nutritional composition, Non‑celiac gluten sensitivity.*

1. INTRODUCTION

Gluten, a composite of storage proteins found in wheat, barley, and rye, elicits an immune-mediated enteropathy in individuals with celiac disease, which affects approximately 1% of the global population (1). Non‑celiac gluten sensitivity (NCGS), a condition whereby individuals exhibit symptoms similar to celiac disease upon gluten ingestion without serological or histological markers of celiac disease, affects an estimated 5‑7% of general populations (2). These conditions have driven interest in gluten‑free diets beyond those medically diagnosed, as consumers perceive additional health benefits and seek to avoid refined wheat flour and processed foods (3).

Traditional snacks such as samosas, ubiquitous in South Asian cuisine, typically utilize wheat‑based crusts, which are not feasible for gluten‑free diets. The critical challenge is finding gluten‑free flours that deliver acceptable taste, texture, structure, and nutritional value. Millets—including finger millet (ragi), sorghum (jowar), and pearl millet (bajra)—are promising candidates. They are inherently gluten‑free and rich in macronutrients, micronutrients, fiber, and bioactive phytochemicals (4 & 5).

Millets are also drought tolerant, require fewer inputs such as water and pesticides, and are resilient to climatic extremes, making them sustainable alternatives to rice and wheat (6). Recent reviews emphasized their role in nutrition security and revival in mainstream diets (7). This study formulates and evaluates millet based samosas to assess both sensory acceptability and nutritional benefits. Millets, including ragi, jowar, and bajra, are staple grains in many parts of Asia and Africa, known for their resilience in arid climates and their high nutritional content (1). These grains are naturally gluten-free and possess high fiber content, essential minerals like calcium, iron, magnesium, and B-vitamins, as well as bioactive compounds with antioxidant properties (4). *Ragi* is particularly notable for its high calcium content, making it an excellent choice for bone health and overall mineral balance. *Jowar* is a rich source of dietary fiber and antioxidants that support cardiovascular health, while *Bajra* contains beneficial polyphenols that may aid in managing blood glucose levels These gluten-free millets also offer functional benefits in food applications. Studies show that millet flours have unique starch structures and high water absorption capacities, which contribute to a tender and slightly crispy crust in baked or fried goods. By incorporating ragi, jowar, and bajra flours into the samosa crust, it may be possible to develop a gluten-free samosa with an acceptable texture and taste that resembles the traditional wheat-based product (8). While there has been considerable research on gluten-free bakery products (8), and very scanty research on other millet based snacks (9, 10, 11), limited studies focus on traditional foods like samosas and the use of nutrient-rich millet-based crusts. This research aims to develop and evaluate gluten-free samosas with crusts made from ragi, jowar, and bajra flours, focusing on optimizing sensory qualities while maintaining a nutritional advantage. By creating a culturally relevant and health-conscious snack, this study seeks to address the gap in gluten-free traditional food products and provide a nutritious, acceptable alternative to conventional wheat-based samosas.

2. METHODOLOGY:

Three experimental samosa crust formulations were prepared using ragi, jowar, and bajra flours, with a wheat based control. Filling ingredients were constant across samples.

Table 1: Composition of Ingredients for Control and Experimental Samosa

Sr. No.	Ingredients	Weight (g)			
		Control Samosa (Refined Wheat Flour)	Experimental 1 Samosa (Jowar)	Experimental 2 Samosa (Bajra)	Experimental 3 Samosa (Ragi)
FILLING					
1.	Potatoes	50	50	50	50
2.	Ginger	1. 5	1.5	1.5	1.5
3.	Fennel seeds	2.5	2.5	2.5	2.5
4.	Coriander seeds	1.5	1.5	1.5	1.5
5.	Cumin seeds	2	2	2	2
6.	Carom seeds	0.75	0.75	0.75	0.75
7.	Black pepper	0.75	0.75	0.75	0.75
8.	Chat masala	1.25	1.25	1.25	1.25
9.	Salt	1.25	1.25	1.25	1.25
10.	Sunflower oil	2.5	2.5	2.5	2.5
OUTER COVERING					
11.	Refined wheat flour	30	15	15	15
12.	Jowar	-	15	-	-
13.	Bajra	-	-	15	-
14.	Ragi	-	-	-	15
15.	Carom seeds	0.75	0.75	0.75	0.75
16.	Salt	0.5	0.5	0.5	0.5
17.	Sunflower oil	4.5	4.5	4.5	4.5
18.	Water	20	22	17.5	16.5
OIL FOR FRYING					
19.	Sunflower oil	20	20	20	20

Method of Preparation:

For Masala–In a pan, add fennel seeds, cumin seeds, coriander seeds and dry roast it for 2-3 minutes on medium flame. Transfer it into a mixer grinder jar and grind it coarsely. Keep it aside for further use.

For Filling–In a bowl, add oil, ginger, prepared masala, boiled potatoes salt to taste, chat masala and mix it well. Keep it aside for further use.

For Dough–In a bowl, add refined flour, oil, carom seeds, salt to taste and knead it well (for control). For the experimental of ragi, jowar & bajra, in a bowl, add refined flour with each of the millet flour (ragi, jowar, bajra), oil, carom seeds, salt to taste and knead it well (for experimental). Add water and knead it into hard dough. Cover it with the damp muslin cloth and keep it aside to rest for 15-20 minutes.

For Samosa–Preheat the kadhai containing oil for 5 minutes. Divide the dough into lemon size balls and flatten it with the help of a rolling pin. Cut the dough into two equal parts and apply water on the edges. Stuff the prepared filling and seal the edges to make samosas. Place prepared samosas into the kadhai and cook for 15-18 minutes at medium flame until they turn golden brown. Transfer it to a serving dish & serve hot.

Sensory Evaluation: Sensory evaluation was performed by six trained judges across three trials using a 10 point hedonic scale for appearance, color, texture, flavor, taste, doneness, and overall acceptability.

Table 2: Score Card for Control and Experimental Samosa

Sr. No.	Samosa	Sensory Attributes						
		Appearance	Colour	Texture	Doneness	Flavour	Taste	Acceptability
1	**C**							
2	**E1**							
3	**E2**							
4	**E3**							

Table 3: Key for Control and Experimental Samosa

Sr. No.	Appearance	Colour	Texture	Doneness	Flavour	Taste	Acceptability	Scores
1	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Highly acceptable	10
2	Good	Good	Good	Good	Good	Good	Acceptable	8
3	Fair	Fair	Fair	Fair	Fair	Fair	Slightly Acceptable	6
4	Poor	Poor	Poor	Poor	Poor	Poor	Unacceptable	4

Calculation of Nutritive Value of Control and Experimental Samosa: Nutritive values of all control and experimental samosa were calculated using standard Indian food composition tables (12).

Statistical Analysis: Scores given by six judges in three trials were tabulated. Means were derived and comparisons between control and experimental recipes were conducted using 'F' test.

Photo Plate- I: Refined Wheat Flour Samosa

Photo Plate- II: Jowar Flour Samosa

Photo Plate- III: Bajra Flour Samosa

Photo Plate- IV: Ragi Flour Samosa

3. RESULTS AND DISCUSSION:

Control samosa made with refined wheat flour to experimental variants using jowar, bajra, and ragi. All samosas had similar stuffing (25 g) and dough weights (50 g), except ragi-based (48 g), possibly due to its lower gluten content affecting binding. Post-frying weights showed that bajra samosas retained the most weight (52 g), followed by ragi (50 g), jowar (46 g), and the control (40 g), indicating higher oil and moisture retention in millet-based variants. Despite equal oil uptake across samples (27.5 g), differences in final weights suggest flour type influences oil retention and texture. Millet flours enhance nutritional value with added fiber and micronutrients but may require formulation adjustments to manage oil absorption and optimize sensory properties.

Table 4: Mean Palatability Evaluation Scores for Control and Experimental Samosa

Sr. No.	Sensory Characteristics	Control Samosa (Refined Wheat Flour)	Experimental 1 Samosa (Jowar)	Experimental 2 Samosa (Bajra)	Experimental 3 Samosa (Ragi)	F Values
1.	Appearance	10	10	9.05	8.11	2.2226 NS
2.	Color	10	10	8.83	8	**4.9542****
3.	Texture	9.88	9.88	9.22	9.38	1.1126 NS
4.	Doneness	9.77	9.77	9.44	9.72	0.5857 NS
5.	Flavor	9.88	9.88	9.5	9.38	1.4354 NS
6.	Taste	9.77	9.77	9.72	9.38	0.7805 NS
7.	Acceptability	9.66	9.66	9.44	9.05	0.6579 NS

**Difference is significant at both 5% & 1% levels.
NS- Insignificant difference.

Jowar flour (E1) samosa received a mean appearance score of 10, identical to the control samosa (refined wheat flour), while bajra (E2) and ragi (E3) samosas received slightly lower scores of 9.05 and 8.11, respectively. Insignificant differences were noted between control and all three experimental samosas for their appearance (F=2.2226).

Similarly, for color, jowar samosa received the highest score (10), whereas bajra and ragi samosas received lower mean scores of 8.83 and 8.00, respectively, likely due to the darker shade of these flours. This yielded significant difference between colour of refined wheat flour samosa and other three experimental samosas with calculated F value as 4.9542.

Texture scores for samosas prepared using jowar and bajra flours were 9.88 and 9.22, respectively, while ragi flour samosa received a slightly higher score (9.38). The slight variation in texture scores can be attributed to the coarser, crispier nature of millet-based crusts compared to refined wheat flour but the differences were insignificant (F=1.1126).

Bajra and ragi flour samosas received slightly lower scores for doneness (9.44 and 9.72, respectively), possibly due to differences in moisture retention and frying characteristics. Control and experimental samosas did not differ significantly for their doneness (F=0.5857).

Regarding flavor and taste, all experimental samosas received high scores, with jowar flour samosa rated on par with the control (9.88). Bajra and ragi samosas received slightly lower mean scores of 9.5 and 9.38, respectively. The slightly lower scores for ragi samosa could be due to the inherent earthy flavor of ragi flour. Flavour and taste of all three experimental millet based samosas showed insignificant differences as compared to that of control samosa. The acceptability of experimental samosas followed a similar trend. Jowar samosa (E1) had the highest acceptability score (9.66), matching the control, while bajra (9.44) and ragi (9.05) samosas received comparatively lower scores which were not significant (F=0.7805). The lower scores for ragi samosa in appearance, color, and taste contributed to its slightly reduced acceptability.

Overall, all experimental samosas were rated highly for their sensory attributes, with jowar flour samosa showing the closest resemblance to the control, while bajra and ragi flour samosas, despite slightly lower scores, were still considered acceptable alternatives (F=06579).

Millet samosas, particularly jowar‑based, balanced sensory acceptability and nutritional enhancement. Results align with the results of many researchers (4) and (5) who emphasized the health potential of millets. Challenges included weaker texture in ragi/bajra samosas, attributable to absent gluten. Blends and hydrocolloids could mitigate this.

Table 5: Energy & Major Nutrients and Fiber Content of Control and Experimental Samosa (per 100 g)

Sr. No.	Nutrients	Control Samosa (Refined Wheat Flour)	Experimental 1 Samosa (Jowar)	Experimental 2 Samosa (Bajra)	Experimental 3 Samosa (Ragi)
1.	Energy (kcal)	343..35	343.35	345.1	341.66
2.	Carbohydrates (g)	27.81	27.19	26.44	27.08
3.	Protein (g)	4.2	4.15	4.27	3.79
4.	Fat (g)	23.74	24.05	24.52	24.08
5.	Soluble Dietary Fiber (g)	0.65	0.78	0.86	0.78
6.	Insoluble Dietary Fiber (g)	1.64	3.26	3.35	3.39
7.	Total Dietary Fiber (g)	3.14	4.09	4.25	4.21

Energy content of samosas ranged between 341.66–345.1 kcal, with control (refined wheat flour) showing 343.35 kcal. Among the experimental samosas, bajra flour samosa (E2) had the highest energy value (345.1 kcal), likely due to higher fat content, while ragi samosa (E3) had slightly lower energy (341.66 kcal). Carbohydrate content was relatively consistent across variants (26.44–27.81 g). Control had the highest carb content (27.81 g), while bajra samosa had the lowest (26.44 g). Protein content was moderately similar across all samples, with bajra samosa (E2) showing the highest protein content (4.27 g), followed by jowar (4.15 g), control (4.2 g), and ragi (3.79 g). The fat content was significantly higher in all experimental samosas compared to control (23.74 g) ranging around 24 g, due to differing absorption and flour properties. This shows that experimental samosas absorb more oil during frying than control. One can opt for air- fried samosas instead of deep- fried to reduce the fat content. The use of millet flours increased dietary fiber content significantly compared to the control samosa. Total dietary fiber (TDF) in control was 3.14 g, whereas experimental samosas had higher values: 4.09 g (jowar), 4.25 g (bajra), and 4.21 g (ragi). Insoluble dietary fiber (IDF) was highest in ragi samosa (3.39 g), indicating improved gut health and satiety. Soluble dietary fiber (SDF) also increased slightly in experimental samples.

Table 6: Fatty Acid Content of Control and Experimental Samosa (per 100 g)

Sr.	Fatty Acids	Control Samosa	Experimental 1 Samosa	Experimental 2 Samosa	Experimental 3 Samosa

No.		(Refined Wheat Flour)	(Jowar)	(Bajra)	(Ragi)
1.	Total SFA (mg)	2.64	1.15	2.75	2.68
2.	Total MUFA (mg)	6.14	6.22	6.31	6.26
3.	Total PUFA (mg)	14.38	14.52	14.71	14.52

Saturated fatty acid (SFA) value was lowest in jowar samosa with 1.15 mg. compared to refined wheat flour, bajra and ragi making it heart-friendlier. All samosas, including the control and experimental samples, demonstrated a good content of total mono unsaturated fatty acids (MUFA), with values ranging between **6.14 and 6.31 mg.** Poly unsaturated fatty acids (PUFA) are the essential fats that the body cannot produce. There is not a significant difference in the values of the samosas but jowar and ragi samosa share the same fatty acid values, 14.52 mg and bajra samosa being higher with 14.71 mg.

For this research, sunflower oil was used. One can use different oils. Fatty acid profile of any deep fried food product is dependent upon the type of oil used for frying. Also, fatty acid content varies depending upon the use of ingredients in the recipe.

Table 7: Vitamin Content of Control and Experimental Samosa (per 100 g)

Sr. No.	Vitamins	Control Samosa (Refined Wheat Flour)	Experimental 1 Samosa (Jowar)	Experimental 2 Samosa (Bajra)	Experimental 3 Samosa (Ragi)
1.	Thiamine (B1) (mg)	0.07	0.09	0.08	0.1
2.	Riboflavin (B2) (mg)	0	0.01	0.02	0.01
3.	Niacin (B3) (mg)	0.8	0.84	0.8	0.87
4.	Folic Acid (B9) (mg)	11.7	12.19	11.77	11..58
5.	β-Carotene (µg)	9.71	10.34	12.85	9.48
6.	Vitamin C (mg)	13.89	22.62	23.05	23.05

Experimental samosas showed improvement in B-complex vitamins compared to the control. Thiamine is essential for converting carbohydrate into energy and it is important for the proper functioning of the nervous system. Samosa made with ragi flour had the highest level of thiamine i.e., 0.1 mg, followed by jowar (0.09 mg), bajra (0.08 mg), and control (0.07 mg) samosas.

Riboflavin plays a crucial role in energy metabolism and is important for maintaining healthy skin and eyes. The values were very low across all the samples, but a slightly higher in bajra flour samosa (0.02 mg).

Niacin is essential in maintaining the health of the heart, blood vessels, and metabolism. The levels of niacin were fairly consistent overall (0.8-0.87 mg), Ragi flour samosa with a higher level, 0.87 mg.

Folic acid helps tissues grow and Form RBCs which help prevent anemia and also helps produce DNA, the building block of the human body, which carries genetic information. All the samosas showed almost the same level of folic acid except jowar flour samosa which showed the highest level with 12.19 mg, indicating potential benefit for cell growth and repair.

β-carotene is converted into vitamin A (retinol). One needs vitamin A for good vision and eye health, for a strong immune system, and for healthy skin and mucous membranes. The level of β-carotene for refined wheat flour and ragi flour samosas was slightly similar, 9.71, 9.48 µg, respectively and had highest in bajra flour samosa i.e., 12.85 µg followed by jowar flour samosa i.e. 10.34 µg.

Vitamin C also known as ascorbic acid is a water-soluble vitamin that plays various crucial role in the human body. Experimental samosas had a higher level of vitamin C (22.62 mg, 23.05 mg, and 23.05 mg) as compared to the samosas prepared using refined wheat flour (13.89 mg).

Table 8: Mineral Content of Control and Experimental Samosa (per 100 g)

Sr. No.	Minerals	Control Samosa (Refined Wheat Flour)	Experimental 1 Samosa (Jowar)	Experimental 2 Samosa (Bajra)	Experimental 3 Samosa (Ragi)
1.	Calcium (mg)	51.7	53.05	53.01	95.45
2.	Iron (mg)	1.71	0.17	2.09	1.86
3.	Magnesium (mg)	39.73	52.96	51.83	54.6

4.	Zinc (mg)	0.44	0.57	0.68	0.64
5.	Sodium(mg)	7.29	7.84	7.67	7.75
6.	Potassium (mg)	363.12	388.86	393.52	403.36

Experimental samosas showed enhancement in most minerals. Calcium is vital for building and maintaining strong bones and teeth. Here, ragi samosa had the highest value i.e., of 95.45 mg due to its known calcium content which was followed by the refined wheat flour samosa which had 51.7 mg of calcium and jowar-bajra samosas being on the same level, 53.05 mg, 53.01 mg, respectively.

Iron is essential in making haemoglobin, a protein in red blood cells. The experimental samosa made with bajra flour exhibited the highest iron level of 2.09 mg following with the refined wheat flour and ragi samosa and jowar samosa being the lowest with the value of 0.17 mg.

Magnesium ranged from 51.83 to 54.6 mg in experimental samosas with ragi samosa being with the highest value, 54.6 mg and refined wheat flour samosa being the lowest, 39.73 mg.

Zinc content was comparatively low in all the variations but still in the experimental samosas there was a slight increase than the one compared to the refined wheat flour samosa. The sodium levels of all the samosas were almost the same with minor differences. Potassium content of the experimental samosas were on a quite higher side with ragi samosa taking the highest place of all by 403.36 mg of the potassium content followed by jowar and bajra samosas and refined wheat flour one being lowest with 363.12 mg. The choice of the flours significantly influenced the textural attributes of the samosa covers, offering a diverse range of options to suit different preferences and dietary needs. Whether one prefers a hearty and wholesome bite of jowar samosa or the crisp and nutrient-rich texture of ragi samosa, this traditional Indian snack offers a diverse sensory experience to suit every palate. The millet-based variations not only enhance nutritional value but also retain consumer acceptability and gastronomic satisfaction. Each bite on each plate reflects a balance of health, taste, and texture – making millet samosas a modern, functional twist to a classic favorite.

The present study successfully demonstrated the potential of incorporating millet flours—jowar, bajra, and ragi—as viable substitutes for refined wheat flour in samosa crust preparation. Sensory evaluation confirmed the overall acceptability of these experimental samosas, with jowar-based samosa closely resembling the control, while bajra and ragi versions showed only minor deviations in attributes such as appearance and color. Nutritionally, millet-based samosas provided comparable energy values, enhanced dietary fiber, higher micronutrient content (notably calcium, iron, and B-complex vitamins), and improved fatty acid profiles. Additionally, the cost analysis revealed that experimental samosas were economically more viable than the control. This study underscores the scope for diversifying traditional snack recipes using millet flours, thereby promoting dietary diversity, nutritional enhancement, and sustainable culinary innovation.

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