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Production and Quality Assessment of Crackers Produced from Wheat-Kidney Beans Flour Blends Flavoured with Onion Powder

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Abstract

This study aimed to produce and evaluate crackers from blends of wheat and kidney beans flour, flavoured with onion powder. Six formulations were prepared: CS1 (control) = 100% wheat flour; CS2 = 90% wheat + 10% kidney beans; CS3 = 80% wheat + 15% kidney beans + 5% onion; CS4 = 70% wheat + 25% kidney beans + 5% onion; CS5 = 60% wheat + 35% kidney beans + 5% onion; CS6 = 50% wheat + 45% kidney beans + 5% onion. Quality evaluation included proximate composition, minerals, vitamins, functional properties, anti-nutrients, physical, microbial, and sensory characteristics, using standard analytical methods. Kidney beans substitution significantly ($p<0.05$) influenced all parameters. Results ranged as follows: moisture (6.690 – 9.701%), protein (7.707 – 9.800%), fat (6.890 –7.556%), carbohydrate (71.449 – 77.914%), phosphorus (133.540–397.410 mg/100 g), calcium (66.500 – 112.850 mg/100 g), vitamin A (0.188–0.280 µg/100 g), vitamin C (2.105 – 3.715 mg/100 g), oil absorption capacity (130.035–143.530%), water absorption capacity (103.805–160.580%), tannin (0.019 – 0.173%), oxalate (0.703 – 1.087%), phytate (0.033 – 0.097%), spread ratio (5.395 – 8.497), breaking strength (24.400 –71.050 N). Sensory evaluation indicated sample CS1 (100 % wheat) was most preferred, followed by CS6 (50:45:5) Crackers enriched with kidney beans and onion demonstrated enhanced nutritional value and potential health benefits.

Keywords: Crackers; Wheat flour; Kidney bean flour; Onion powder; Nutritional composition

Introduction

The global rise in population, changing consumer preferences, and growing knowledge of the nutritional benefits have driven food scientists to innovate diverse food products that appeal to various consumer needs. Among snack foods, crackers are widely consumed by people of all ages and are produced in various shapes, sizes, and flavours (Tiwani *et al*., 2023). Their popularity stems from versatility, convenience, and affordability, making them ideal for on-the-go consumption (Kulkami, 2019). A defining feature of crackers is their low moisture content (< 5 %), which contributes to a long shelf life and reduced microbial spoilage risk (Vu *et al*., 2020) Typically, crackers contain at least 60 % cereal-based flour, with variations such as soda and saltine crackers, cream crackers, snack crackers, 'Maltkist', 'TUC', 'Ritz', vegetable crackers, and calcium crackers. Their nutritional value depends largely on the cereal base and other ingredients (Tiwani *et al*., 2023).

Traditional wheat-based product, while popular, lack certain essential nutrients and dietary fibre, making them less suitable for health-conscious consumers. (Rawat and Indrani, 2015). Research is therefore focused on incorporating alternative flours, including legume-based flours such as kidney bean flour, which are rich in plant protein and fibre (Dangi *et al*., 2022). Functional ingredients like onion powder, a source of antioxidants, vitamins, and minerals, are also being explored for enhancing crackers' nutritional quality, flavour, and potential health benefits (Kumar *et al*., 2022).

Wheat (*Triticum aestivum*), one of the oldest and most important cereal grains from the Poaceae family, is versatile in applications such as bread, biscuits, pasta, and crackers. It contains gluten proteins that provide elasticity and structure in baked goods, along with micronutrients like iron, thiamine, niacin, calcium, and vitamin B6. Although a staple food, wheat dependency in Nigeria is problematic due to high import volumes, economic cost, and gluten intolerance issues in some consumers (Iqbal *et al*., 2022)

Kidney beans (*Phaseolus vulgaris*) named for their resemblance to the human kidney rank third among legumes after soybean and peanut (Punia *et al*., 2020). Native to Southern Mexico, India, and Central America, they are now cultivated globally in Nigeria (Audu and Aremu 2011). Kidney beans occur in various colours and patterns and are notable for their high protein, iron, fibre, and bioactive compounds. They are also rich in minerals such as molybdenum, folate, copper, manganese, potassium, and vitamin K1, offering benefits such as blood sugar regulation, weight management, and colon cancer prevention. However, they require proper processing to eliminate natural toxins (Punia *et al*., 2020).

Onion (*Allium cepa L.*), a member of the Allium genus, is cultivated worldwide and valued for its flavour, aroma, and medicinal properties. It ranks second in global vegetable production after tomato (FAO, 2012). Onions vary in skin colour, pungency, and storage life, and are available in white, yellow, and red varieties. Rich in prebiotics, antioxidants, and flavonoids, onions may lower blood sugar, improve bone health, and reduce risks of cancer and chronic diseases (Marathe *et al*., 2016).

Incorporating kidney bean flour into cracker production can reduce wheat imports, diversify snack options, and increase the utilization of locally available legumes. Incorporating onion powder not only enhances flavour and aroma but also fortifies the product with antioxidants and micronutrients. This combination has the potential to produce a nutritionally superior snack that supports consumer health while promoting the use of indigenous crops.

This study therefore aims to develop crackers from blends of wheat and kidney bean flours flavoured with onion powder, and to evaluate their proximate composition, micronutrients, functional and physical properties, anti-nutritional factors, microbial safety, and sensory acceptance.

Study Materials

Wheat flour (commercial baking grade) and dry red kidney beans (Phaseolus vulgaris) were purchased from Ogige Market, Nsukka, Nigeria. Fresh onions (Allium cepa L.) were obtained from the same market. All reagents used were of analytical grade

Preparation of the Kidney Beans Flour

Kidney beans were sorted to remove defective seeds and extraneous matter. The beans were boiled for 10 minutes, soaked in clean water for 24 hours, drained, and dried in a hot-air oven at 52 ± 2 °C for 12 h. The dried beans were broken in an attrition mill, dehulled, finely milled, and sieved through a 200 µm mesh to obtain the flour.

Preparation of Onion Powder

Fresh onions (*Allium cepa L.*) were peeled, washed, and sliced into ~3 mm thickness. The slices were dried in a hot-air oven at 52 ± 2 °C for 9 h, milled, and sieved through a 200 µm mesh to obtain uniform onion powder

Cracker Formulation and Production

Six cracker formulations were prepared: A (Control): 100% wheat flour, B: 90% wheat + 10% kidney bean flour, C: 80% wheat + 15% kidney bean flour + 5% onion powder, D: 70% wheat + 25% kidney bean flour + 5% onion powder, E: 60% wheat + 35% kidney bean flour + 5% onion powder, F: 50% wheat + 45% kidney bean flour + 5% onion powder. All dry ingredients were weighed accurately, mixed using a laboratory dough mixer at 125 rpm for 5 min, sheeted to 3 mm thickness, and cut into uniform shapes. Crackers were baked in a preheated oven at 230 °C for 12–15 min, cooled to room temperature (25 ± 2 °C), and packaged in airtight polyethylene bags until analysis.

Sample Analysis

Functional properties: Water and oil absorption capacities (WAC and OAC) were determined following Lin *et al*. (1974). One gram of flour was mixed with 10 ml of distilled water (for WAC) or vegetable oil (for OAC), centrifuged at 3500 rpm for 15 min, and the supernatant decanted. The tube with sediment was reweighed, and capacity was calculated as:

Capacity (g/g) = (Weight of sediment – Weight of flour) / Weight of flour

Physical properties: Cracker height and width were measured using a vernier calliper, weight with a weighing balance, and volume by seed displacement. Density and breaking strength were determined as described by Egwujeh *et al*. (2018). Each parameter was based on the mean of six replicates.

Proximate /Micronutrient: Moisture, protein, fat, ash, fibre, and carbohydrate contents, as well as mineral and vitamin profiles, were analysed according to AOAC (2010) standard procedures.

Anti-nutritional factors: Tannin content was determined using the Folin–Denis method (Onwuka, 2005), where absorbance was read at 250 nm and percentage tannin calculated as:

%Tannin = (An/As) × (C/Vn) × Vf × (100/W)

Oxalate was analysed following Day and Underwood (1986). One gram of sample was extracted with 3M H_2SO4, filtered, and 25 ml of the filtrate titrated hot (80 °C) against 0.05 M $KMnO_4$ solution to a faint pink endpoint.

Sensory evaluation: Twenty semi-trained panelists evaluated the crackers using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) for appearance, aroma, taste, texture, crispiness, and overall acceptability. Samples coded with random three-digit numbers were presented in randomized order under white fluorescent light, with water provided for palate cleansing.

Statistical analysis: Data were analysed using one-way ANOVA in a completely randomized design, and mean differences were separated by Duncan's Multiple Range Test at $p < 0.05$.

Results

The result of the functional properties of the formulated crackers in table 1 showed that the oil absorption capacity of the cracker samples (CS1– CS6) ranged from 130.04% to 143.53 % in table 1. Sample CS1 (100:0:0) had the lowest value (130.04 %), while sample CS4 (70:25:5) had the highest (143.53 %). OAC increased with higher substitution levels of kidney bean flour, suggesting an enhanced ability to bind oil. The water absorption capacity of the samples ranged from 103.81% to 160.58 %. Sample CS2 (90:10:0) exhibited the lowest value (103.81%), whereas sample CS6 (50:45:5) recorded the highest (160.58%). WAC generally increased with the addition of kidney bean flour, indicating improved hydration capacity in the composite flour blends.

Table 1: Functional properties of flour from kidney beans and wheat flour flavoured with onion powder

Samples	OAC (%)	WAC (%)
CS1	130.035a± 0.02	122.525ab± 0.02
CS2	136.050ab± 0.02	103.805a± 0.02
CS3	135.140ab± 0.02	124.025b± 0.02
CS4	143.53b± 0.01	160.560c± 0.02
CS5	137.180ab± 0.01	129.450b± 0.02
CS6	137.690ab± 0.01	160.580c± 0.02

Values are mean ± standard deviation determination. Values with the same superscripts in the same column are significantly ($p<0.05$) different.

CS1 (Control sample) = 100% Wheat flour, CS2 = 90% Wheat flour + 10% Kidney beans flour, CS3 = 80% Wheat flour + 15% Kidney beans flour + 5% Onion powder, CS4 = 70% Wheat flour + 25% Kidney beans flour + 5% Onion powder, CS5 = 60% Wheat flour + 35% Kidney beans flour + 5% Onion powder, CS6= 50% Wheat flour + 45% Kidney beans flour + 5% Onion powder

The physical properties of the crackers showed that the spread ratio ranged from 5.395 – 8.497, with sample CS1 (100:0:0) having the lowest and sample CS6 (50:45:5) the highest. Weight varied between 5.101 g (sample CS2) and 7.988 g (sample CS4). Height ranged from 5.33 (sample CS6) to 9.900 (sample CS4), while diameter ranged between 44.267 mm (sample E) and 54.933 mm (sample CS3). Break strength decreased with kidney bean substitution, from 71.0125 (sample CS1) to 24.400 (sample CS6).

Table 2: Physical properties of crackers from kidney beans and wheat flour flavoured with onion powder

Samples	Spread Ratio	Diameter (mm)	Weight (g)	Breaking Strength	Height (mm)
CS1	5.395^{a}±0.36	45.503^{ab}±0.08	6.294^{a}± 0.01	71.013^{b}± 0.11	8.667^{bc}± 0.01
CS2	5.895^{b}±0.36	44.773^{a}± 0.08	5.101^{a}± 0.07	61.400^{b}± 0.11	8.840^{bc}± 0.01
CS3	7.145^{b}±0.48	54.933^{b}± 0.05	5.946^{a}± 0.07	59.800^{b}± 0.11	7.733± 0.01
CS4	7.195^{b}±0.48	54.647^{b}± 0.05	7.988^{a}± 0.07	54.650^{b}±0.11	9.900^{c}± 0.02
CS5	7.546^{bc}±0.48	44.267^{a}± 0.08	5.434^{a}± 0.07	51.350^{b}± 0.11	7.240^{ab}± 0.05
CS6	8.497^{c}±0.89	52.573^{bc}±0.08	6.137^{a}± 0.07	24.400^{a}± 1.00	5.300^{a}± 0.05

Values are mean ± standard deviation determination. Values with the same superscripts in the same column are significantly ($p<0.05$) different.

CS1 (Control sample) = 100% Wheat flour, CS2 = 90% Wheat flour + 10% Kidney beans flour, CS3 = 80% Wheat flour + 15% Kidney beans flour + 5% Onion powder, CS4 = 70% Wheat flour + 25% Kidney beans flour + 5% Onion powder, CS5 = 60% Wheat flour + 35% Kidney beans flour + 5% Onion powder, CS6= 50% Wheat flour + 45% Kidney beans flour + 5% Onion powder

The proximate composition of the composite crackers is presented in table 3 below. The moisture content of the composite biscuits ranged from 6.690 to 9.701%, with sample CS1 (100:0:0) having the lowest and sample CS6 (50:45:5) the highest increase in moisture were associated with higher proportions of kidney bean flour. There was a slight significant ($p > 0.05$) difference between samples

CS1 and CS3, as well as between samples CS2, CS4, and CS5. Protein content ranged from 7.707 to 9.980 %, with sample CS1 (100:0:0) showing the lowest and sample CS6 (50:45:5) the highest. No significant ($p > 0.05$) differences were observed between samples CS1 and CS3, and also between CS3, CS4, and CS5. Fat content ranged from 6.890 to 7.556 %, with sample CS1 recording the lowest and sample CS6 the highest. No significant ($p > 0.05$) differences occurred between samples CS1 and CS3, and among samples CS2, CS4, and CS5. Ash content ranged from 0.200 to 1.295 %, with sample CS1 showing the lowest and sample CS6 the highest. Slight significant ($p > 0.05$) differences were observed between samples CS1 and CS3, and among samples CS2, CS4, and CS5. Fibre content ranged from 0.019 to 0.325%, with sample CS1 having the lowest and sample CS6 the highest. Slight significant ($p > 0.05$) differences were observed between samples CS1 and CS3, and among samples CS2, CS4, and CS5. Carbohydrate content varied between 71.449 and 77.914 %, with sample CS6 (50:45:5) having the lowest and sample CS1 (100:0:0) the highest. No significant ($p > 0.05$) differences were found between samples CS1 and CS3, as well as among samples CS2, CS3, and CS6.

Table 3: Proximate composition of crackers from kidney beans and wheat flour flavoured with onion powder

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	Carbohydrate (%)
CS1	6.69^{a}±1.00	7.707^{a}±0.27	6.890^{a}±0.07	0.480^{b}±0.05	0.325^{c}±0.12	77.914^{b}±0.15
CS2	7.715^{b}±1.00	8.061^{a}±0.27	7.180^{ab}±0.07	0.500^{a}±1.00	0.286^{bc}±0.86	76.256^{ab}±0.06
CS3	8.920^{c}±0.78	8.301^{a}±0.27	7.300^{ab}±0.07	0.700^{bc}±0.05	0.224^{bc}±0.86	74.555^{ab}±0.06
CS4	9.000^{c}±0.98	9.501^{b}±0.37	7.425^{ab}±0.07	0.915^{cd}±0.59	0.182^{abc}±0.76	72.977^{a}±0.06
CS5	9.690^{d}±0.97	9.780^{b}±0.37	7.445^{ab}±0.07	0.995^{d}±0.45	0.125^{ab}±0.76	71.965^{a}±0.06
CS6	9.701^{d}±0.97	9.980^{b}±0.37	7.556^{b}±0.21	1.295^{e}±1.00	0.019^{a}±0.76	71.449^{a}± 0.06

Values are mean ± standard deviation determination. Values with the same superscripts in the same column are significantly ($p<0.05$) different.

CS1 (Control sample) = 100% Wheat flour, CS2 = 90% Wheat flour + 10% Kidney beans flour, CS3 = 80% Wheat flour + 15% Kidney beans flour + 5% Onion powder, CS4 = 70% Wheat flour + 25% Kidney beans flour + 5% Onion powder, CS5 = 60% Wheat flour + 35% Kidney beans flour + 5% Onion powder, CS6= 50% Wheat flour + 45% Kidney beans flour + 5% Onion powder

The result of the micronutrient composition of the crackers shown in table 4 demonstrated that the calcium content of the crackers ranged from 66.50 to 112.85 mg/100 g, with sample CS1 (100:0:0) having the lowest and sample F (50:45:5) the highest. Samples CS2 – CS6 had closely related values, reflecting the contribution of kidney bean flour, which is rich in calcium. The phosphorus content ranged between 133.54 and 397.41 mg/100 g. The lowest value was observed in sample CS1 (100:0:0), while the highest was recorded in sample CS6 (50:45:5). The vitamin C content varied from 2.105 to 3.715 mg/100 g, with sample B (90:10:0) having the lowest and sample CS6 (50:55:5) the highest value recoreded in sample CS1(100:00). The vitamin A content ranged from 0.188 to 0.280 mg/100 g. The lowest was observed in sample CS1 (100:0:0), while the highest was in sample CS6 (50:45:5). Slight significant ($p > 0.05$) differences were observed between some of the samples, indicating the effect of flour substitution levels.

Table 4: Micronutrient composition of crackers from kidney beans and wheat flour flavoured with onion powder

Samples	Phosphorus (mg/100g)	Calcium (mg/100g)	VitaminA (µg/100g)	VitaminC (mg/100)
CS1	397.410^{e}± 1.00	66.500^{a}± 0.01	0.188^{a}±0.82	3.715^{a}±0.05
CS2	321.650^{d}± 1.00	68.740^{b}± 0.01	0.1 90^{a}±0.82	2.780^{a}±0.05
CS3	244.975^{c}± 1.00	73.150^{c}± 0.01	0.217^{b}±0.36	2.785^{a}±0.05
CS4	197.260^{b}± 1.00	79.880^{cd}± 0.01	0.225^{b}±0.36	2.535^{c}±0.08
CS5	137.500^{c}± 0.79	99.605^{d}± 0.01	0.245^{c}±1.00	2.460^{a}±0.05
CS6	133.540^{a}± 0.79	112.850^{e}± 0.01	0.280^{d}±1.00	2.105^{bc}±0.09

Values are mean ± standard deviation determination. Values with the same superscripts in the same column are significantly ($p < 0.05$) different.

CS1 (Control sample) = 100% Wheat flour, CS2 = 90% Wheat flour + 10% Kidney beans flour, CS3 = 80% Wheat flour + 15% Kidney beans flour + 5% Onion powder, CS4 = 70% Wheat flour + 25% Kidney beans flour + 5% Onion powder, CS5 = 60% Wheat flour + 35% Kidney beans flour + 5% Onion powder, CS6= 50% Wheat flour + 45% Kidney beans flour + 5% Onion powder

The antinutrient composition of the formulated crackers showed that tannin content of the crackers ranged from 0.094 – 0.1733 %, with sample CS1 (100:0:0) having the lowest and sample CS6 (50:45:5) the highest. Oxalate content ranged from 0.7033 – 1.0867 %, increasing with kidney bean flour substitution, while phytate values ranged between 0.033 – 0.0967 %, also highest in sample CS6.

The sensory attributes of the crackers varied across samples CS1 – CS6. Crunchiness ranged from 3.25 - 6.10, with sample CS1 (100:0:0) being the crunchiest and sample CS2 (90:10:0) the least. Taste scores were between 3.25–5.75, with sample CS3 (80:15:5) rated lowest and samples CS5 (60:35:5) and CS6 (50:45:5) highest. Mouthfeel scores ranged from 3.45 - 6.03, with sample CS5 scoring highest and CS6 lowest. Colour scores varied from 3.50 - 5.25, increasing with kidney bean flour inclusion. Aftertaste scores ranged between 3.00 – 6.33, with sample CS1 highest and sample CS6 lowest. Texture scores were between 3.50 – 5.25, with sample CS1 highest and CS6 lowest. Flavour scores ranged from 3.35 – 6.75, with sample CS5 highest and CS6 lowest. Overall acceptability ranged from 3.00 – 6.10, with sample CS1 being the most preferred and sample CS2 the least.

Table 5: Anti-Nutrient composition of crackers from kidney beans and wheat flour flavoured with onion powder and the flour

Samples	Tannins (%)	Oxalate (mg/100)	Phytate (mg/100)
CS1	0.0I9^{a}±0.117	0.703^{b}±0.095	0.033^{b}±1.00
CS2	0.107^{a}±0.117	1.027^{b}±0.095	0.052^{c}±1.00
CS3	0.131^{b}±0.074	1.037^{b}±0.095	0.067^{d}±0.389
CS4	0.140^{b}±0.074	1.047^{b}±0.095	0.070^{d}±0.37
CS5	0.147^{b}±0.074	1.057^{b}±0.095	0.083^{e}±0.93
CS6	0.173^{c}±1.00	1.087^{b}±0.095	0.097^{f}±1.00
RKBF	0.207^{d}±1.00	0.037^{a}±1.00	0.021^{a}±1.00
WF	0.387^{e}±1.00	1.657^{c}±1.00	0.083^{d}±0.931

Values are mean ± standard deviation determination. Values with the same superscripts in the same column are significantly ($p < 0.05$) different. Values are mean ± standard deviation determination. Values with the same superscripts in the same column are significantly ($p < 0.05$) different.

Keys: CS1 (Control sample) = 100% Wheat flour, CS2 = 90% Wheat flour + 10% Kidney beans flour, CS3 = 80% Wheat flour + 15% Kidney beans flour + 5% Onion powder, CS4 = 70% Wheat flour + 25% Kidney beans flour + 5% Onion powder, CS5 = 60% Wheat flour + 35% Kidney beans flour + 5% Onion powder, CS6= 50% Wheat flour + 45% Kidney beans flour + 5% Onion powder
RKBF = Red kidney beans flour and WF = Whear flour

The sensory attributes of the cracker samples varied significantly across CS1–CS6. Flavour scores ranged from 3.00 to 6.75, with CS5 recording the highest value, while CS6 had the lowest. Texture values ranged from 3.00 to 6.00, with CS1 having the highest score and CS6 the lowest. Taste ranged from 3.25 to 5.75, with CS5 and CS6 recording the highest values, while CS3 had the lowest. Crunchiness ranged from 3.25 to 6.10, with CS1 recording the highest value and CS2 the lowest. Mouthfeel ranged from 3.40 to 6.03, with CS5 having the highest score and CS6 the lowest. Colour ranged from 3.50 to 5.74, with CS6 recording the highest value and CS1 the lowest. Aftertaste ranged from 3.00 to 6.33, with CS1 being the highest and CS6 the lowest. Overall acceptability ranged from 3.23 to 6.10, with CS1 being the most preferred sample, while CS2 was the least preferred.

Table 6: Sensory score of crackers from kidney beans and wheat flour flavoured with onion powder

Parameters	CS1	CS2	CS3	CS4	CS5	CS6
Flavour	$5.75^{c}\pm0.15$	$3.35^{ab}\pm 0.02$	$4.15^{b}\pm0.02$	$5.00^{c}\pm0.43$	$6.75^{d}\pm0.02$	$3.00^{a}\pm0.02$
Texture	$6.00^{d}\pm0.25$	$4.25^{ab}\pm0.02$	$4.25^{ab}\pm0.02$	$5.00^{b}\pm0.02$	$5.75^{c}\pm0.02$	$3.00^{a}\pm0.23$
Taste	$4.20^{ab}\pm0.25$	$4.25^{ab}\pm0.02$	$3.25^{a}\pm0.02$	$5.11^{c}\pm0.02$	$5.75^{c}\pm0.02$	$5.75^{c}\pm0.02$
Crunchiness	$6.10^{d}\pm0.22$	$3.25^{ab}\pm0.02$	$4.15^{b}\pm0.02$	$5.10^{c}\pm0.02$	$5.00^{c}\pm0.02$	$5.75^{c}\pm0.02$
Mouthfeel	$4.21^{b}\pm0.23$	$5.45^{c}\pm0.03$	$4.00^{ab}\pm0.10$	$3.45^{a}\pm0.11$	$6.03^{d}\pm0.02$	$3.40^{a}\pm0.01$
Colour	$3.50^{a}\pm0.25$	$4.50^{b}\pm0.50$	$5.25^{c}\pm0.02$	$4.00^{ab}\pm0.02$	$5.24^{c}\pm0.02$	$5.74^{c}\pm0.02$
Aftertaste	$6.33^{d}\pm0.25$	$4.15^{ab}\pm0.02$	$4.11^{ab}\pm0.02$	$5.09^{b}\pm0.02$	$5.65^{c}\pm0.02$	$3.00^{a}\pm0.23$
Overall acceptability	$6.10^{d}\pm0.22$	$3.23^{ab}\pm0.02$	$4.12^{b}\pm0.02$	$5.12^{c}\pm0.02$	$5.01^{c}\pm0.02$	$5.56^{c}\pm0.02$

Values are mean ± standard deviation determination. Values with the same superscripts in the same row are significantly ($p < 0.05$) different.

Keywords: CS1 (Control sample) = 100% Wheat flour, CS2 = 90% Wheat flour + 10% Kidney beans flour, CS3= 80% Wheat flour + 15% Kidney beans flour + 5% Onion powder, CS4= 70% Wheat flour + 25% Kidney beans flour + 5% Onion powder, CS5= 60% Wheat flour + 35% Kidney beans flour + 5% Onion powder, CS6= 50% Wheat flour + 45% Kidney beans flour + 5% Onion powder.

Discussion

Functional properties of the crackers showed that the oil absorption capacity (OAC) of the crackers increased with kidney bean flour incorporation, ranging from 130.04% in sample A (100% wheat flour) to 143.53% in sample CS4 (70:25:5). The higher OAC observed in the composite crackers could be attributed to the higher protein content and presence of damaged starch granules in kidney bean flour, which provide additional hydrophobic sites for oil binding. This result aligns with the findings of Ahmed *et al*., (2023), who reported that legumes generally exhibit higher OAC due to the presence of polar and nonpolar amino acid side chains that enhance oil retention. Improved OAC in baked products is desirable as it contributes to flavor retention, mouthfeel, and the extension of shelf life by reducing moisture migration. Water absorption capacity (WAC) also increased with substitution, ranging from 103.81 % in sample CS2 (90:10:0) to 160.58 % in sample CS6 (50:45:5). The higher WAC values in the composite crackers could be linked to the higher protein and carbohydrate content of kidney bean flour, as well as gelatinization during baking, which exposes hydrophilic groups capable of binding water. Similar trends have been reported by Singh *et al*. (2011) in legume-enriched baked products. Increased WAC enhances dough handling properties and improves the textural attributes of crackers, though excessive water absorption may also impact crispness. Overall, the incorporation of kidney bean flour significantly improved both OAC and WAC of the crackers, suggesting better functional properties compared to the 100 % wheat flour control. These results are consistent with previous studies on composite flours, where the addition of legumes enhanced hydration and oil-binding capacity (Keskin *et al*., 2022). The functional property improvements observed in this study highlight the

technological potential of kidney bean flour in bakery applications, particularly in improving product texture and nutritional quality without compromising sensory acceptability.
Higher spread ratio and diameter with kidney bean flour may be due to increased fat content, enhancing dough extensibility. Weight and height variations reflect sugar content and air retention in the dough, with higher values in moderately substituted samples. The decline in break strength indicates weakening of the gluten network as legume flour increased, consistent with earlier reports on composite flour crackers (Okpala and Okoli, 2013; Tiwari *et al*., 2023

The proximate composition of the composite crackers showed notable variations depending on the substitution levels of wheat flour with kidney bean flour and pericarp flour. The moisture content (6.690 – 9.701%) increased with the proportion of kidney bean flour, which has higher fibre and water-binding capacity. Low moisture content is desirable in baked products as it prolongs shelf life by reducing microbial activity (Tiwari et al., 2023). The values in this study fall within the acceptable range for crackers and are comparable to those reported by Venkatachalam and Nagarajan (2017) for savoury crackers (4.46 – 6.59 %) and Ahmed and Abozed (2015) for Hibiscus sabdariffa crackers (6.06 – 8.30 %). Protein levels (7.707–9.980%) improved progressively with the inclusion of kidney bean flour, reflecting its high content of essential amino acids such as lysine, leucine, and valine. This highlights the potential of bean–wheat composite crackers as a better protein source compared to wheat-only formulations. The values obtained are slightly lower than those reported by Ujong (2023) for fibre-enriched crackers (10.81–12.91%) but higher than those observed by Okoye *et al*. (2020) in wheat–maize African yam bean blends (4.41 – 9.33%). Fat content ranged from 6.890 –7.556 %, with higher values observed in samples containing more kidney bean flour. Fat contributes to the tenderness, flavour, and palatability of baked goods, but excessive fat can reduce shelf stability due to rancidity (Neo *et al*., 2007). The values obtained are within the range reported by Ahmed and Abozed (2015) (5.30 –7.45 %) and slightly lower than those reported by Neo *et al*. (2007) (9.57–11.59%) in Malaysian biscuits. The ash content (0.200 – 1.295 %) increased significantly with kidney bean substitution, indicating higher mineral enrichment. Minerals are essential for metabolic processes, bone development, and enzymatic functions (Hohman and Weaver, 2014). However, the levels reported here are lower than those reported by Ujong (2023) (0.82 – 2.09 %) and Mosha *et al*. (2010) (2.32–3.87%) for enriched crackers, suggesting room for further fortification strategies. Fibre content ranged from 0.019–0.325%, with higher levels observed in crackers containing kidney bean flour. Although these values are relatively low compared to recommended dietary fibre intakes (USDA, 2015), the upward trend reflects the functional role of legumes in improving fibre content. Fibre is associated with improved digestion, satiety, and reduced risk of chronic diseases. The values obtained here are higher than those reported by Rados *et al*. (2022) (0.022– 0.16 %) but lower than those reported by Okoye *et al*. (2020) (1.55–2.14 %). Carbohydrate constituted the bulk of the cracker composition (71.449 – 77.914 %), as expected in cereal-based products. The values decreased slightly with higher levels of kidney bean flour, which contributed more protein, fat, and fibre at the expense of carbohydrates. Crackers are known to be energy-dense snacks, and the carbohydrate content reported here exceeds the values reported by Olagunju (2018) (65.871–73.984%) and Murtuza *et al*. (2015) (60.02–60.52%) for acha–pigeon pea and cassava crackers, respectively.

The mineral and vitamin composition of the composite crackers showed clear improvement with the inclusion of kidney bean flour. Calcium levels increased with higher kidney bean substitution, ranging from 66.50 – 112.85 mg/100 g. The enrichment effect is expected, since legumes are known calcium sources. Adequate calcium intake is essential for bone formation, muscle contraction, and nerve transmission. The calcium levels reported here were higher than those observed by Ahmed and Abozed (2015) in Hibiscus sabdariffa-based crackers (31.00 – 38.25 mg/100 g), suggesting that kidney bean flour is a more effective fortification source. Phosphorus content (133.54–397.41 mg/100 g) also increased with kidney bean inclusion, reflecting its natural richness in phosphorus. Phosphorus plays a critical role in energy metabolism, cell signaling, and bone mineralization. The values in this study exceeded those reported by Okoye *et al*. (2020) for wheat–maize–African yam bean–cassava cortex crackers (58.89 – 136.80 mg/100 g), indicating higher nutritional benefits from kidney bean fortification. Importantly, the values were within the recommended dietary intake of 700 –1250 mg/day (USDA, 2015). Vitamin C levels (2.105 - 3.715 mg/100 g) were enhanced in samples containing kidney bean flour, with the highest content observed in sample D. Vitamin C is an essential antioxidant that supports immune function and collagen synthesis. Although the levels are modest compared to the recommended daily allowance (75–90 mg/day for adults, USDA, 2015), they indicate a supplementary contribution to dietary intake. Similar increments in vitamin C from legume-enriched baked products have been reported in earlier studies. Vitamin A values (0.188 – 0.280 mg/100 g) increased with the inclusion of kidney bean flour. This micronutrient plays a key role in vision, immune defense, and cellular development. The values observed fall within the adult RDA of 700 – 900 µg/day (USDA, 2015), suggesting that the crackers can contribute to daily intake. However, the vitamin A values here are lower than those reported by Okoye *et al*. (2020) (129.03 – 580.65 µg/100 g) for African yam bean composite crackers, possibly due to differences in raw material composition.

The progressive increase in tannin, oxalate, and phytate contents with higher kidney bean incorporation reflects the natural abundance of these compounds in legumes. Although tannins and phytates are known to interfere with protein digestibility and mineral bioavailability (Ifie and Emeruwa, 2011; Ifie *et al*., 2012), the levels observed in this study remained within permissible limits and were markedly lower than values reported in other studies of legume-based crackers (Okoye et al., 2020; Dokić et al., 2015). The relatively low tannin levels (0.094 – 0.1733 %) are consistent with reductions that occur during processing methods such as baking, which diminish anti-nutrient activity. Similarly, the oxalate content (0.7033 – 1.0867 %) was higher than the range reported by Okoye *et al*. (2020), but still below levels associated with adverse health effects. Phytate levels (0.033 – 0.0967 %) were significantly lower than the 2.50 % reported in wheat-based crackers by Okoye *et al*. (2020), suggesting that substitution with kidney bean flour did not elevate phytate content beyond safe levels. Overall, while kidney bean addition increased anti-nutrient content slightly, the values remained low and safe for human consumption, especially considering that thermal processing reduces their activity.

The results of the sensory scores of the formulated crackers indicated that substitution with kidney bean flour influenced sensory attributes, particularly crunchiness, texture, and flavour. While the control sample (100% wheat) was rated highest in overall acceptability, higher substitution levels reduced scores, likely due to changes in fibre, phenolic compounds, and aftertaste from kidney beans. However, samples CS5 and CS6 still achieved good scores for taste, flavour, and acceptability, suggesting that partial incorporation of kidney beans can enhance nutritional quality without compromising consumer preference.

Conclusion

The incorporation of kidney bean flour into wheat-based crackers significantly improved their nutritional quality, particularly protein, fibre, minerals (calcium, phosphorus), and vitamins (A and C), while keeping anti-nutritional factors within safe consumption limits. Moisture content increased slightly with substitution, but values remained acceptable for shelf stability. Sensory evaluation confirmed that the 100% wheat control was most preferred, though crackers with moderate kidney bean and onion inclusion were also well accepted. Overall, the study demonstrates that wheat–kidney bean–onion crackers are a viable functional snack with enhanced dietary value.

Recommendations

Further research should focus on:

• Optimizing formulations to improve consumer acceptance of higher kidney bean substitution levels.

• Conducting extended storage and shelf-life studies, including packaging trials and microbial stability.

• Evaluating the functional health benefits of the crackers (e.g., glycaemic index, antioxidant potential, and satiety).

• Exploring the use of other local legumes and spices to diversify and enrich cracker formulations

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