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Evaluation and Optimization of Proximate Composition, Farinographical, Extensographical and Sensory Properties of Sausage Rolls Made from Wheat-Breadfruit Flour Composite

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ABSTRACT: Flour forms the skeleton that supports the other ingredients in a baked products such as bread, cakes, and pastries. Both the physical and chemical characteristics of flours affect their quality and the subsequent products from them. Hence, this paper evaluates the proximate composition, farinographical and extensographical properties and sensory evaluation of sausage rolls made from wheat-breadfruit flour composite using standard methods. Breadfruit substitutions decreased the protein contents while ash, crude fibre and moisture contents increased significantly ($p \leq 0.05$) in the blends. Likewise, the pasting properties and sensory evaluation showed that BF substitution up to 25 % resulted in the dough and a sausage rolls that were similar to 100 % wheat dough and sausages. Further optimisation of the baking parameters showed that 25 % bf substituted flour could be baked at (160 -190 ºC) for 20 – 29 min to produce a highly acceptable sausage roll. These results of the study showed the possibility of replacing wheat flour with breadfruit flour in the production of good quality sausage rolls.

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The sausage roll is a popular snack prepared from a sheet of pastry dough shaped into tubes around sausage meat and baked before being coated with egg or milk. (Oyekunle*et al.*, 2019). In Nigeria, it is commonly served at parties and packaged as a fast-food under various trade names. Dough made entirely of wheat flour is primarily used to produce sausage rolls. However, composite flour is considered advantageous in developing countries because it reduces the importation of wheat flour and encourages using locally grown crops as flour. Composite flour is a binary or ternary mixture of different plant flours rich in starch (e.g. tubers like cassava, yam, sweet potato or cereals such as maize, rice, millet, buckwheat) (Hasmadi*et al*, 2020; Ekunseitan*et al*., 2016; Liu *et al*., 2019; Awolu, 2017) and rich in proteins(Gbenga-Fabusiwa*et al*., 2018), with or without the addition of wheat flour. The substitution of wheat flour with local raw materials is increasing due to the growing market for confectioneries and higher nutrition consciousness among food consumers (Gbenga-Fabusiwa*et al*., 2018; Adeyeye, 2020). Breadfruit (A*rtocarpus altilis*) is a member of the Moraceae family grown in about 90 countries, mainly the tropics. It is a rich source of carbohydrates (22.8 – 84.2%), fat (0.8 – 2.36%), and proteins (0.7 – 5%),

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with significant amounts of specific vitamins and minerals (Mehta*et al.*, 2023; Eke-Ejiofor and Friday, 2019). Hence, breadfruit has been processed into many forms, such as starch (*Eke-Ejiofor and Friday*, 2019; Bezerra*et al.*, 2019) and flour (Anwar, 2017; Nochera and Ragone, 2019) for its utilization in the food industries. The processed forms have been used as thickeners or fillers in products like custard, soup, baby foods, ice cream and pharmaceuticals (Nochera and Ragone, 2019; Okunlola and Adewusi, 2019). The flour blend and baking parameters directly affect the organoleptic and nutritional properties of baked goods, which significantly impact the quality and consumer acceptance (Mehta*et al.*, 2023; Chauhan *etal.*, 2016). It is, therefore, necessary to optimally combine these parameters for a high-quality sausage roll. Response Surface Methodology (RSM) is a multivariate statistical method based on experimental design that examines the influence of independent variables (factors) on dependent variables (responses) and predicts optimal process conditions by maximising the dependent variables (Anderson and Whitcomb, 2016). It has been used several times to optimize the properties of various baked products (Awolu, 2017; Nochera and Ragone, 2019; Pereira *et al*., 2023). This study aims to evaluate the proximate composition, farinographical and extensographical properties and sensory evaluation of sausage rolls made from wheat-breadfruit flour composite.

Materials and methods

*Materials:*The wheat flour (golden penny), breadfruits, baking powder, baking fat, eggs, and salt used for this study were purchased from an open market in Ota, South-Western Nigeria. The breadfruits were cleaned and floured. A Kenwood mixer (Model A 907 D), electric oven (SL- 9 Infrared Food Oven, China) and other baking equipment from Bells University of Technology bakery were used.

Preparation of breadfruit into flour: Mature bread fruits was harvested, cleaned, peeled, cored, sliced, blanched at 100 ºC for 5 min and then dried in the oven at 105 ºC for 3 hours (Gao*et al.*, 2019; Wari and Abidin, 2023). The dried breadfruit slices were then hand milled into powder, screened through a 0.25 mm sieve (Model BS 410) and packaged in ziplock bags.

Preparation of composite flours:About 25 and 50 parts by weight of breadfruit flour were mixed with 75 and 50 parts by weight of 100 % wheat flour to obtain 25 and 50 % of breadfruit/wheat composite flour respectively (Table 1). 100 % wheat flour was used as control. The prepared flours were stored in polyethylene bag.

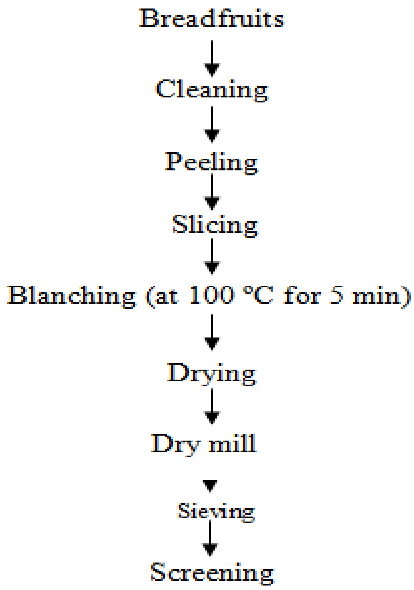

Fig 1: Flowchart for breadfruit flour production (Olaoye and Onilude, 2018)

Table 1: Formulation for wheat and breadfruit enriched sausage roll

	Enrich (%)	BF (g)	WF (g)
WF	100	0	500
WFBF	25	125	375
WFBF	50	250	250

*Preparation of breadfruit enriched sausage roll samples:*The composite flour (500 g) and salt (5 g) were mixed in a large bowl. Butter (45 g) was added and incorporated until it became uniform. The dough was then kneaded with 200 ml of water in stages until it formed a stiff ball. The dough was smoothened and allowed to rest for 30 min. The minced meat was mixed with grated ginger, onions, and spices and set aside. The dough was divided into four, and one half was rolled into a long sheet with the help of a lightly floured board and rolling pin. The dough was press-moved until it was about 1/8 inch thick. The uneven edges of the left side were cut and added to the rest of the dough in the bowl. The sausage meat was rolled into a slightly thick log with the hand (flour was rubbed on the hands to prevent sticking when the sausage meat was rolled into logs). Rolled sausage meat was added from the edge of the dough, and the cut edge was gently lifted over the meat and sealed at the edges with a wet palm. The top of the sausage rolls was prickled in several places with a sharp knife. The sausage rolls were transferred into a baking pan greased with fat, and it was subsequently glazed with beaten eggs and baked in a preheated oven according to experimental design. Freshly baked sausages were cooled on a rack and stored in an airtight ziplock bag at room temperature (Arinola and Akingbala, 2022;

Obiakor-Okeke and Nnamdi, 2014).

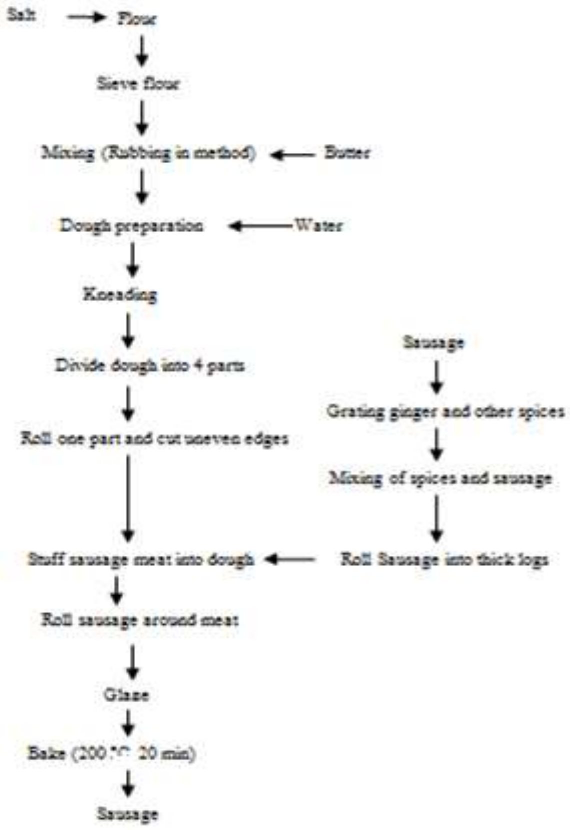

Fig 2: Flowchart for Sausage rollproduction

*Experimental Design:*A three-factor response surface methodology Box Behnken design optimised the sausage roll production, resulting in 17 experimental runs. The independent variables were formulation (0, 25, 50 %), baking times (10 – 30 min) and temperatures (160 – 220 ºC), while consumer acceptance of sausage rolls was the response (Table 2). Regression analysis was performed for each reaction to estimate the effect of combined independent variables on the responses using the statistical software Design-Expert 11.1 (Stat Ease, Inc., Minneapolis, USA). Each response was tested for possible linear, quadratic and cubic models to find out the best fitting model. The quadratic polynomial model (Equation 1) was used to calculate regression coefficients. The significance of each model term was determined with analysis of variance (ANOVA). The fit of the models was evaluated by comparing R^2 and adjusted-R^2. The statistical significance was checked by F-test. To illustrate how independent variables affected the responses, three-dimensional surface plots were created using the final equation found for each response:

$$Y=\beta_0+\sum_{i=1}^{3}\beta_I X_i \sum_{i=1}^{3}\beta_{ii} X_i^2+\sum_{i=1}^{2}\Sigma_{j=i+1}^{3}\beta_{ij}X_I X_J \ldots 1$$

Where$Y$ is the response variable (acceptability) and β_0,β_i, β_{ii}, and $\beta_{ij}$are the intercept, linear, quadratic, and interaction model coefficients, respectively. Additional experiments were subsequently conducted to verify the validity of the statistical experimental design under specific conditions.

*Determination of Proximate Composition, Functional Properties and Gluten Content of Flours:*The proximate composition of the breadfruit flour and breadfruit enriched sausage rolls samples were determined by standard methods (AOAC, 2005). Each sausage roll sample was ground with their crusts prior to the analysis. Each sample was analysed for moisture, ash, crude fibre, crude protein, crude fat and carbohydrate (by difference). The wet gluten content of the different formulations was determined using the method of AACC (2000) modified by Zhang *et al*. (2020).The water absorption capacity (WAC) was determined using the procedure of Awolu *et al.* (2017), bulk density (BD) by method of Falade *et al*. (2019), swelling index (SI) and solubility index by Adegunwa *et al.* (2019).

Farinographical and Extensographical Properties of the Individual Flours and Their Blends: The dough rheological properties of different flour blends were examined using a Brabender farinograph-E (Brabender GmbH and Co KG, Duisburg, Germany)as described by AACC (2000). Water absorption (WA), dough development time (DDT), stability time (ST), mixing tolerance index (MTI) and farinograph quality number (FQN) were determined following the method of AACC (2002). Extensograph properties were evaluated by a BrabenderExtensograph-E (Brabender GmbH and Co KG, Duisburg, Germany) to obtain the Water Absorption (%), Energy (Area under the curve) (cm^3), Resistance to Extension (BU), Extensibility (mm), Maximum (BU), Ratio number, Ratio number (Max) using AACC (2002) protocols.

Sensory Evaluation: Acceptability tests were conducted with 20 semi-trained panellists made up of a population of staff and students of Bells University of Technology, who declared themselves as regular consumers of sausage rolls Samples were randomly coded and analysed for attributes such as appearance, colour, flavour, texture and overall acceptability, using a 9-point structured hedonic scale (1 = dislike extremely to 9 = like extremely). To prevent carry-over flavour during the tasting, panellists were instructed to pass a piece of lemon fruit in their mouths or rinse with water after each stage of sensory evaluation (Da-Silva-Simão 2020).

Table 2: Experimental design for the optimisation of the sausage roll baking process

STD	Run	Factor I Formulation (%)	Factor II Temperature (^{O} C)	Factor III Time (min)	Response Acceptability
10	1	25	220	10	6.73
12	2	25	220	30	4.20
4	3	50	220	20	5.87
13	4	25	190	20	7.07
15	5	25	190	20	6.89
8	6	50	190	30	5.27
6	7	50	190	10	5.67
1	8	0	160	20	7.67
2	9	50	160	20	6.07
11	10	25	160	30	7.33
3	11	0	220	20	7.00
7	12	0	190	30	7.73
9	13	25	160	10	4.47
16	14	25	190	20	7.35
17	15	25	190	20	6.69
5	16	0	190	10	6.73
4	17	25	190	20	6.97

RESULTS AND DISCUSSION

*Proximate Composition, Functional Properties and Gluten Content ofthe Individual Flours and Their Blends:*The breadfruit flour (BF) had significantly higher (p≤0.05) moisture, crude fibre and ash with lower crude protein, fat and carbohydrate compared to wheat flour (Table 3). The protein contents in the composite flour significantly decreased (p≤0.05) with increasing BF substitution. In contrast, ash, crude fibre and moisture contents increased significantly (p≤0.05) in the blends as the proportion of BF increased. The reduction in the natural fat and carbohydrate content as BF substitution rose from 25 to 50% was insignificant (p≤0.05).

Table 3: Proximate composition, functional and physiochemical properties of wheat flour, breadfruit flour and composite flour (dry weight basis)

Proximate composition (%)	BF	WF	25%BFWF	50%BFWF
Moisture content	13.95±0.01^d	11.33±0.02^a	11.98±0.01^b	12.64±0.01^c
Crude protein	5.86±0.08^a	13.69±0.10^d	13.02±0.03^c	11.60±0.06^b
Crude fat	1.88±0.08^a	2.32±0.03^c	2.21±0.04^{bc}	2.10±0.05^b
Ash	2.09±0.02^d	0.66±0.05^a	0.99±0.01^b	1.40±0.06^c
Crude fibre	3.02±0.03^d	0.35±0.05^a	1.00±0.01^b	1.74±0.06^c
Carbohydrate	73.62±0.42^a	76.76±0.23^c	75.94±0.26^{bc}	74.31±0.01^b
Functional properties				
pH	6.25±0.05^b	6.01±0.00^a	6.07±0.01^a	6.11±0.01^a
Bulk density (g/ml)	0.53±0.01^a	0.71±0.01^d	0.67±0.01^c	0.62±0.01^b
Water absorption capacity (%)	255.88±0.53^d	171.40±0.01^a	192.74±0.11^b	208.48±0.02^c
Water solubility (%)	2.86±0.05^a	4.59±0.42^c	3.87±0.04^{bc}	3.52±0.03^{ab}
Swelling power (%)	44.50±0.07^a	39.5±4.20^a	37.69±0.06^a	40.00±0.10^a
Wet gluten (%)	0	26	16	1.6

Means ± standard error; Means with different superscripts in the sameroware significantly different (P<0.05)

KEY: BF- breadfruit flour, WF- wheat flour, 25%BFWF- 25% breadfruit flour + wheat flour, 50%BFWF-50% breadfruit flour + wheat flour.

The superior ash and fibre content and the low protein content of breadfruit have been reported by several researchers (Adebowale *et al*., 2017; Bakare *et al*., 2016; Malomo *et al*., 2011). BF's higher ash and fibre content is desirable for improving the composite flour's nutritional profile for sausage roll production. This is because consuming foods with high fibre has been associated with a reduced risk of colon cancer, irritable bowel syndrome, obesity and associated diseases. At the same time, ash indicates the mineral content in a food (Akin *et al.*, 2020)—the functional properties of a food material aid in determining its applicability for various food products. The functional characteristics of the individual and composite flours were investigated, and it was discovered that BF had a lower bulk density and water solubility, as well as a more extensive water absorption capacity and swelling power than WF (Table 3). Furthermore, with increasing BF substitution, the bulk density significantly decreased (p≤0.05), whereas the reduction in the water solubility was insignificant. In a similar trend, the water absorption capacity was significantly raised from 192.74 % in 25 % BFWF to 208.48 % in 50 % BFWF, while the increase in the swelling power was insignificant (Table 3). Flour or wheat mixes' particle size and density generally influence bulk density. In the food industry, it is essential to determine the packaging requirements, raw material handling, and application in wet processing. A high bulk density is desirable as it significantly reduces costs (Amidon *et al.*,2017; Mas and Larasati, 2022). Furthermore, the swelling index is a quality criterion in some food formulations, such as baked products. It is evidence of non-covalent bonding/interactions between molecules within starch granules and a factor of the ratio of amylose and amylopectin. Low solubility and high swelling power have been attributed to good quality starch with a more highly ordered internal arrangement of starch granules, high starch content, high paste viscosity and low fat content (Olawuni, 2017; Arinola and Akingbala, 2022). Generally, low amylose content produces high swelling power, and the amylose content of the starch is related to the strength and character of the micellar network of the starch.Moreover, high-fat content leads to the formation of amylase-lipid complexes that restrict swelling. This may also explain the higher water absorption capacity exhibited by the flour. Water absorption capacity is essential in formulating ready-to-eat products that require hydration, such as baked goods. A high water absorption capacity may ensure improved handling characteristics and product cohesiveness (Olawuni, 2018). High WAC is attributed to many hydrophilic groups within starch molecules and the polymer's lost structure (Qiao *et al*., 2017; Arinola and Akingbala, 2022). The increase in the WAC as BF substitution rose from 25% to 50% suggests greater water incorporation into dough formulation and improved handling characteristics in composite flours with higher BF. Ajatta *et al*. (2016) also reported a high WAC in BF and an increase in WAC with higher BF substitution in various ratios of BFWF composite flours. The WAC is a valuable indication of the ability of flour to associate with water molecules and absorb it during processing (Kraithong*et al*., 2018; Adeyeye *et al*. 2023; Njoku *et al*., 2023). High WAC implies improving the food product's texture, viscosity and handling (Umezuruike and Nwabueze, 2017). Also, there was a 10-fold reduction in the gluten content of the composite flour with a 25 % increase in BF substitution (Table 3). This is expected as wheat flour has the highest gluten form among all cereals. Dough from wheat flour and 25% BFWF flour were elastic during kneading and washing under water.

*Effect of Breadfruit Flour Substitution Levels on Dough Rheological Properties of Sausage Roll:*The addition of Breadfruit flour (BF) caused an increase in the WAC of the dough from 63.70 to 72.80 %, which was significantly higher than the control (57.80 %) (Table 4). This is probably due to the high crude fibre content in the BF (Table 4). These results are those found in the literature for most composite flours (Wirkijowska *et al*., 2020; Ayo-Omogie, 2021; Li *et al*., 2022). Development time (DDT) is the time from the first addition of water to when the dough reaches the point of most excellent torque. During this mixing phase, the water hydrates the flour components, and the dough is developed. The DDT of composite flours increased significantly with higher BF substitution. DDT is reportedly influenced by crude protein content and gluten content (Chisenga *et al*., 2020; Oloniyo *et al.*, 2022). The elevated DDT observed could be attributed to decreasing gluten content with increasing BF substitution, which might have disrupted the formation of the gluten network, thereby increasing DDT (Jafari *et al*., 2018). The dough consistencies of the breadfruit substituted flours were within tolerable limits (480 to 520 FU) except for 50 % BFWF, which was 462 FU. The peak consistency value of the wheat dough was higher than that of the composite, indicating a decreasing trend with increasing BF substitution. Chisenga *et al*. 2020 reported a positive correlation between dough consistency and gluten content, which is expected because gluten is mainly responsible for dough structure and strength. Dough stability (DST) is the time until the loss of consistency is lower than 11 % of the maximum consistency reached during the mixing. It is a factor that determines the extent to which a dough can withstand mechanical stress during proofing and at an early stage of baking in the oven. High dough stability values are usually related to the strength of flours. Dough from the composite flours had a more extended stability than 100 % wheat flour (Table 4), indicating a more excellent resistance to mechanical stress when compared to the control. Also, DST showed a decreasing trend as BF substitution increased from 25 % to 50 %. The DST of the 100 % wheat bread obtained in this study is lower than some previous studies, which show that 100 % wheat flour had the most extended stability, with the composite flours showing a decreasing DST with increasing substitution (Wirkijowska *et al*., 2020; Ayo-Omogie, 2020; Edun *et al*. 2019). DST correlates with crude protein and fibre content (Chisenga et *al*., 2020). The increased fibre and starch content in the composite flour could have contributed to increased water absorption required to develop gluten structure. The mixing tolerance index (MTI) values ranged from 0 to 56 BU, with the WF having the highest values. MTI also decreased as BF was replaced in the blends. Generally, flours with good tolerance to mixing have low MTI; the higher the MTI value, the weaker the flour (Bakare *et al*., 2016; Jafari *et al.,* 2018). Breakdown Time (TBD), like MTI, is also an index of the relative strength of flours. The TBD values ranged from 2.90 to 20.00 min, with the blends of composite flour showing better resilience than the WF (Table 4). The 50% breadfruit substituted wheat flour had the highest farinonograph quality of 200. Overall, adding 25 and 50% BF led to an improved dough rheological characteristic, consistent with the findings of Oloniyo *et al*. (2022) and Njoku *et al*. (2023).

Table 4: Farinograph and Extensograph parameters for wheat flour-breadfruit composite flour

FARINOGRAPH TREATMENTS	**WF**	**25 % BFW**	**50 % BFWF**
Water absorption (%) (corrected for 500 FU)	60.40±0.01[a]	68.70±0.01[b]	.60±0.01[c]
Water absorption (corrected for 14 %)	60.30±0.01[a]	67.10±0.01[b]	74.20±0.01[c]
Development Time (min)	1.90±0.01[a]	7.80±0.01[b]	17.70±0.01[c]
Stability (min)	2.60±0.01[a]	10.10±0.01[b]	7.2±0.01[c]
Consistency (FU)	515.00±0.01[c]	488.00±0.01[b]	462.00±0.01[a]
Tolerance Index (MTI) (FU)	56.00±0.01[a]	28.00±0.01[b]	0.00±0.01[a]
Time to break (min)	2.90±0.01[a]	12.90±0.01[b]	20.00±0.01[c]
Farinograph Quality Number	29.00±0.01[a]	129.00±0.01[b]	200.00±0.01[c]
EXTENSOGRAPH TREATMENTS			
Water absorption (%)	57.50±0.01[a]	63.70±0.01[b]	72.80±0.01[c]
Proving Time (min)	45.00±0.00[a]	45.00±0.00[a]	45.00±0.00[a]
Energy (cm^2)	101.00±0.01[a]	69.00±0.01[b]	28.00±0.01[a]
Resistance to Extension (BU)	472.00±0.01[b]	636.00±0.01[c]	208.00±0.01[a]
Extensibility (mm)	158.00±0.01[c]	85.00±0.01[b]	60.00±0.01[a]
Maximum (BU)	612.00±0.01[b]	636.00±0.01[c]	346.00±0.01[a]
Ratio Number	3.00±0.01[a]	7.50±0.01[c]	3.50±0.01[b]
Ratio Number (Max.)	3.90±0.01[a]	7.50±0.01[c]	5.80±0.01[b]
Falling no (seconds)	563.00±0.01[b]	499.00±0.01[a]	613.00±0.01[c]

Means ± standard error; Means with different superscripts in the same row are significantly different (P<0.05).
Key: WF*: Wheat Flour;* ***25%BFWF****: Breadfruit flour + wheat Flour;* ***50%BFWF****: Breadfruit flour + wheat Flour*

Resistance to extension (RE) indicates the gluten network's strength and the dough's gas-holding capacity (Jafari *et al*., 2018). The results shown in Table 4 suggest that adding more than 25 % BF caused a gradual decline in the RE and a maximum resistance (MR) value of the composite flour blends. Extensibility (ES) is indicative of the ductility and plasticity of the dough, and the extension energy (EE) provides information about the strength of the gluten and the baking properties of the flour (Li *et al*., 2019).

The results show that the ES and EE decreased steadily with the increase in BF. The dough stretching ratio is the maximum resistance to the extensibility ratio. The results of this study show that the composite flour's stretching ratio was higher than the 100 % WF; however, increasing the BF from 25 % to 50 % led to a significant decrease in the ratio. This extensographic properties analysis showed that adding BF up to 25% enhanced the strength of the dough network and had a better effect on the dough than control. The findings are consistent with those of Zainol *et al*. (2022), who researched the rheological stability and incorporation of gluten-free and bioactive compounds as an intermediate ingredient in health-related products.

Effect of wheat flour substitution on the sensory properties of the sausage roll: From the result obtained, a significant difference (P≤0.05) existed between samples for colour, taste, texture, mouth feel, aroma, flavour, softness and overall acceptability (Table 5).

The sausage roll produced from 100 % WF (control) had the highest score for all the attributes tested except for flavour and mouthful, in which sample 13 had the highest score. Generally, the scores of the sausage rolls decreased as the substitution level increased except for flavour and mouth feel. This may be due to better texture (tenderness and flakiness) with darker, more intense crust colour of the pastry obtained from the composite flours compared to 100 % wheat flour (control). This intense brown colour may be due to carbohydrates (sugars) in these flour blends, producing more caramelizing products.

The overall acceptability of the sausage roll samples also followed the same trend, and all the sausage rolls were accepted except for samples 6 and 2. This sample's acceptability was too low either because of the high temperature and baking time (sample 6) or the low temperature and short baking time (sample 2) used to produce it, leading to burnt or half-baked sausage rolls, respectively.

It has been previously reported that the BF-substituted composite bread was not different (p<0.05)from the whole wheat bread concerning internal texture, taste, appearance and general acceptability for up to 15 % BF substituted levels (Olaoye and Onilude, 2018).

Table 5: Sensory scores of sausage rolls

Sample no	Sample	Temp (°c)	Time (min)	Colour	Taste	Texture	Mouth feel	Aroma	Flavour	Softness	Overall acceptability
1	100%WF	190	30	$7.67±0.27^{de}$	$7.27±0.28^{f}$	$7.13±0.31^{cd}$	$7.13±0.36^{ef}$	$7.40±0.21^{d}$	$7.13±0.31^{de}$	$7.13±0.34^{d}$	$7.73±0.18^{g}$
2	25%BF75%WF	160	10	$4.60±0.45^{a}$	$4.47±0.57^{a}$	$4.47±0.50^{a}$	$4.13±0.41^{a}$	$4.93±0.30^{a}$	$4.67±0.40^{ab}$	$5.87±0.34^{bc}$	$4.47±0.42^{ab}$
3	25%BF75%WF	190	20	$7.47±0.17^{de}$	$6.73±0.36^{bcd}$	$6.40±0.38^{bcd}$	$6.27±0.46^{def}$	$6.80±0.28^{cd}$	$7.27±0.18^{de}$	$6.93±0.41^{cd}$	$7.07±0.23^{fg}$
4	50%BF50%WF	220	20	$5.60±0.48^{ab}$	$5.80±0.43^{abc}$	$5.47±0.39^{ab}$	$5.40±0.29^{bcd}$	$6.33±0.34^{bc}$	$6.60±0.28^{de}$	$6.60±0.46^{cd}$	$5.87±0.19^{cd}$
5	100%WF	160	20	$7.73±0.40^{e}$	$7.20±0.28^{d}$	$7.13±0.31^{cd}$	$7.20±0.30^{ef}$	$6.93±0.25^{cd}$	$7.13±0.22^{de}$	$7.47±0.39^{d}$	$7.67±0.25^{fg}$
6	25%BF75%WF	220	30	$4.60±0.54^{a}$	$4.73±0.56^{a}$	$4.80±0.43^{a}$	$4.87±0.50^{abc}$	$5.47±0.40^{ab}$	$5.47±0.52^{bc}$	$3.87±0.42^{a}$	$4.20±0.47^{a}$
7	50%BF50%WF	190	10	$5.80±0.45^{abc}$	$5.20±0.66^{a}$	$6.60±0.31^{cd}$	$6.00±0.37^{cde}$	$5.40±0.43^{ab}$	$5.07±0.58^{ab}$	$6.53±0.38^{cd}$	$5.67±0.39^{c}$
8	25%BF75%WF	220	10	$7.13±0.24^{de}$	$6.93±0.25^{cd}$	$7.07±0.23^{cd}$	$6.93±0.23^{ef}$	$6.47±0.24^{cd}$	$6.67±0.30^{de}$	$6.87±0.24^{cd}$	$6.73±0.30^{def}$
9	100%WF	220	20	$6.87±0.36^{cde}$	$6.87±0.34^{bcd}$	$7.27±0.34^{d}$	$7.20±0.42^{ef}$	$6.73±0.27^{cd}$	$7.33±0.27^{e}$	$6.80±0.31^{cd}$	$7.00±0.30^{efg}$
10	50%BF%WF	190	30	$5.47±0.41^{ab}$	$4.73±0.47^{a}$	$4.40±0.55^{a}$	$4.67±0.40^{ab}$	$4.87±0.40^{a}$	$4.20±0.30^{a}$	$5.00±0.41^{b}$	$5.27±0.32^{bc}$
11	50%BF50%WF	160	20	$6.53±0.52^{bcde}$	$5.60±0.45^{ab}$	$5.93±0.38^{bc}$	$6.47±0.46^{def}$	$6.27±0.34^{bc}$	$6.20±0.28^{cd}$	$7.00±0.40^{cd}$	$6.07±0.33^{cde}$
12	100%WF	190	10	$7.07±0.37^{de}$	$7.33±0.35^{d}$	$6.80±0.30^{cd}$	$7.07±0.42^{ef}$	$7.27±0.25^{cd}$	$6.93±0.27^{de}$	$7.13±0.29^{d}$	$6.73±0.27^{def}$
13	25%BF75%WF	160	30	$6.40±0.46^{bcd}$	$7.00±0.24^{cd}$	$7.00±0.26^{cd}$	$7.33±0.35^{f}$	$6.87±0.35^{cd}$	$7.33±0.32^{e}$	$6.60±0.35^{cd}$	$7.33±0.23^{fg}$

Means ± standard error; Means with different superscripts in the same column are significantly different (P<0.05)
Key: *S/N = sample number; WF =Wheat flour; 25%BFWF =25% breadfruit flour + 75% wheat flour; 50%BFWF = 50% breadfruit flour + 50% wheat flour*

Modelling and Optimisation of Breadfruit-Wheat Blend and Baking Parameters of Sausage Roll Production: Analysis of variance and model fitting: From the experimental results (Table 6), second-order polynomial regression equations were obtained (Equation 2) for each dependent variable.The model adequacy and significance of each coefficient were checked by the variance analysis (ANOVA) (Table 6). The models' importance and each coefficient were determined by *F*- and *P*-values. The model F-values of 41.40 with a low probability value (P < 0.0001) imply a highly significant model. Furthermore, the lack of fit was also insignificant for the entire model. The high R^2-values of 0.9816 indicated a satisfactory agreement of the quadratic model to the experimental data. Flour composition and oven temperature significantly negatively affect consumer acceptability, similar to the quadratic term's oven temperature and baking time. Also, interactive terms between baking time and flour composition and baking time and oven temperature hurt consumer acceptability. The quadratic model predicted that the optimum conditions for maximum consumer acceptability of breadfruit-wheat flour sausage roll were flour composition (25 %), oven temperature (160 ºC) and *b*aking time (29 mins), and this was validated experimentally.

$$Y = 6.99 - 0.7812*A - 0.2175*B + 0.1163*C + 0.1175*AB - 0.3500*AC - 1.35*BC + 0.183*BC + 0.163*A^2 - 0.5045*B^2 - 0.8070*C^2 \quad \ldots 2$$

Where *Y* is consumer acceptability, *A* is Flour composition, *B* is Oven Temperature, and *C* is Baking time.

Table 6: ANOVA **for the quadratic model for consumer acceptability of sausage roll**

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	17.22	9	1.91	41.40	< 0.0001	significant
A-Flour composition	4.88	1	4.88	105.67	< 0.0001	
B-Oven temperature	0.3785	1	0.3785	8.19	0.0243	
C-Baking time	0.1081	1	0.1081	2.34	0.1700	
AB	0.0552	1	0.0552	1.20	0.3105	
AC	0.4900	1	0.4900	10.60	0.0139	
BC	7.26	1	7.26	157.19	< 0.0001	
A^2	0.1119	1	0.1119	2.42	0.1637	
B^2	1.07	1	1.07	23.19	0.0019	
C^2	2.74	1	2.74	59.34	0.0001	
Residual	0.3234	7	0.0462			
Lack of Fit	0.0871	3	0.0290	0.4916	0.7070	not significant
Pure Error	0.2363	4	0.0591			
Cor Total	17.54	16				

Fit Statistics

Std. Dev.	**0.2150**	R^2	**0.9816**
Mean	6.45	**Adjusted R^2**	0.9579
C.V. %	3.33	**Predicted R^2**	0.8995
		Adeq Precision	21.4419

Effect of Flour composition, baking temperature and time on consumer acceptability of sausage roll: At 25 % breadfruit flour substitution, a simultaneous increase in baking temperature and time led to a rise in consumer acceptability up to a certain point (Fig 3a). The maximum acceptability was obtained when baking temperature and time were 190 ºC and 20 min, respectively, indicating that as the most acceptable/ optimum baking temperature and time. The lowest and highest combination of baking temperature and time resulted in the least adequate sausage rolls. This is because a low temperature and short baking time led to an improperly baked sausage, while a high temperature and long baking time resulted in a burnt sausage roll, both of which negatively impacted all sensory attributes tested.

Furthermore, a higher level of breadfruit substitution increased the baking time requirement for an acceptable sausage roll (Fig 3b). At the midpoint temperature of 190 ºC, lower blends of up to 25 % breadfruit substitution, the maximum baking time was 20 minutes or less. However, composite flour with more than 25 % breadfruit substitution required more time; this is consistent with the findings of Ezeofor (2022) and Okoye *et al.* (2022).

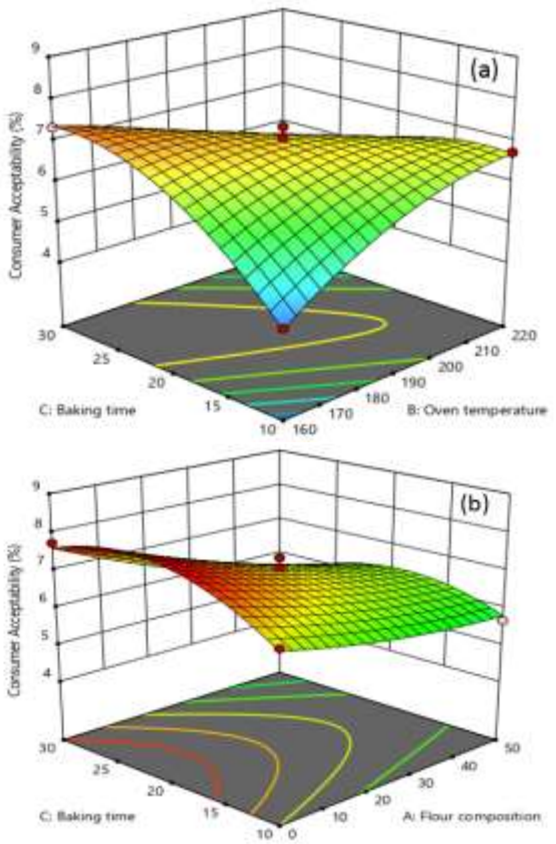

Fig 3: 3D Response surface graph showing the interactive effect of oven temperature and baking time, flour composition and baking time on consumer acceptability.

Conclusion: In this study, attempt was made to evaluate the extent to which WF could be substituted with BF and the optimum baking parameters for the composite flours. This was done by analysing the rheological properties of the flour and dough, as well as overall consumer acceptance of sausage rolls made from BF-WF composite flour. It was concluded that BF substitution up to 25 % was generally more acceptable by consumers compared to control. However, higher blends reduced consumer acceptance and increased the baking time and temperature requirements. A baking time of 20 -29 mins and temperature of 160 -190 ºC was optimal to produce sausage rolls made with BF-WF composite flours.

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