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Effect of High-Quality Cassava Flour Inclusion on the Profitability and Sensory Acceptability of Pastry Products

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Abstract
The demand for wheat flour in Nigeria is expected to rise due to the increasing consumption of pastries. A study was conducted to assess the profitability and sensory qualities of doughnuts, cookies, and chin-chin made from wheat and high-quality cassava flour (HQCF). HQCF was mixed with wheat flour in varying ratios (5, 10, and 15%), with 100% wheat flour as the positive control and HQCF as the negative control. Profitability was calculated using a standard method, while sensory acceptability was evaluated by fifteen (15) panelists using a structured questionnaire. The results showed that all composite products made from wheat and HQCF are profitable. The cookies made with 5%, 10%, and 15% HQCF generated profits of 143%, 163%, and 297%, respectively. The doughnuts made with 5%, 10%, and 15% HQCF yielded profits of 24.96%, 40.37%, and 47.98%, respectively. The chin-chin made with 5%, 10%, and 15% HQCF produced profits of 5.03%, 17.94%, and 22.08%. Sensory evaluation showed that cookies, chin-chin, and doughnuts made with 5-15% HQCF were similar in

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most sensory attributes, while those made with 100% wheat flour and 100% HQCF were different. Thus, the 5% HQCF composite cookies, chin-chin, and doughnuts may offer both profitability and acceptability, supporting Nigeria's cassava inclusion policy and decreasing import expenses.

Keywords: High-quality cassava flour, wheat flour, profitability, sensory acceptability, viable business

INTRODUCTION

Nigeria is the world's largest producer of cassava roots. Currently, cassava is recognized as a food security crop, combating poverty and enhancing livelihoods for many households, particularly marginalised women and youths in rural areas (Awoyale *et al*., 2018). Cassava root is highly perishable after harvesting due to its high moisture content. As a result, it is processed into shelf-stable products such as starch, *fufu*, tapioca, *lafun* (fermented cassava flour), and high-quality cassava flour (HQCF), among others (Abass *et al*., 2018). HQCF is simply unfermented cassava flour used as a partial replacement for wheat flour in many bakeries and pasta products (Abass *et al*., 2018). It is also a white or creamy smooth flour that is odourless, plain, and gluten-free (Abass *et al*., 2018).

Accordingly, research on non-wheat and composite baked products, especially bread in Nigeria, gained momentum in the 1970s with the formulation of composite flours from different blends of wheat, maize, sorghum, millet, fermented cassava flour (*lafun*), and cassava starch (Kuye *et al*., 2011). It is on record that, in 1984, the Federal Government of Nigeria mandated the use of fermented cassava flour produced by the Federal Institute of Industrial Research, Oshodi (FIIRO) for bread making in the country (Abass *et al*., 2018). Unfortunately, the policy faded with a change of government in Nigeria. In 1985, the HQCF technique was developed by the International Institute of Tropical Agriculture (IITA) and subsequently tested for commercial bread baking and other food items (Onabolu *et al*., 1998). The success of the tests in Nigeria encouraged the training of many extension agents and scientists to scale up the technology in Africa. Subsequent research on cassava bread done by research centres in Nigeria was based on this new technique of producing unfermented but safe cassava flour (Onabolu *et al*. 1998).

The Nigerian government's program to reduce wheat import expenditure through the mandatory inclusion of 10% HQCF in wheat flour has stimulated the upscaling of the HQCF technology and appears to be hastening the acceptance and consumption of wheat-cassava composite bread in Nigeria (Awoyale *et al*., 2018). Hence, the existing commercial inclusion of HQCF in wheat flour for all-purpose flour is being done by some of the flour mills.

The substitution of 10-20% HQCF for wheat in baked products may save substantial foreign exchange earnings spent on the importation of wheat flour by Nigeria and other African countries, especially now that the importation of wheat is impeded by the war between Ukraine and Russia, the global suppliers of wheat. For instance, Amena *et al.* (2024) reported that using HQCF in confectioneries and bakeries in Abuja, Benue, and Nasarawa states of Nigeria is profitable. The researchers added that most firms have been losing profit due to non-compliance with policies requiring the inclusion of HQCF in their products. Shittu and Sowunmi (2019) also reported that it is estimated that successful replacement of 10% of wheat flour with cassava flour (HQCF), the government will save an estimated US$40 million per year, which, they say, will be injected into the Nigerian cassava industry. This will not only encourage cassava cultivation but also create employment opportunities along the value chain. However, there is presently no documented report on the profitability analysis and sensory acceptability high-quality cassava flour (HQCF) and wheat flour composite to make doughnuts, cookies, and chin-chin.

Therefore, this study aimed to evaluate the profitability analysis and sensory acceptability of wheat flour and HQCF composite to make cookies, chin-chin, and doughnuts.

MATERIALS AND METHODS

About 200 kg of fresh cassava root (TME 419) was purchased from a farm in Malete, Kwara state. The wheat flour, butter, sugar, eggs, baking powder, nutmeg flavour, yeast, eggs, salt, vegetable oil, and milk were purchased from Oja-oba market, Ilorin, Kwara state. The baking equipment, frying pan, spoon, local oven, and gas cooker were used at the Food Processing laboratory of the Department of Food Science and Technology, Kwara State University, Malete, Kwara State, Nigeria.

Production of High-quality Cassava Flour

The freshly harvested 12-month-old cassava roots were processed into HQCF using the method described by Abass *et al.* (2018). The cassava roots were cleaned to remove extraneous substances, peeled manually with a knife, washed with clean portable water, and chipped manually with a knife. The chipped cassava roots were dried using the sun for about 3 days. After drying, it was dry milled using a local attrition mill, cooled, sieved, and packaged in a Ziplock bag before use.

Preparation of Products

All the products (cookies, chin-chin, and doughnuts) for the 5%, 10%, and 15% wheat flour and HQCF composite, and the controls were produced using the recipe combinations shown in Table 1.

Table 1. Recipes used to produce chin-chin, doughnuts, and cookies.

Products	Recipes	Quantity
Cookies	Wheat flour: HQCF	380 g: 20 g, 360 g: 40 g, & 340 g: 60 g
	Butter	100 g
	Sugar	50 g
	Egg	45 g
	Salt	2.5 g
	Vanilla essence	5 mL
	Water	30- 60 mL
Chin-chin	Wheat flour: HQCF	380 g: 20 g, 360 g: 40 g, & 340 g: 60 g
	Sugar	100 g
	Butter	40 g
	Baking powder	10 g
	Egg	90 g
	Nutmeg	3 g
	Flavour	3 g
	Water	30 mL
	Vegetable oil	750 mL
Doughnut	Wheat flour: HQCF	380 g: 20 g, 360 g: 40 g, & 340 g: 60 g
	Sugar	50 g
	Yeast	5 g
	Egg	45 g
	Flavour	1.5 g

	Butter	20 g
	Salt	1.5 g
	Water	30-60 mL
	Vegetable oil	750 mL

HQCF-High-quality cassava flour. The 100% wheat flour and 100% HQCF were used as positive and negative controls, respectively, for each of the products.

Cookies
The quantity of each of the recipes used to produce cookies is shown in Table 1. Butter and sugar were whisked together until thoroughly combined. Wheat-HQCF composite was added to a bowl, and the whisked butter and sugar were added to the dry ingredients. The egg and flavour were added to the mixture and combined until all ingredients were thoroughly incorporated. The mixture was then kneaded, rolled, cut into desired shapes, and arranged carefully on a greased pan. The pan was then placed in a preheated local oven maintained at 190 °C for 10 min (Sanni *et al.*, 2006). The 100% wheat flour (positive control) and 100% HQCF (negative control) cookies were also produced using the same process above.

Chin-chin
All the dry ingredients (wheat flour-HQCF, salt, baking powder, nutmeg, and sugar) were combined as shown in Table 1 using the method reported by Sanni *et al.* (2006), with slight modifications in the recipe combination. The wet ingredients (eggs, milk, and flavour) were whisked together until a homogenous mixture was formed. The wet ingredients were poured into the dry ingredients and mixed until all ingredients were fully combined to form a pastry. The pastry was then kneaded, rolled, cut into desired shapes manually, and fried in hot vegetable oil for 5 min. The positive control (100% wheat flour) and negative control (100% HQCF) chin-chin were also produced using the same process as above

Doughnuts
The wheat flour-HQCF composite, sugar, and yeast were mixed in a bowl, and milk, butter, and egg (Table 1) were then added and mixed properly until they formed a dough. The dough was flattened and cut into the desired shape manually and was placed on a greased pan and covered. Afterwards, it was left for 20 min to rise. The dough was then fried in preheated oil on low heat for 5 min (Sanni *et al.*, 2006). It was only the positive control (100% wheat flour) that was used for doughnuts, because the negative control (100% HQCF) could not form a good doughnut using the recipe in Table 1.

Product Yield
The quantity of the final products (cookies, chin-chin, and doughnuts) produced from a specific amount of the 100% wheat flour, 100% HQCF, and wheat flour-HQCF composite flour combined with a fixed quantity of other recipes was divided by the initial quantity of the raw materials used to get the percentage product yield, as shown in Equation 1 (Awoyale *et al.*, 2020).

$$\text{Percentage product yield } = \frac{\text{Quantity of products}}{\text{Quantity of raw materials}} \times 100 \quad (1)$$

Profitability Analysis of Products
The profitability analysis was computed by extracting key costs cum price variables at each level of production from the raw materials to the final products. Hence, the basic costs of input at each level of HQCF production were sourced at current market prices as of 2024. Second, the quantity of HQCF that can be produced at each level cum attributable cost, was determined. Third, the quantity of value-added products that can be produced from a given

quantity of wheat flour, wheat flour-HQCF composite, and HQCF was also estimated. Finally, prices for the value-added products were set using a market penetration pricing strategy. This means the products were priced low at the start to attract buyers. Equations 2, 3, and 4 were then used to calculate the profit margin, adjusted profit margin, and maximum daily output, respectively (Babatunde *et al.,* 2022).

Profitability was calculated using the profit margin equation shown in Equation 2.

$$\text{Profit Margin (\%)} = \frac{\text{Selling Price} - \text{Total Cost}}{\text{Total cost}} \times 100 \quad (2)$$

To assess price volatility, a sensitivity analysis was performed using the adjusted profit margin equation as shown in Equation 3.

$$\text{Adjusted Profit Margin (\%)} = \frac{\text{Selling Price} - (\text{Base Cost x } (1-\Delta P))}{\text{Base Cost x } (1+\Delta P)} \times 100 \quad (3)$$

$\Delta P = \text{Change in price}$

Production constraints were quantified using the maximum daily output equation as shown in Equation 4.

$$\text{Maximum Daily Output} = \text{Milling Capacity} \times \text{Yield Factor} \times \text{HQCF Proportion} \quad (4)$$

Prices were compared with what others are charging for similar pastries in Ilorin markets (₦100–₦150 for a 25 g pack of chin-chin and ₦100 for cookies). The decision was also guided by Shittu and Sowunmi (2019), who found that people in Oyo State are willing to pay for products made with HQCF. A sensitivity analysis checked how profit might change if cassava or wheat flour prices go up or down by 20%, like what can happen if there's a drought affecting cassava or if wheat prices rise in the world market. The study also looked at economies of scale and production limits, like how much HQCF is available and how much can be processed based on cassava supply and milling facilities in Kwara State. All this helped us to clearly understand the profit potential.

Sensory Evaluation of Products

The sensory evaluation of the products (chin-chin, cookies, and doughnut) from the %100 wheat flour, %100 HQCF, and wheat flour-HQCF composite (5%, 10%, and 15%) were done using a well-structured questionnaire to score for to score for attributes such as taste, texture, appearance, aroma, and overall acceptability using the 9-point hedonic scale, where 9 is like extremely, 8 like very much, 7 like moderately, 6 like slightly, 5 neither like or dislike, 4 dislike slightly, 3 dislike moderately, 2 dislike very much, 1 dislike extremely.

Statistical Analysis

The results of the sensory evaluation were subjected to a one-way analysis of variance at $p < 0.05$, using the Statistical Package for the Social Sciences (SPSS) statistical software (version 21). The Principal Component Analysis (PCA) was done using XLSTAT (free version 2024).

RESULTS AND DISCUSSION

Product Yield

The percentage of product yield is shown in Table 2. The chin-chin yield is 24 pieces of 25 g for 100% wheat flour, 25 pieces of 25 g for 100% HQCF, 24 pieces of 25 g for 5% HQCF composite flour, 27 pieces of 25 g for 10% HQCF composite flour, and 28 pieces of 25 g for 15% HQCF composite flour. The cookies are 30 pieces for 100% wheat flour, 50 pieces for 100% HQCF, 34 pieces for 5% HQCF composite flour, 37 pieces for 10% HQCF composite flour, and 56 pieces for 15% HQCF composite flour. The yield of the doughnut is 15 pieces of 75 g for 100% wheat flour, 16 pieces of 75 g for 5% HQCF composite flour, 18 pieces of 75 g for 10%

HQCF composite flour, and 19 pieces of 75 g for 15% HQCF composite flour. The 100% HQCF was unable to form a doughnut, which may be due to the little or non-elastic nature of the 100% HQCF (Alimi *et al.*, 2023). This implied that the quantity of the chin-chin, cookies, and doughnuts increased as the percentage of HQCF increased in the composite flour. This may be attributed to the high-water absorption capacity and swelling power of the HQCF (Eduardo *et al.*, 2013; Li *et al.*, 2023).

Table 2. Percentage yield of products from different wheat flour-HQCF composite and control

Products	Wheat flour	HQCF	Yield (%)
Cookies	400 g (100%)	Nil	30 pcs
	0 g	400 g (100%)	50 pcs
	380 g	20 g (5%)	34 pcs
	360 g	40 g (10%)	37 pcs
	340 g	60 g (15%)	56 pcs
Chin-chin	400 g (100%)	Nil	24 pcs of 25 g
	0 g	400 g (100%)	25 pcs of 25 g
	380 g	20 g (5%)	24 pcs of 25 g
	360 g	40 g (10%)	27 pcs of 25 g
	340 g	60 g (15%)	28 pcs of 25 g
Doughnut	400 g (100%)	Nil	15 pcs of 75 g
	0 g	400 g (100%)	No product formed
	380 g	20 g (5%)	16 pcs of 75 g
	360 g	40 g (10%)	18 pcs of 75 g
	340 g	60 g (15%)	19 pcs of 75 g

HQCF-High quality cassava flour, pcs-pieces

Profitability of Products

Table 3 depicts that the 100% wheat flour gave 30 cookies, 100% HQCF gave 50 cookies, and the 5%, 10%, and 15% HQCF composite flour gave 34, 37, and 56 cookies, respectively. The 30 cookies produced from 100% wheat flour cost ₦1,391.07; the selling price is ₦3,000, the profit is ₦1,608.93, and the percentage gain is 115.66%. The total cost of producing 50 cookies from 100% HQCF is ₦1,520, the selling price is ₦3,480.00, and the percentage gain is 228.95% (Table 3). The total cost of producing 34 cookies from the 5% HQCF composite flour is ₦1,397.50, the selling price of ₦3,400, the profit is ₦2,002.50, and the percentage gain is 143.29%. The total cost of producing 37 cookies from the 10% HQCF composite flour is ₦1,403.95, the selling price of ₦3,700, the profit is ₦2,296.05, and the percentage gain is 163.54%. The total cost of producing 56 cookies from the 15%HQCF composite flour is ₦1,410.41, the selling price of ₦5,600, the profit is ₦4,189.59, and the percentage gain is 297.05% (Table 3). The implication of this is that cookies from HQCF composite flour are profitable with approximately 143%, 163%, and 297% gain from 5%, 10%, and 15% HQCF composite flour, respectively (Table 3). Sensitivity analysis revealed that a 20% increase in cassava flour price reduced profit margins by 8–12% across products (15% HQCF cookies dropped from 297.05% to 260.14%), while a 20% wheat flour price increase improved HQCF composite profitability by 5–7% due to cost savings. The amount of HQCF available makes it hard to expand production, since Kwara State grows only about 10% of the country's cassava. On top of that, most milling operations are small and can't handle more than 500 kg a day. To attract buyers, prices were set to match what's already common in local pastry markets (₦100–₦150 per unit). This approach also fits what buyers are looking for low-cost HQCF products as revealed by Amena *et al.* (2024), helping the business compete well right from the start.

Table 3. Profitability of cookies, chin-chin, and doughnuts from 100% wheat flour, 100% HQCF, and HQCF composite flour

Products/composite	Cost implication (₦)	Quantity of cookies produced (pieces)	Price per cookie (₦)	Total selling price (₦)	Profit (₦)	Percentage gain (%)
Cookies						
100% WF	1,391.07	30	100	3,000.00	1,608.93	115.66
100% HQCF	1,520.00	50	100	5,000.00	3,480.00	228.95
5% HQCF	1,397.50	34	100	3,400.00	2,002.50	143.29
10% HQCF	1,403.95	37	100	3,700.00	2,296.05	163.54
15% HQCF	1,410.41	56	100	5,600.00	4,189.59	297.05
Chin-chin						
100% WF	3,421.07	24	150	3600	178.93	5.23
100% HQCF	3,550.00	25	150	3750	200	5.63
5% HQCF	3,427.50	24	150	3600	172.5	5.03
10% HQCF	3,433.95	27	150	4050	616.05	17.94
15% HQCF	3,440.41	28	150	4200	759.59	22.08
Doughnuts						
100% WF	3,835.00	15	300	4,500.00	665	17.34
100% HQCF	NP	NP	NP	NP	NP	NP
5% HQCF	3,841.17	16	300	4,800.00	958.83	24.96
10% HQCF	3,847.07	18	300	5,400.00	1,552.93	40.37
15% HQCF	3,852.00	19	300	5,700.00	1,848.00	47.98

HQCF-High-quality cassava flour, NP-Not produced

The 100% wheat flour gave 24 pieces of 25 g chin-chin, and the 100% HQCF gave 25 pieces of 25 g chin-chin. The 5%, 10%, and 15% HQCF composite flour gave 24, 27, and 28 pieces of 25 g chin-chin, respectively (Table 3). The 24 pieces of 25 g chin-chin produced from 100% wheat flour cost ₦3421.07, the selling price is ₦3,600, the profit is ₦178.93, and the percentage gain is 5.23%. The total cost of producing 25 pieces of 25 g chin-chin from 100% HQCF is ₦3,550, the selling price is ₦3,750, and the percentage gain is 200%. The total cost of producing 24 pieces of 25 g chin-chin from the 5% HQCF composite flour is ₦3,427.50, the selling price is ₦3,600, the profit is ₦172.50, and the percentage gain is 5.03%. The total cost of producing 27 pieces of 25 g chin-chin from the 10%HQCF composite flour is ₦3433.95, the selling price is ₦4,050, the profit is ₦616.05, and the percentage gain is 17.94%. The total cost of producing 28 pieces of 25 g chin-chin from the 15% HQCF composite flour is ₦3440.41, the selling price is ₦4,200, the profit is ₦759.59, and the percentage gain is 22.08%. The implication of this is that chin-chin from HQCF composite flour is profitable with approximately 5.03%, 17.94%, and 22.08% gain from the 5%, 10%, and 15% HQCF composite flour, respectively (Table 3).

The 100% wheat flour gave 15 pieces of 75 g doughnuts, and the doughnut was not formed from the 100% HQCF, which may be attributed to the non-elastic nature of the HQCF (Li *et al.*, 2023). The 5%, 10%, and 15% HQCF composite flour gave 16, 18, and 19 pieces of 75 g doughnuts, respectively. The 15 pieces of 75 g doughnuts produced from 100% wheat flour cost ₦3,835, the selling price is ₦4,500, the profit is ₦665, and the percentage gain is 17.34% (Table 3). The total cost of producing 16 pieces of 75 g doughnuts from the 5% HQCF composite flour is ₦3,841.17, the selling price is ₦4,800, the profit is ₦958.83, and the percentage gain is 24.96%. The total cost of producing 18 pieces of 75 g doughnuts from the 10% HQCF composite flour is ₦3,847.07, the selling price is ₦5,400, the profit is ₦1,552.93, and the percentage gain is 40.37%. The total cost of producing 19 pieces of 75 g doughnuts from the 15% HQCF composite flour is ₦3,852, the selling price is ₦5,700, the profit is ₦1,848, and the percentage gain is 47.98 % (Table 3). The implication of this is that doughnuts from HQCF composite flour are profitable with approximately 24.96%, 40.37%, and 47.98% gain from the 5%, 10%, and 15% HQCF composite flour, respectively (Table 3).

Sensory Attributes of the Products.

Due to human biological variations and how people perceive sensory attributes, sensory evaluation is an expression of an individual's likes or dislikes for a product (Awoyale *et al.*, 2022). On average, all the sensory attributes of the cookies produced from 100% wheat flour, 100% HQCF, and 5-15% HQCF composite fall within the slightly liked range. Significant difference ($p<0.05$) exists in all the sensory attributes of the cookies, with cookies produced from 100% wheat flour moderately liked and those from 100% HQCF neither liked nor disliked by the panelists ($p<0.05$). The overall acceptability of the cookies from the 5-15% HQCF composite flour falls within the slightly liked range (Table 4). The likeness of the 5% and 10% HQCF composite cookies may be due to the appearance, texture, colour, and taste of the product. This was because the 5% and 10% HQCF composite flour and the 100% wheat flour were in the same quadrant, with the appearance, texture, colour, and taste of the product (Figure 1).

Table 4. Sensory attributes of cookies, chin-chin, and doughnuts from 100% wheat flour, 100% HQCF, and HQCF composite flour

Samples	Taste	Texture	Colour	Appearance	Aroma	Overall acceptability
Cookies						
100% WF	8.13±0.99[a]	7.60±0.83[a]	7.07±1.10[a]	7.60±1.88[a]	6.93±1.67[a]	7.33±1.68[a]
100% HQCF	3.40±0.83[c]	3.27±1.22[c]	3.73±1.79[c]	4.07±1.67[c]	3.87±0.99[c]	4.93±1.91[c]
5% HQCF composite	5.80±1.21[b]	6.00±1.25[b]	5.93±1.39[b]	5.93±1.22[b]	5.40±1.40[b]	6.40±1.12[ab]
10% HQCF composite	6.13±1.73[b]	5.47±1.19[b]	6.00±1.25[b]	6.13±1.13[b]	5.53±0.99[b]	6.53±1.13[ab]
15% HQCF composite	5.53±1.55[b]	5.67±1.35[b]	5.53±1.06[b]	6.00±1.31[b]	6.80±1.37[a]	6.13±1.30[b]
Mean	5.8	5.6	5.65	5.95	5.71	6.27
p level	***	***	***	***	***	**
Chin-chin						
100% WF	7.93±0.46[a]	7.93±1.28[a]	7.60±0.83[a]	7.93±1.22[a]	7.33±1.50[a]	8.13±0.64[a]
100% HQCF	3.47±1.85[d]	4.27±1.79[c]	4.00±1.69[c]	3.60±1.76[c]	3.73±1.44[d]	4.80±1.32[c]
5% HQCF composite	5.87±1.46[bc]	6.20±1.61[b]	5.87±1.64[b]	5.47±1.68[b]	5.60±1.35[bc]	6.40±1.06[b]
10% HQCF composite	5.40±1.64[c]	5.53±1.51[b]	5.27±1.53[b]	5.40±1.18[b]	4.60±1.88[c]	5.87±1.25[b]
15% HQCF composite	6.67±1.80[b]	6.73±1.71[b]	6.40±1.99[b]	6.27±2.09[b]	5.87±1.60[b]	6.60±1.35[b]
Mean	5.87	6.13	5.83	5.73	5.43	6.36
p level	***	***	***	***	***	***
Doughnuts						
100%WF	7.53±1.46[a]	7.80±1.08[a]	7.40±1.06[a]	8.00±1.20[a]	7.73±1.22[a]	7.73±1.28[a]
100%HQCF	NP	NP	NP	NP	NP	NP
5% HQCF composite	5.53±0.83[b]	5.53±1.41[b]	5.40±1.99[b]	5.33±1.45[c]	5.60±1.24[bc]	5.47±1.60[b]
10% HQCF composite	5.93±1.10[b]	6.20±1.26[b]	6.07±1.28[b]	6.33±1.50[b]	6.33±1.18[b]	6.13±1.06[b]
15% HQCF composite	6.27±1.71[b]	5.47±1.19[b]	5.73±1.62[b]	5.53±1.41[bc]	5.47±1.30[c]	5.80±1.42[b]
Mean	6.32	6.25	6.25	6.30	6.28	6.28
p level	***	***	***	***	***	***

HQCF-High-quality cassava flour, WF-Wheat flour, NP-Not produced,
**$p<0.01$, ***$p<0.001$

Means with different superscripts within the same column are significantly different (p<0.05)
9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely

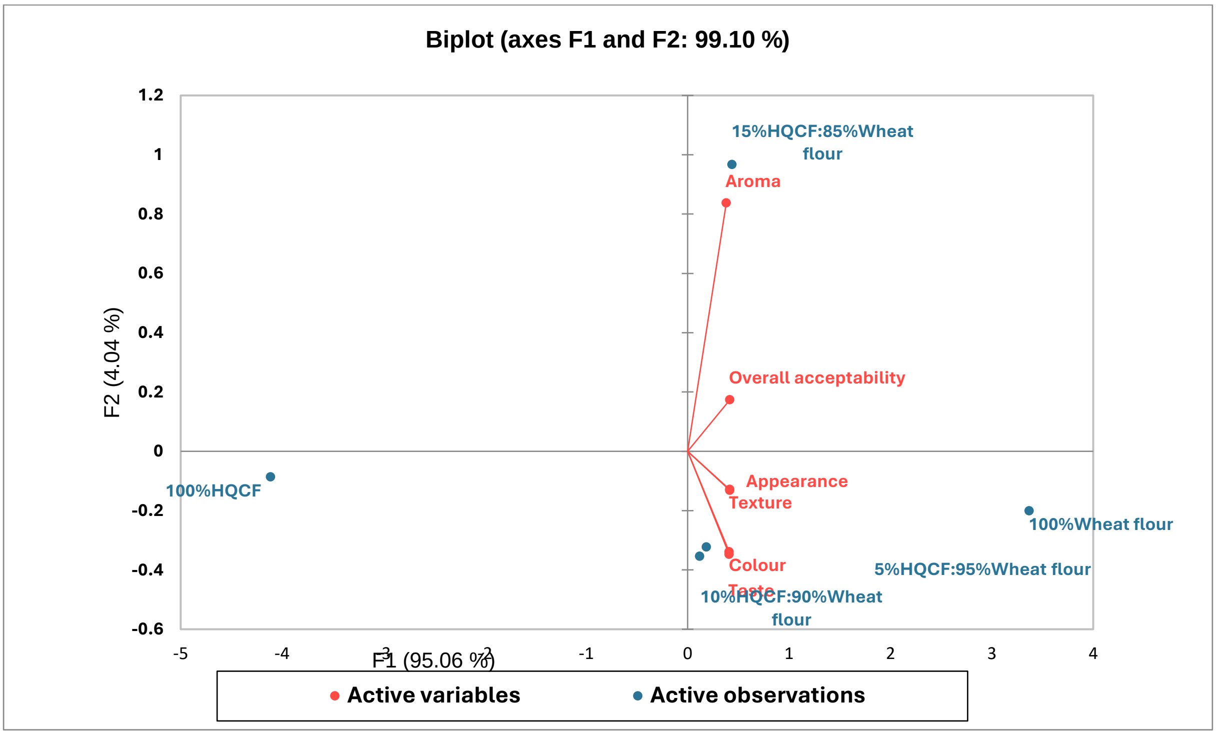

Figure 1: Principal Component Analysis Biplot of the sensory attributes of cookies

The sensory attributes of the chin-chin produced from 100% wheat flour, 100% HQCF, and 5-15% HQCF composite fall within the slightly liked range (except aroma, which falls within neither liked nor disliked). Significant difference(p<0.05) exists in all the sensory attributes of the chin-chin, with chin-chin produced from 100% wheat flour liked very much, and those from the 100% HQCF neither liked nor disliked by the panelists (p<0.05). The overall acceptability of the chin-chin from the 5-15% composite flour falls within the slightly liked range (Table 4). The likeness of the 5% HQCF composite chin-chin may be attributed to the aroma and texture. This was because the 5% HQCF composite and the 100% wheat flour chin-chin were in the same quadrant, with the aroma, texture, and overall acceptability of the product. Likewise, the likeness of the 15% HQCF composite chin-chin may be attributed to the colour, taste, and appearance of the product since the 15% HQCF composite chin-chins are within the same quadrant as the colour, taste, and appearance of the product (Figure 2).

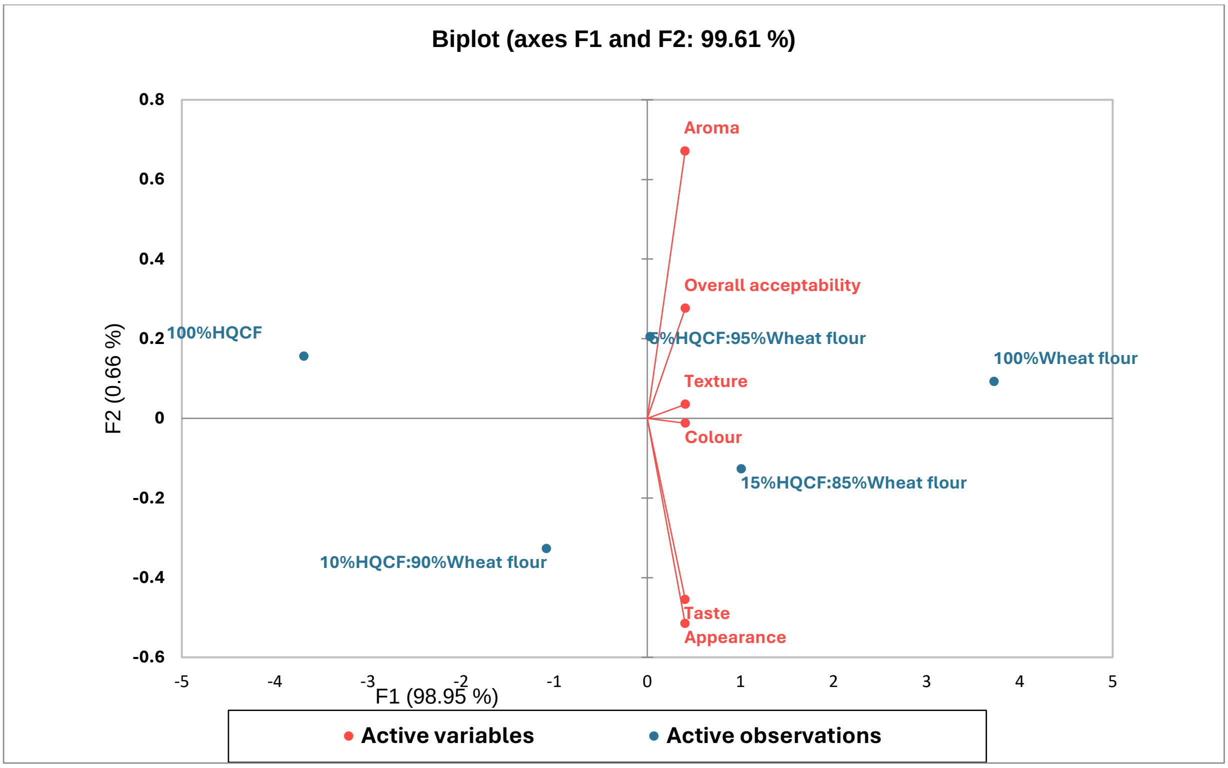

Figure 2: Principal Component Analysis Biplot of the sensory attributes of chin-chin

All the sensory attributes of the doughnut produced from 100% wheat flour and 5-15% HQCF composite fall within the slightly liked range. Significant difference ($p<0.05$) exists in all the sensory attributes of the doughnuts, with doughnuts produced from 100% wheat flour liked and those from 10-15% HQCF composite slightly liked by the panelists; however, 100% HQCF could not form doughnuts (Table 4). This may be attributed to the non-elastic nature of the HQCF, due to the absence of gluten (Li *et al.*, 2023). The 5% and 10% HQCF, and 100% wheat flour doughnuts were within the same quadrant, with texture, aroma, and appearance of the product. Likewise, the 15% HQCF composite doughnut was in the same quadrant as the colour, taste, and overall acceptability of the product (Figure 3). Therefore, 5% and 10% HQCF composite doughnuts may be comparable to the 100% wheat flour doughnut in terms of texture, aroma, and appearance.

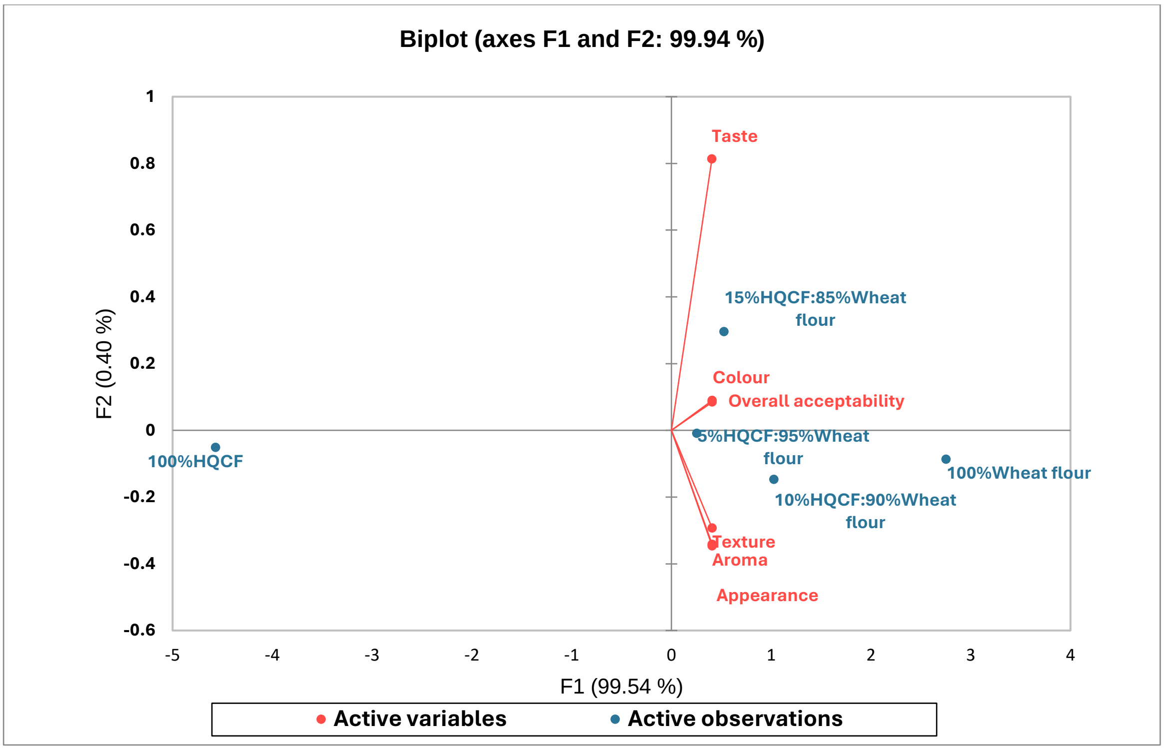

Figure 3: Principal Component Analysis Biplot of the sensory attributes of the doughnuts

CONCLUSION AND RECOMMENDATION

The cookies from wheat-HQCF composite flour are profitable with approximately 143%, 163%, and 297% gain from 5%, 10%, and 15% HQCF composite flour, respectively. Chin-chin from HQCF composite flour is profitable with about 5.03%, 17.94%, and 22.08% gain from the 5%, 10%, and 15% HQCF composite flour, respectively. Correspondingly, doughnuts from HQCF composite flour are profitable with about 24.96%, 40.37%, and 47.98% gain from the 5%, 10%, and 15% HQCF composite flour, respectively. All the sensory attributes of the cookies and chin-chin (except aroma) produced from 100% wheat flour, 100% HQCF, and 5-15% HQCF composite fall within the slightly liked range, while that of the doughnut falls within the range of neither liked nor disliked. The cookies, chin-chin, and doughnuts from 5-15% HQCF were statistically the same for most of the sensory attributes, while those from 100% wheat flour and 100% HQCF were statistically different, with the products from the 100% wheat flour extremely liked and those from 100% HQCF disliked. Also, the 5% HQCF composite chin-chin was comparable to that of the 100% wheat flour in terms of aroma, texture, and overall acceptability. The cookies from the 5% and 10% HQCF composite were comparable to those of the 100% wheat flour in terms of appearance, texture, colour, and taste. The doughnuts from the 5% and 10% HQCF composite were comparable to those of the 100% wheat flour in terms of texture, aroma, and appearance. Therefore, at least 5% HQCF inclusion in composite cookies, chin-chin, and doughnuts may not only be profitable but also acceptable, just like those of the 100% wheat flour to the consumers.

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Conflict of interest

The authors declare no conflict of interest.

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