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Formulation and quality characteristics of macaroni substituted with chickpea and banana flour

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Abstract

The objective of this study was to develop macaroni products from chickpea and green bananas flours by partial substitution wheat flour in order to improve the nutritional composition of the product in the direction of increasing the content of resistant starch, fiber, ash and high quality protein. Four macaroni formulas were established with the control recipe. In five designed recipes, the amount of flour used was gradually reduced from 100% to 70%, while the amount of chickpea and green banana flour substituted increased from 0% to 16% and 0% to 14%, corresponding. The physicochemical characteristics including cooking quality, microstructure, color and nutritional characteristics of macaroni were evaluated. Sensory evaluation of the products created from the formulations was also carried out. The research results have shown that substituting chickpea flour and green banana flour in macaroni formulations affected the physical and chemical properties of the final product. Among the 5 designed formulations, the F3 formula replacing wheat flour with 13% chickpea flour and 10% green banana flour was selected as this product improved the desired nutritional properties. The macaroni product made from the F3 formula contained higher levels of protein, resistant starch, lipids, ash and fiber than the control sample, while the lower carbohydrates have been noted. The rehydration rates, volume gain and cooking loss of F3 product were recorded at values of 67.3%, 91.45% and 3.77%, respectively. The highest number of sensory assessors preferred (80-100%) to the F3 product compared to the macaroni products made up of the remaining formulations.

Keywords: macaroni; composite flour; cooking quality; physical-chemical properties; sensory evaluation.

Practical Application: Macaroni is a popular product in daily meals. This study aims to develop a new macaroni product on the basis of reducing wheat flour and replacing it with functional valuable flour sources (chickpea and green banana flours) with the desire to improve the nutritional function for human consumption (increasing content of resistant starch, fiber, minerals and protein quality improvement). The processed product is highly acceptable from a technological and sensory point of view. The results of the study can be applied at different technological scales, helping the food industry to provide new foods with nutritional value to different types of consumers.

1 Introduction

Macaroni originated in Italy because of its convenience and nutritional value. It is an ideal foundation to meet the needs for a healthy and nutritious meal when eaten with other nutrient-rich ingredients (Mishra et al., 2022). Over the years, gluten-free or low-gluten products have been more widely consumed by gluten-intolerant celiacs, so diversifying products and replacing/adding ingredients with nutritional and functional characteristics to macaroni recipes also aims to meet consumers' increasing demand. A good source might be green banana flour, which is a complex carbohydrate rich in resistant starch (RS), minerals, vitamins, and fiber (Tribess et al., 2009). RS in green bananas is not hydrolyzed in the digestive tract but is fermented directly in the colon, so the use of banana flour in food processing helps lower blood sugar in obese, diabetic people. In addition, chickpeas (*Cicer arietinum* L.) have also been reported to have high content of proteins (Chibbar et al., 2010; Biabani & Sajadi, 2018) and a source of almost all amino acids except sulfur-rich amino acids (methionine and cystine) (Alajaji & El-Adawy, 2006). Chickpea has also a good source of dietary fiber, vitamins, minerals (Muzquiz & Wood, 2007) and starch (37.5 to 50.8%) (Biabani & Sajadi, 2018).

In a rapidly changing world, with altered food habitsand modern lifestyles, consumers demand for more hygienicand nutritious food for their healthier life (Prema et al., 2018). Dutta et al. (2018) and Saget et al. (2020) found that pasta made with chickpea flour has more protein, fiber, and essential fatty acids than pasta made with durum wheat. However, when replacing different ingredients in the recipe, the additive ingredients that help create a good structure for the product must also be considered. Alternative ingredients in macaroni processing have been studied to increase protein content while providing additional sources of fiber and antioxidants (Sharma et al.,

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2021), such as forms of macaroni supplemented with mango peel powder (Ajila et al., 2010), barley flour (Ivanišová et al., 2018), and fruit peel (Mishra et al., 2022). So far, there has not been much research on combining green banana and chickpea flour in macaroni recipes. This study used chickpea and green banana flours to create synthetic flour for macaroni recipes to improve product quality. The physico-chemical properties and organoleptic attributes of macaroni were also evaluated.

2 Materials and methods

2.1 Method of preparing ingredients

Banana flour preparation

Banana (“Xiem” cultivar) bunches (*Musa* spp.) were collected when the fruit was still green but reached maturity, then prepared and dried (Tai et al., 2021; Thuy et al., 2023a). Dried sliced banana was finely ground and sieved (212 µm), placed in a sealed container, and kept at room temperature (25 ± 2 ^oC) for further study.

Chickpea flour (Organic Chickpea Flour, Peru)and wheat flour (Interflour, Vietnam) were usedin this study. All other raw materials (shown in Table 1) were purchased from the local market.

2.2 The formulation for macaroni samples

Chickpea flour (CF) (0, 6, 10, 13, and 16%) and green banana flour (GBF) (0, 5, 7, 10, 14%) were mixed with wheat flour (WF) (100, 89, 83, 77, 70%) in different proportions to produce macaroni (Table 1). F0 is the control sample, and the formulas from F1 to F4 are macaroni samples with 4 ratios replaced with CF and GBF. The values expressed in units of mass are gram. The flour mixture was put into the macaroni maker (Philips, Japan). The dough was incubated for 30 minutes (Thuy et al., 2020), then the machine was pressed. Macaroni was cooked at boiling temperature for 5 minutes and the product quality was analyzed.

Proximate analysis

Standard procedures were utilized to evaluate the moisture, protein, fat, crude fiber, and ash content of raw materials and products (Association of Official Analytical Chemists, 2005). The total carbohydrate content was determined (McCseady, 1970).

Resistant starch (RS) analysis

RS was determined using the Association of Official Analytical Chemists (AOAC) Method 2002.02 (Ang, 2011).

Hardness testing

Texture attributes of macaroni were analyzed using a Brookfield CT3 (Texture analyzer, MA, USA) equipped with a 1,500 g load cell.

Cooking quality analysis

The cooking loss (%), rehydration rate (%), and volume increase (%) were analyzed (Thuy et al., 2020). 50 g of macaroni was placed in 500 mL and boiled for 4 minutes (the time needed to complete starch gelatinization). The cooked macaroni was separated; the collected cook water was dried at 105 ^oC in an oven for cooking loss (CL) quantification (Equation 1).

$$ü\ (\%) = \frac{m_1}{m_o}\ 100 \quad (1)$$

Where m_1 is the weight of residue from cooking water and m_o is the weight of macaroni sample.

The cooked macaroni was dried in an oven at 105 ^oC for 20 hours to estimate the rehydration rate (RR%) (Equation 2). The volume increase (VI%) was measured using Equation 3.

$$RR(\%) = \frac{m_2 - m_3}{m_3} x100 \quad (2)$$

Where $m_2$is the weight of cooked macaroni and $m_3$is the original weight of macaroni.

$$VI(\%) = \frac{v_2 - v_1}{v_1} \quad (3)$$

Where $v_1$is the volume of uncooked macaroni and $v_2$is the volume of cooked macaroni.

Table 1. Formulation used in the macaroni.

Ingredients	F0	F1	F2	F3	F4
Wheat flour	239	212.71	198.37	184.03	167.3
Chickpea flour	0	14.34	23.9	31.07	38.24
Green banana flour	0	11.95	16.73	23.9	33.46
Semolina	6	6	6	6	6
Potato starch	55	55	55	55	55
Salt	2	2	2	2	2
Xanthan gum	6.3	6.3	6.3	6.3	6.3
Eggs	65	65	65	65	65
Water	63	63	63	63	63
Total (g)	436.3	436.3	436.3	436.3	436.3

Colour analysis

The sample's color (L* and b*) was measured using a Colorimeter (CR 400 Konica Minolta, Tokyo, Japan). At least three measurements were obtained on each sample.

Sensory evaluation

Twenty panelists did a Check-All-That-Apply (CATA) and Quantitative Descriptive Analysis (QDA) sensory evaluation of macaroni samples. The sample was described by seven descriptive qualities: egg smell, banana smell, chickpea smell, sweetness, toughness, bright yellow and saltiness. The sensory evaluation method was carried out according to Thuy et al. (2023b) and Too et al. (2022).

Statistical analysis

Statistical analysis was carried out using Statgraphics Centurion XIX (USA). Results were expressed as mean ± standard deviations. LSD was used at a 95% significance level to compare mean individuals. In addition, sensory analysis was carried out using XLSTAT 2014 for Principal Component Analysis (PCA).

3 Results and discussions

3.1 Estimation of some chemical components of ingredients used

The approximate analytical results of the ingredients used in the formulation are presented in Table 2. As observed, the protein content of the analyzed chickpea flour (CF) was about 21.6 g/100 g, similar to the published result (20.3 g/100 g) (Ghribi et al., 2015). CF had a good source of protein, with almost twice the content (24.4%-25.4%) of wheat flour (9.3%–14.3%) (Rachwa-Rosiak et al., 2015). It is also evaluated as a rich source of lysine, which can enhance protein quality when combined with other cereal flour (Havemeier et al., 2017). CF is also considered an essential source of nutrition for the poor who cannot afford animal protein (Jukanti et al., 2012).

In our analysis, CF had nearly twice as much fiber as WF. Rachwa-Rosiak et al. (2015) reported that a higher fiber content was found in CF (3.9%-11.2%) compared to WF (0.9%-1.8%) and is a good source of fat (3.7-5.1%) (Rachwa- Rosiak et al., 2015) of which linoleic acid (an essential PUFA) is present. The analytical moisture content of CF was 8.3 ± 0.3%, slightly lower than the published results of Mohammed et al. (2011), with values of 9.35% and 9.5%, respectively.

The RS content of GBF was measured as 46.8 ± 0.3%, which is quite similar to the results of Tribess et al. (2009), with RS content in the range of 40.9-58.5 g/100 g and 52.2-68.1 g/100 g, respectively. The apparent advantages of GBF include high total starch (73.4%), RS (17.5%), and fiber content (~14.5%) which were mentioned by Juarez-Garcia et al. (2006). In general, the flour ingredients used have outstanding advantages from the nutritional point of view, especially for the protein, lipid, fiber, ash and RS contents

3.2 Effect of mixing ratio of WF:CF:GBF on the chemical components of macaroni

The addition of CF and GBF affected the quality of macaroni products according to a nutritional point of view, decreasing carbohydrate content, but increasing RS and increasing other quality values, especially protein, fiber, and ash (Table 3). Furthermore, chickpeas are high in essential amino acids like lysine, histidine, phenylalanine, valine, and threonine (Kuen et al., 2017). Therefore, it would be the perfect dietary supplement combined with WF to improve protein quality and ensure a better overall amino acid balance. In addition, the high RS content in GBF may contribute to colon health (Nugent, 2005) by possessing functional properties similar to dietary fiber. This feature shows the physiological benefits to humans when used to prevent diseases. Food with high RS content created fewer calories and lower glycemic load (Thuy & Van Tai, 2022). This formulation may also benefit persons with diabetes or are overweight.

3.2 Effect of mixing ratio of WF:CF:GBF on the color and texture of macaroni

The color of macaroni

The L* (0-100: black to white) and b* values (-b to +b: color from blue to yellow) of macaroni products partially replacing flour with CF and GBF in different proportions (Table 4). The mixed sample (WF: CF: GBF) at 89:6:5 had the highest L* value, and the composite sample at 70:16:14 had the lowest L* value. When the percentage of partial replacement of wheat flour with green banana flour and chickpea flour increased, the L* value of the product decreased due to the CF and GBF having darker colors than WF. In addition, the b* value decreases with increasing percentage replacing part of the WF with a mixture of GBF and CF

Table 2. Proximate analysis of ingredients.

Ingredients	Protein (%)	Carbohydrate(%)	Lipid (%)	RS (%)	Fiber (%)	Moisture (%)	Ash (%)
Wheat flour	10.2 ± 0.2	74.3 ± 0.4	0.9 ± 0.05	2.9 ± 0.1	2.4 ± 0.1	11.6 ± 0.2	0.5 ± 0.1
Chickpea flour	21.6 ± 0.3	57.3 ± 0.3	3.9 ± 0.03	4.9 ± 0.1	4.6 ± 0.1	8.3 ± 0.3	2.7 ± 0.1
Green banana flour	2.65 ± 0.02	78.1 ± 0.8	1.8 ± 0.05	46.8 ± 0.3	8.5 ± 0.1	5.6 ± 0.2	3.1 ± 0.2
Semolina	10.70 ± 0.1	70.8 ± 0.2	1.1 ± 0.04	-	3.2 ± 0.05	12.4 ± 0.5	0.8 ± 0.05
Potato starch	4.30 ± 0.05	80.1 ± 0.2	0.3 ± 0.01	63.4 ± 0.4	0.5 ± 0.01	14.0 ± 0.5	0.3 ± 0.05
Egg	12.60 ± 0.1	0.7 ± 0.05	9.5 ± 0.05	-	-	75.3 ± 0.8	1.1 ± 0.1

Values are means ± standard deviations ($n = 3$).

Table 3. Proximate analysis of the macaroni quality (after boiling for 5 minutes).

Mixing ratios (WF:CF:GBF) (%)	Form-ulas	Protein (%)	Carbohydr-ate (%)	Lipid (%)	RS (%)	Fiber (%)	Ash (%)
Control sample (100% WF.)	F0	4.92 ± 0.01	31.29 ± 0.2	1.21 ± 0.01	2.94 ± 0.05	0.86 ± 0.01	0.28 ± 0.01
89:6:5	F1	4.98 ± 0.02	30.76 ± 0.15	1.27 ± 0.05	3.30 ± 0.03	1.0 ± 0.02	0.36 ± 0.01
83:10:7	F2	4.99 ± 0.05	30.05 ± 0.2	1.29 ± 0.05	3.41 ± 0.07	1.05 ± 0.01	0.40 ± 0.01
77:13:10	F3	5.01 ± 0.05	29.80 ± 0.3	1.32 ± 0.02	3.62 ± 0.08	1.12 ± 0.05	0.45 ± 0.05
70:16:14	F4	4.97 ± 0.06	29.37 ± 0.5	1.35 ± 0.01	3.88 ± 0.05	1.21 ± 0.04	0.50 ± 0.03

Values are Means ± STD (n = 3), WF: Wheat flour, CF: Chickpea flour, GBF: Green banana flour.

Table 4. Color of macaroni in different mixing ratios (WF:CF:GBF).

Mixing ratios (WF:CF: GBF) (%)	Formulas	Color		Hardness
		L*	b*	
Control sample (100% wheat flour)	F0	79.55^{d**}	13.63^{c}	136.25^{a}
89:6:5	F1	78.42^{c}	12.97^{b}	138.62^{b}
83:10:7	F2	77.73^{c}	12.37^{b}	159.85^{c}
77:13:10	F3	73.29^{b}	11.30^{a}	162.05^{c}
70:16:14	F4	70.06^{a}	10.89^{a}	176.60^{d}

**The same letter in a column indicates no significant difference (P > 0.05). WF: Wheat flour, CF: Chickpea flour, GBF: Green banana.

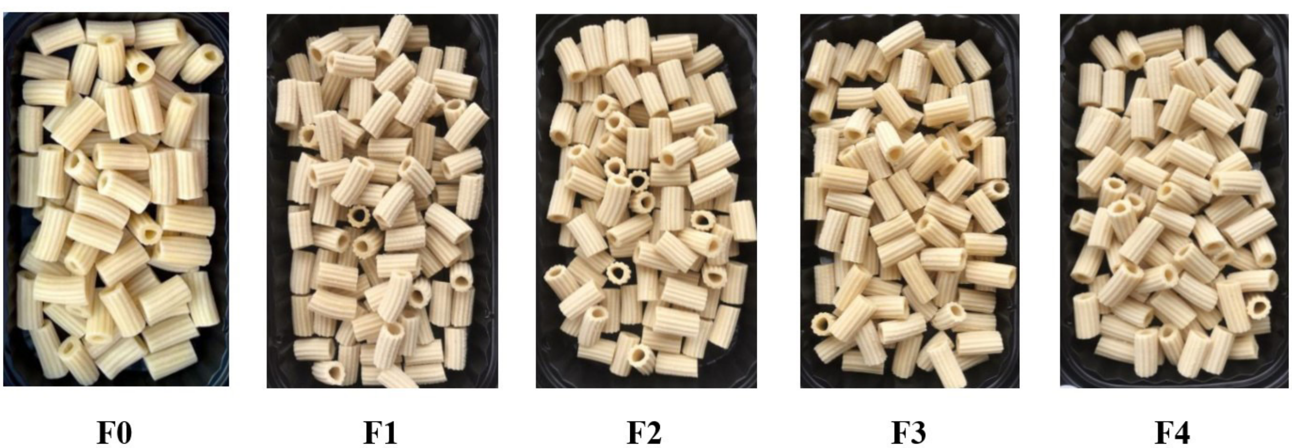


Figure 1. Macaroni color at different mixing ratio of WF:CF:GBF.

because both have less yellow color than WF. However, there was no statistically significant difference in b* values between samples of 77:13:10 and 70:16:14. Macaroni (the control sample and flour substituted with different proportions) are shown in Figure 1.

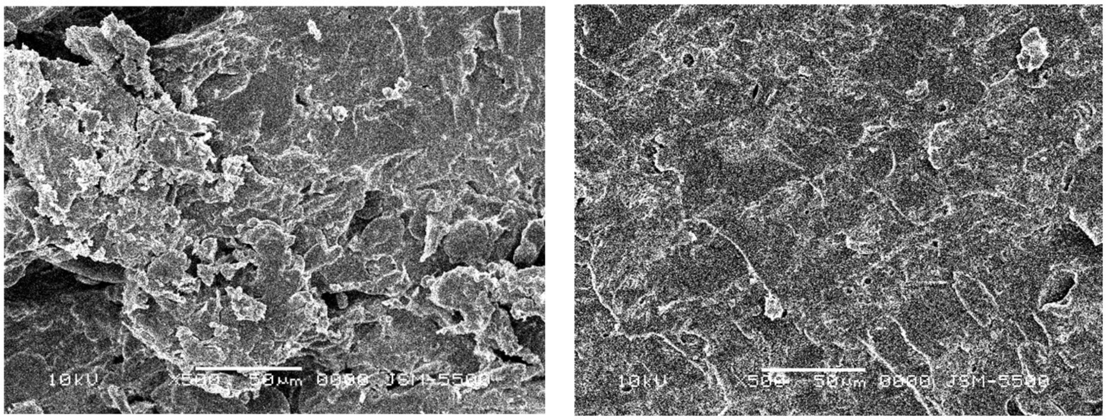
The hardness

The effect of partial replacement of WF with CF and GBF on the structural properties of the product was also documented;increasing the percentage of partial replacement of WF with a mixture of CF and GBF, the product hardness increased. Specifically, the product has the lowest hardness (138.6 g force) in the ratio of WF:CF and GBF at 89:6:5 and the highest (167.0 g force) at the mixing ratio of 70:16:14 (%) (Table 4). Samples with mixing ratios of 83:10:7 (%) and 77:13:10 (%) have medium hardness (159.85 to 162.05 g force). Increasing the fiber content (from CF and GBF) in macaroni processing has also increased product hardness (Ajila et al., 2010).

The microstructure

The scanning electron microscopy of macaroni microstructures revealed the arrangement of the gluten and starch networks in the boiled macaroni (Figure 2). The structural image of the control sample (Figure 2a) showed a few voids, and the components were tightly bound together. The macaroni sample supplemented with CF and GBF (Figure 2b) had almost no voids. CF and GBF are good sources of protein and polysaccharides that can support the protein-gluten network, thus enhancing the binding ability of starch granules and gluten proteins in the dough.

Sun et al. (2019) suggested that adding yam flour improved the binding capacity of starch granules and gluten protein in



a. b.

Figure 2. SEM micrographs of (a) wheat flour macaroni and (b) supplemented with chickpea flour and green banana flour.

Table 5. The cooking quality of macaroni made from recipes with different ratios of wheat flour: chickpea flour and green banana flour.

Mixing ratios (WF:CF:GBF) (%)	Formulas	Rehydration rate (%)	Cooking loss (%)	Volume increase (%)
Control sample	F0	62.50^{a}	2.80^{a}	80.85^{a}
89:6:5	F1	63.85^{b}	2.85^{a}	82.93^{b}
83:10:7	F2	66.65^{c}	3.48^{b}	88.07^{ac}
77:13:10	F3	68.80^{d}	3.77^{ab}	91.45^{d}
70:16:14	F4	69.11^{d}	3.95^{b}	92.50^{d}

WF: Wheat flour, CF: Chickpea flour, GBF: Green banana; The same letter (a, b, c, d) in a column indicates no significant difference (P > 0.05).

the dough. It could also be that the gelatinous properties of protein and starch in CF and GBF caused the starch granules to fill more firmly in the gluten network. In addition, the distance between starch molecules and gluten protein decreases gradually, forming a dense and smooth structure, which is also the reason for increasing the hardness of the product. These findings were consistent with Han et al. (2022) in studying the addition of white kidney bean flour in noodles.

Cooking quality

Testing the cooking quality of macaroni showed increased volume and water absorption as the contents of CF and GBF increased (Table 5).

GBF has a high RS and amylose content (Thuy et al., 2022), resulting in the mixed flour in this study having a higher amylose content than the control sample, thus causing network swelling during the boiling. It is also relatively consistent with the published results of Kuen et al. (2017) in making instant noodles from chickpea and okara flours. Because of these ingredients' relatively high fiber content, increasing the percentage of partial replacement of WF with a mixture of CF and GBF increased the macaroni volume, which accelerated the fiber and promoted water absorption, thereby increasing the heating processof the volume and mass of macaroni after cooking. The extent of volume gain during macaroni boiling was also influenced by starch gelatinization and protein hydration. Adding CF and GBF affected the cooking loss of macaroni. As the amount of WF decreased, the amount of gluten in the flour mixture also reduced, causing the overall structure of the protein-starch matrix to weaken, resulting in more soluble components of the macaroni being washed out into the cooking water. The highest cooking loss (3.95%) at the WF:CF:GBF mixing ratio was 70:16:14, and the lowest (2.85%) at the 89:6:5 mixing ratio.

Sensory evaluation

The dispersion of the macaroni recipes on the graph (Figure 3) showed that changing the flour mixture (WF:CF:GBF) significantly influences the organoleptic properties of macaroni. Formulas of groups F1 and F4 located quite far from the first principle component axis have low sensory scores, yellow noodles, uncharacteristic products, or a strong smell of beans and bananas. Formula F0 has a strong egg smell, while formula group F2 and F3 is rated well (near the first principle component axis), the product had a slight smell of chickpeas and banana, reasonablestructure, pleasant sweetness, and strange color (between light brownish and yellow). Preference mapping analysis also showed similar results (Figure 4). The chart again confirms that the F3 formula is the most preferred by consumers (80-100%); the product has a delicious and characteristic taste. Meanwhile, formulas F0 and F2 have a good preference level (60-80%), and groups F1 and F4 have a lower level of consumer acceptance (40-60%). Therefore, combining all the results from the physicochemical analysis, cooking quality, and sensory

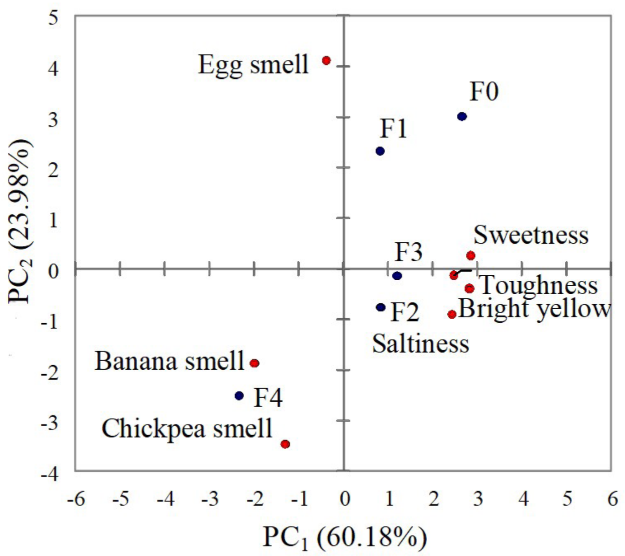


Figure 3. Correlation of sensory attributes with different macaroni formulas.

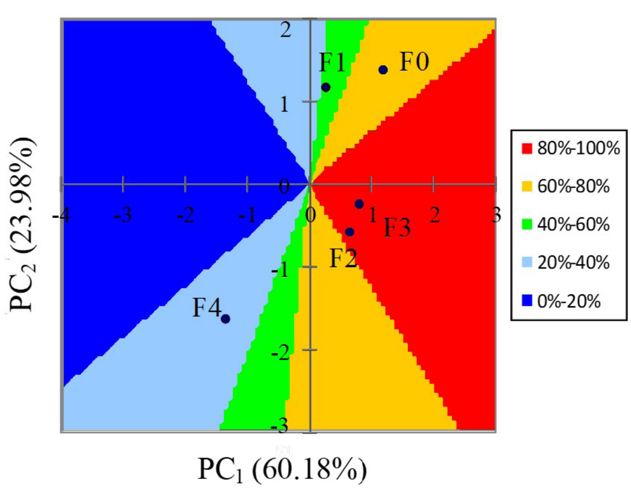


Figure 4. Preference mapping of macaroni with different formulas.

evaluation, the formula F3 (WF:CF:GBF of 77:13:10%) was selected. This combination was determined to be a suitable value in terms of enriching the quality of the product without sacrificing its technological properties.

4 Conclusions

Experimental results have proved that CF and GBF can partially replace WF in macaroni processing; the product has increased protein, fiber, resistant starch, and mineral. The texture of macaroni, as evidenced by several parameters such as water absorption, volume increase, firmness and microstructure was improved when supplemented. In addition, high sensory evaluation was obtained, up to 23% incorporation of CF and GBF. Adding CF and GBF could promote the close binding of starch particles to the gluten protein. More in-depth research will be developed with parameters achieved at a larger production scale applied. Complete product quality analysis will be fundamental to ensuring macaroni products can be manufactured on an industrial scale

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