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Development of High-value Food Products from Selected Indigenous and Underutilized Crops to Increase Food Utilization and Reduce Food Loss

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Fresh agricultural produce is inherently perishable, and substantial losses – ranging from slight loss of quality to total spoilage – are incurred during production, processing, and distribution. The causes of these losses include physical damage during handling and transport, physiological decay, or simply surpluses in the marketplace. Food processing and preservation play major roles in reducing food loss and wastage. Here, at various sites (Tayabas, Candelaria, and Dolores, in Quezon Province, the Philippines), we identified selected indigenous and underutilized crops, namely saba banana (*Musa acuminata*×*balbisiana*, ABB group, 'Saba'), white corn (*Zea mays* L.), and sweet potato (*Ipomoea batatas* L.), for possible product development. These crops were processed into flours, which were consequently used to make bread or muffins. In the course of performing these product development experiments we also characterized the physicochemical and sensory properties of the flours. Generally, up to 50% substitution of APF with saba or sweet potato flour and up to 25% substitution with MCF and 100% substitution with MSCF was acceptable in the food products tested. Indigenous and underutilized crops should be explored for their processing possibilities. Processing of these raw materials makes them shelf-stable, prevents losses and wastes and could eventually increase their market value. Development of food products and optimization of processing technology are effective channels for promoting underutilized crops as alternative food sources. These measures may encourage local farmers in the study areas to expand their production of these crops, not only as additional sources of income but also for their own subsistence.

Key words: indigenous and underutilized crops, product development; reduction of food loss

Introduction

In many developing countries with humid and warm climates, such as the Philippines, more than 40% of food losses occur during the production, postharvest, and processing stages of the food supply chain. Such losses are caused by deterioration of perishable crops, lack of storage and processing facilities, and inadequacy of market systems (FAO, 2011). As a result of food loss and waste, essential nutrients that could contribute to energy supply are also lost. Projections of food wastage and the corresponding nutrient losses across the entire Philippine population reveal considerable negative economic impacts (FNRI-DOST, 2014).

The United Nations' Food and Agriculture Organization (FAO, 2011) has highlighted some of the reasons behind food loss in developing countries such as the Philippines. These include (a) premature harvesting due to food deficiency or immediate need for money; (b) poor storage and processing facilities and

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infrastructure; (c) failure to comply with food safety standards; (d) lack of direct markets between small farmers and consumers; and (e) wasteful consumption habits. As a result, crops lose both economic and nutritional value and may end up being unsuitable for consumption. Food loss is also rooted in agricultural land degradation due to poor maintenance. In the Philippines, recent conversion of farmlands into commercial and residential areas may also be a factor.

Horticultural crops are an important part of agricultural production in the Philippines: they account for 44% of the total volume of food crops, make a major contribution to the economy, and are important sources of export earnings. However, average postharvest losses are 42% for vegetables and 28% for fruit. For instance, in one trial shipment of saba cooking bananas from going to Manila a loss of 20% was reported. The causes of postharvest losses are diverse, but the most common ones are overripening, disease, harvesting when the fruit is immature, and mechanical damage (FFTC, 1993).

Here, we tested the use of saba banana, sweet potato, and white corn flours in food products that are popular in the Philippines. Our aim was to encourage the residents of the study areas to utilize these crops in various types of processing and thus to minimize food loss and wastage.

Materials and Methods

The selected crops in Tayabas, Dolores and Candelaria in Quezon Province, Philippines – namely saba banana (*Musa acuminata*×*balbisiana* (ABB Group) 'Saba'), white corn (*Zea mays* L.), and sweet potato (*Ipomoea batatas* L.) – were processed into flours, which were consequently processed into value-added products. The physicochemical properties of the flours were determined by using the methods of the Association of Official Analytical Chemists (AOAC) International (2012).

Processing of saba banana, sweet potato, and corn

Unripe but mature saba bananas were washed and peeled. The bananas were sliced thinly without the core and then soaked in 0.05% sodium metabisulfite solution for 1 h to inhibit browning. The slices were dried in a cabinet dryer at 60℃ for 24 h. The dried slices were cooled, ground into flour in a disk attrition mill, and passed through an 80-mesh US Standard sieve. Sweet potato flour was obtained from white-fleshed tubers. The tubers were peeled, washed, and cut into thin slices, thus increasing the surface area for faster drying. The slices were placed on drying trays and dried in a cabinet dryer for at least 6 h at 60℃. The dried slices were cooled, ground into flour with a disc attrition mill, and passed through an 80-mesh sieve.

Flour produced from mature corn (IPB var 6) was obtained from the Institute of Plant Breeding (IPB), University of the Philippines Los Baños. In addition, a white cultivar of corn at the milk stage was obtained from one of the study areas in Quezon Province. The ears were washed and the kernels removed from the cobs. The corn kernels were placed in a cabinet drier (60℃) until a moisture content of $\leq$10% was reached. The dried kernels were then ground in a disc attrition mill and passed through a 50-mesh sieve to obtain uniformly sized flour particles.

Product development studies

We replaced conventional all-purpose flour (APF) with saba, sweet potato, or white corn flour at different ratios. The most acceptable mix that contained the highest amount of saba, sweet potato, or white corn flour but that did not differ in the overall sensory attributes and general acceptability significantly from the APF control was selected for further testing. Proximate compositions, including moisture content, ash content, crude fiber, crude protein, and nitrogen-free extract (NFE), were determined. Sensory evaluations using quality scoring were also conducted to compare the organoleptic properties of the products. The analyses done varied depending on the product. The most acceptable mix for each product type was determined by using the data from the physicochemical and sensory analyses.

Use of saba banana and sweet potato flour in* pandesal *("salt bread") production. *Pandesal* was formulated in accordance with the following baker's percentages (based on the total amount of flour): bread A =100% APF; breads B and C=25% and 50% saba flour, respectively; and breads D and E=25% and 50% sweet potato flour, respectively. All other ingredients were kept constant and the amounts computed by using baker's percentages. Figure 1 shows the steps used to produce *pan de sal.*

Bread samples made from the different flour blends were evaluated by 15 panelists composed of BS Food Technology students of UP Los Banos by using quality scoring on a 7-point scale. Attributes evaluated were color (crust), aroma, taste, texture, and overall accept-

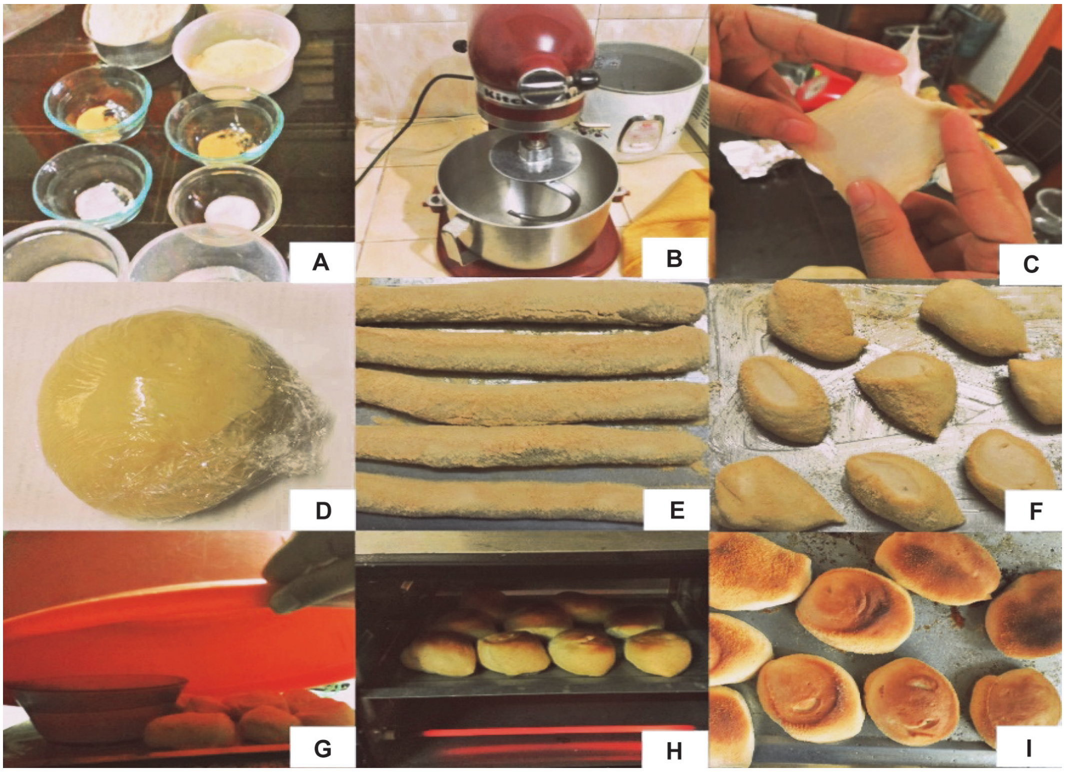

Fig. 1. Processing of *pandesal*. (A) preparation of ingredients; (B) mixing; (C) film test (stretching the dough into thin film without breaking to test for well-developed gluten); (D) dough shaping; (E) and (F) rolling, cutting, and shaping; (G) proofing; (H) baking; (I) finished product.

ability. The control and the experimental product rated highest in the sensory evaluation were analyzed for their proximate contents of a number of components by using AOAC International (2012) methods. Moisture content was measured by using an oven-drying method, and ash content was determined by dry-ashing. Protein content was analyzed by using the Kjeldahl method and a conversion factor of 5.70 (for wheat). Crude fat content was measured by using the Soxhlet method. Crude fiber content was determined by sequential acid and base extraction. NFE (carbohydrate) content was estimated by difference of the % crude fat, % crude protein, % crude fiber, % moisture and % ash from 100%. Further details on the methods are found in AOAC (2012).

Use of white corn flour in muffin production. Muffins were prepared by using flour produced from mature white corn kernels (MCF) or from flour produced from milk-stage white-corn kernels (MSCF) and baked at 175℃ for 20 min. in a temperature-controlled oven. Varying amounts of wheat flour and cornflour were used for each preparation, and sensory evaluations were conducted separately for the MCF and MCSF combnations to determine the best formulation of flour mixture. Sensory attributes – namely color, aroma, mouthfeel, texture, sweetness, flavor, aftertaste, and general acceptability – of muffins produced by using the different formulations were evaluated by 15 panelists (Food Technology students of UP Los Banos). The formulations that were the most generally acceptable were then used to compare the effects of the maturity of the corn on the other sensory attributes of the muffins. The most acceptable formulations of muffins for the two types of cornflour were also analyzed in terms of proximate composition and shelf life.

The storage stability of those muffins produced by adding MCF or MSCF that were considered most acceptable upon sensory evaluation was determined by monitoring changes in the moisture content, water activity, pH, total suspended solids (TSS), and microbiological properties of the samples. Parameters were measured from time zero (t_0) the day of baking of the samples, and at the second and fourth day while the samples were stored at room temperature.

Statistical analysis

All experiments were performed in triplicate. We used a completely randomized design for the analyses. A randomized complete block design was used for the sensory evaluation. Analysis of variance was performed with the SAS General Linear Models (GLM) procedure with SAS software 9.1.3. 2003. Significance of differences was defined at $P \leq 0.05$. Differences among treatments were examined for the level of significance by using the least significant difference (LSD) test.

Results and Discussion

Physicochemical properties of flours made with saba banana, sweet potato, or white corn

Table 1 shows the protein, ash, and moisture contents of the three kinds of flour used in making *pandesal*. These data were obtained from previous studies by other researchers. These components are the primary ones taken into consideration when purchasing flour for bread preparation. Saba flour and sweet potato flour have almost the same percentage of protein; it is much lower than that of APF and therefore it cannot help in extensive expansion or aeration of the dough during bread preparation. Although saba and

Table 1. Proximate compositions of bread, saba and sweet potato flours.

Parameters	Bread flour[1]	Saba flour[2]	Sweet potato flour[3]
Protein, %	12.50 to 13.70	2.30 ± 0.30	2.30 ± 0.07
Ash, %	0.53 to 0.57	2.20 ± 0.10	1.56 ± 0.19
Moisture, %	13.30 to 14.00	10.20 ± 0.60	8.70 ± 0.10
Fiber, %	no data	2.0 ± 0.10	9.40 ± 0.08
Fat, %	no data	0.50 ± 0.00	0.52 ± 0.06

[1] Philippine Foremost Milling Corporation, 2015.
[2] Lau, 2007.
[3] Singh *et al*., 2008.

(A) (B)

Fig. 2. Flour produced from (A) mature and (B) milk-stage white corn.

Table 2. Proximate compositions of *pandesal* produced by using different ratios of all-purpose flour (APF) with saba or sweet potato flours.

Component	Mean value[1]		
	100% APF	75% APF: 25% saba flour	75% APF: 25% sweet potato flour
Moisture, %	14.89 ± 0.20^b	20.78 ± 0.17^a	19.76 ± 0.02^a
Crude protein, %	10.47 ± 0.34^a	7.99 ± 0.06^b	8.47 ± 0.37^b
Crude fat, %	1.23 ± 0.07^a	1.11 ± 1.20^a	2.15 ± 0.09^a
Crude fiber, %	1.39 ± 1.17^b	2.18 ± 0.85^b	4.96 ± 2.43^a
Ash, %	0.08 ± 0.00^a	1.74 ± 0.09^a	0.75 ± 0.09^a
Nitrogen free extract (NFE), %	72.53 ± 0.28^a	65.99 ± 0.49^b	59.80 ± 8.06^c

[1] Mean values followed by the same letter within a row are not significantly different from each other at $P \leq 0.05$ using LSD.

sweet potato flours have high nutritional value, when they are used as alternatives to APF in bread selected additives are required to improve bread volume, texture, flavor, shelf life, and overall quality (Lu and Gao, 2011).

MCF or MSCF (Fig. 2) was used as a partial substitute for wheat flour in the production of muffins. One way to determine the quality and degree of chlorination of a flour is to determine its pH. The pH of flour decreases as the amount of chlorine used to treat the flour increases. Importantly, the corn flours used in this study were not treated with chlorine and thus had pH values of 5.5 (MCF) and 5.8 (MSCF). APF has a higher pH than corn flour (6.0–6.1). The TSS value of MSCF was higher (4.5 ºBx) than that of MCF (2.0 ºBx)and all-purpose flour (2.0 ºBx). This can be explained by the fact that the concentration of simple sugars is higher in young fruit, vegetable, grain, and cereal crops and decreases with maturity as more sugar is converted to starch.

When starch granules in water suspension are heated, they gradually start to absorb water. The increase in size of the granules through the breakdown of intermolecular bonds, and the consequent engagement of more water by hydrogen binding sites, irreversibly dissolves the starch granules.This process – referred to as gelatinization – results in loss of birefringence and opacity, an increase in viscosity, and the formation of a paste or gel (Corn Refiners Association, 2006). The behavior, size, and shape of each starch are characteristic of its plant source, and the gelatinization point (or range) is specific to each starch. As discussed by Griswold (n.d.), the gelatinization range for cornstarch is 64 to 72℃. This range was also observed in the starches obtained from both MCF and MSCF. High gelatinization temperature is due to the low-molecular weight amylose and amylopectin with shorter chain length of the starch in corn compared with all purpose flour. This property has considerable impacts in the baking behavior of flour and the properties of the baked products (Belitz, *et al.,* 2009).

Proximate composition of *pandesal* made by adding saba or sweet potato flour

Table 2 shows the proximate compositions of the most acceptable *pandesal* formulations. Moisture, protein, NFE and fiber were the abundant components. Bread made with 100% APF had the highest protein content (10.47%±0.34%), whereas bread made by using 25% sweet potato flour had the highest fiber content (4.96%±2.43%). Crude fat or ash content did not differ among the breads, whereas NFE was in the order of standard bread flour ＞ added saba flour ＞ added sweet potato flour.

Sensory properties of *pandesal*

Quality scores for crust color, aroma, texture, flavor, and general acceptability of *pandesal* are shown in Table 3.

In terms of color, the crust of *pandesal* usually ranges from light brown to brown. There were no differences in crust color between breads A (100% APF) and B (75% APF and 25% saba flour), and between breads C (50% APF and 50% saba flour) and D (75% APF and 25% sweet potato flour). In contrast, the crust color in treatment E (50% bread flour and 50%

Table 3. Mean scores for each sensory attribute of the different *pandesal* formulations. APF, all-purpose flour.

Sensory attributes[2]	Mean sensory score[1]				
	Bread A (100% APF)	Bread B (75% APF: 25% saba flour)	Bread C (50% APF: 50% saba flour)	Bread D (75% APF: 25% sweet potato flour)	Bread E (50% APF: 50% sweet potato flour)
Color (crust)	4.27[b]	4.33[b]	5.00[a]	5.00[a]	1.73[c]
Aroma	2.27[a]	2.47[a]	3.53[b]	4.60[c]	4.67[c]
Texture	2.20[a]	2.07[a]	4.53[b]	5.67[c]	5.73[c]
Flavor	2.60[a]	2.53[a]	4.60[b]	4.87[b]	6.13[c]
General acceptability	6.40[c]	6.00[c]	3.27[b]	3.13[b]	1.53[a]

[2] Mean values followed by the same letter within a row are not significantly different from each other at $P \leq 0.05$ using LSD.

Color: 1=light brown, 7=dark brown; Aroma: 1=weak, 7=strong; Texture: 1=soft, 7=firm; Flavor: 1=weak, 7=strong; General acceptability: 1=not acceptable, 7=highly acceptable

sweet potato flour) was significantly lighter than those in any of the other treatments.

Adding saba flour at 50%, but not 25%, produced a significant difference in aroma compared with that of bread made with 100% standard flour. Adding sweet potato at either 25% or 50% produced a significant difference in aroma compared with those of the standard or saba breads. In terms of texture, typical *pandesal* has a hard crust and an aerated or spongy texture. Moderate or high-level substitution with sweet potato flour resulted in a dough with less expansion and bread with small air cells and a compact texture: breads D (75% APF and 25% sweet potato flour) and E (50% APF and 50% sweet potato flour) did not have the characteristic spongy body of *pan de sal*. Bread from treatment C was significantly firmer than that from treatments A and B but significantly less firm than that from the sweet potato flour treatments. During kneading, the blends of APF and sweet potato flour were harder to work into a dough than the pure APF. Dough with added saba flour was smoother to work—similar to working on a dough with 100% bread flour. Flavor contributes markedly to the acceptability of, and preference for, a product. The perceived intensities of flavor of breads A and B did not differ from each other but were significantly weaker than those of the other treatments; the intensities of flavor of breads C and D did not differ significantly from each other either. In terms of general acceptability, there was no significant difference between the highest-scoring breads, namely A and B. Taken together, these results showed that 25% substitution with saba flour in the *pan de sal* formulation did not significantly alter the overall sensory properties or general acceptability of the bread.

Sensory properties of muffins with varying ratios of wheat and white-corn flour

Various ratios of APF to white-corn flour (A=100% and 0%, respectively; B=75% and 25%; C=50% and 50%; D=25% and 75%; and E=0% and 100%) were used to produce the muffins. Muffins made from MCF and MSCF were evaluated separately to determine the most acceptable formulation.

Color is an important sensory characteristic of food. It affects product acceptability because it gives the first impression of food quality (Selim et al., 2008), and it gives character to almost all foods through flavor association Table 4 shows that muffins prepared by substitution of APF with 25% or 50% MCF were not significantly different from the controls (100% APF) in terms of their golden brown color (also see Figure 3). Muffins D and E did not differ significantly in color from each other but were significantly lighter in color than the other treatments. Muffin B had the highest mean sensory score for color (6.40). The muffins became lighter in color as the amount of flour from mature corn (MCF) increased (Fig. 3).

Table 5 shows the scores for each sensory attribute of muffins produced with varying ratios of APF to MSCF (A=100% and 0%, respectively; B=75% and 25%; C=50% and 50%; D=25% and 75%; and E=

Table 4. Mean scores for the sensory attributes of muffins produced by using various ratios of all-purpose flour (APF) to mature-white-corn flour (MCF).

Attribute	Mean sensory score[1]				
	Muffin A (100% APF)	Muffin B (75% APF: 25% MCF)	Muffin C (50% APF: 50% MCF)	Muffin D (25% APF: 75% MCF)	Muffin E (100% MCF)
Color	5.93^{a}	6.40^{a}	6.20^{a}	3.40^{b}	3.60^{b}
Aroma	5.07^{a}	4.73^{a}	4.87^{a}	4.00^{a}	3.80^{a}
Mouthfeel	4.07^{a}	4.33^{a}	4.60^{a}	3.33^{b}	2.80^{b}
Texture	4.73^{a}	3.40^{a}	4.07^{a}	3.53^{a}	2.00^{b}
Sweetness	4.13^{a}	3.93^{a}	3.93^{a}	4.20^{a}	3.80^{a}
Flavor	5.13^{a}	4.53^{a}	3.87^{ab}	3.13^{b}	2.80^{b}
Aftertaste	5.73^{a}	5.00^{a}	5.00^{a}	4.87^{a}	4.27^{a}
General acceptability	5.33^{a}	5.13^{a}	4.73^{a}	3.53^{b}	2.87^{b}

[1] Mean scores followed by the same letter within the same row are not significantly different from each other at $P<0.05$ using LSD.
Color: 1=light brown, 7=golden brown; Aroma: 1=perceivable corn aroma; 7=no perceivable corn aroma; Mouthfeel: 1=dry and crumbly, 7=moist and chewy; Texture (perceived by using the fingers): 1=firm; 7=soft; Sweetness: 1=bland, 7=sweet; Flavor: 1=perceivable corn flavor; 7=no perceivable corn flavor; Aftertaste: 1 =perceivable, 7=not perceivable; General acceptability: 1=not acceptable, 7=acceptable

Table 5. Mean scores of the sensory attributes of muffins produced by using various ratios of all-purpose flour (APF) to milk-stage-white-corn flour (MSCF).

Attribute	Mean sensory score[1]				
	Muffin A (100% APF)	Muffin B (75% APF: 25% MSCF)	Muffin C (50% APF: 50% MSCF)	Muffin D (25% APF: 75% MSCF)	Muffin E (100% MSCF)
Color	6.20^{a}	5.93^{a}	6.33^{a}	5.73^{a}	4.60^{b}
Aroma	5.40^{a}	3.33^{b}	3.80^{b}	3.73^{b}	3.47^{b}
Mouthfeel	2.93^{c}	3.13^{c}	3.73^{c}	5.40^{b}	6.53^{a}
Texture	3.60^{c}	3.00^{c}	3.60^{c}	5.27^{b}	6.67^{a}
Sweetness	3.53^{b}	3.80^{b}	4.33^{b}	4.20^{b}	5.27^{a}
Flavor	4.47^{a}	4.27^{a}	3.80^{ab}	3.00^{b}	3.00^{b}
Aftertaste	5.07^{a}	4.73^{a}	3.93^{a}	4.40^{a}	4.47^{a}
General acceptability	4.33^{b}	4.13^{b}	4.20^{b}	4.47^{b}	5.53^{a}

[1] Mean scores followed by the same letter within the same row are not significantly different from each other at $P<0.05$ using LSD.
Color: 1=light brown, 7=golden brown; Aroma: 1=perceivable corn aroma; 7=no perceivable corn aroma; Mouthfeel: 1=dry and crumbly, 7=moist and chewy; Texture (perceived by using the fingers): 1=firm; 7=soft; Sweetness: 1=bland, 7=sweet; Flavor: 1=perceivable corn flavor; 7=no perceivable corn flavor; Aftertaste: 1 =perceivable, 7=not perceivable; General acceptability: 1=not acceptable, 7=acceptable

0% and 100%). Muffin E had a significantly lighter color than those of the other muffins. Muffins A to D had the desirable characteristic of golden brown color (Fig. 4). According to Smith and Hui (2004), muffins are expected to have a pleasing golden brown crust

There was no significant difference among treat-

Fig. 3. Muffins prepared from different levels of all-purpose flour (APF) and mature white-corn flour (MCF): A=100% APF; B=25% MCF and 75% APF; C=50% MCF and 50% APF; D=75% MCF and 25% APF; E=100% MCF.

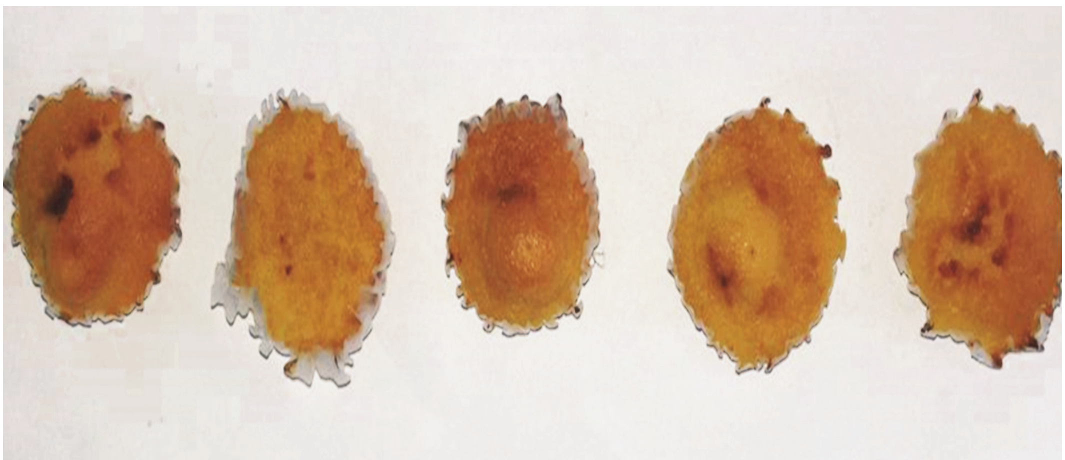

Fig. 4. Muffins prepared from different levels of all-purpose flour (APF) and milk-stage white-corn flour (MSCF): A=100% APF; B=25% MSCF and 75% APF; C=50% MSCF and 50% APF; D=75% MSCF and 25% APF; E=100% MSCF.

ments and the control in terms of aroma in muffins produced from MCF (Table 4), although MSCF (muffins B, C, D, and E) gave a significantly greater perceivable corn aroma than in the controls (A) (Table 5). Unlike MCF, MSCF has a sweet, creamy aroma that is typical of young corn. This therefore contributed to the corn aroma perceived by the panelists during the sensory evaluation.

MCF muffin C had the highest mean sensory score in terms of mouthfeel (4.60; Table 4). MCF muffins D and E had low mean scores, implying that increasing the substitution of APF with MCF produced a dry and crumbly muffin. Muffin E (100% MCF) also had the lowest mean score (2.00) for texture, as perceived by using the fingers. Muffins produced from this formulation were tough, with a coarse texture. Muffins B and C had the same texture and mouthfeel as the control.

When MSCF was used, muffins B and C (Table 5) did not differ significantly from each other and from the control in terms of mouthfeel and texture. The sensory scores for mouthfeel (6.53) and texture (6.67) of muffins E produced with 100% MSCF were both highest. The resulting product was moist, chewy, and tender and conformed to the standards of a desirable muffin, as described by Hui (2007).

There was no significant difference in sweetness among muffins in the experiment using MCF (Table 4). The mean sweetness scores all fell about midway between bland and sweet. In the case of muffins made with MSCF, muffin E had a significantly higher sweetness score (5.27) than did the other muffins (Table 5). The MSCF likely retained some of the characteristic sweetness of the corn and thus added to the sweetness of the product.

In terms of flavor, muffins B and C made by using either type of corn flour did not differ significantly from the controls (Tables 4 and 5). Thus, substitution of APF with up to 50% MCF or MSCF did not significantly alter the flavor of the product. Moreover, there were no significant differences in aftertaste among the controls and muffins made by using either type of cornflour: the aftertaste perceived by the panelists did not have a negative effect on the desired flavor of the muffins.

Lastly, the panelists assessed general acceptability as a basis for determining the best formulation of muffins produced from the two different types of corn flour. General acceptability is usually based on the flavor or taste of the product. Other attributes may also affect it, but flavor represents the overall quality of the food. When MCF was used, there were no significant differences in general acceptability among muffins A, B, and C, which had significantly greater acceptability scores than muffins D and E (Table 4). When MSCF was used, muffin E was significantly more acceptable than the other muffins, including the control, and had the highest mean score (5.53; Table 5) The corn flavor retained in the MSCF added to the pleasant flavor of the muffins, but because the corn flavor was detected strongly by the panelists. Taken together, the overall results of the sensory evaluation indicated that up to 50% substitution with MSCF results in generally acceptable muffins.

Comparison of sensory properties and proximate compositions of the selected formulations of muffins

We analyzed the proximate compositions of the formulations considered most acceptable in the sensory evaluations. We also conducted further sensory evaluations to directly compare the acceptability of APF (control) muffins and the most acceptable MCF and MSCF muffins (Table 6).

Muffins with 25% MCF were found to be comparable to the controls in terms of the overall sensory attributes, and with superior color. Muffins with 100%

Table 6. Comparison of the sensory attributes of muffins with the most acceptable formulations. APF, all-purpose flour; MCF, mature-white-corn flour; MSCF, milk-stage-white-corn flour.

Attribute	Mean sensory score[1]		
	Control (100% APF)	75% APF: 25% MCF	100% MSCF
Color	3.40^{a}	4.67^{b}	6.60^{c}
Aroma	4.67^{a}	3.67^{a}	4.07^{a}
Mouthfeel	3.60^{a}	3.27^{a}	6.40^{b}
Texture	3.87^{a}	3.60^{a}	6.07^{b}
Sweetness	3.80^{a}	3.93^{a}	5.87^{b}
Flavor	4.13^{a}	4.00^{a}	2.80^{b}
Aftertaste	4.47^{b}	4.47^{b}	3.07^{a}
General acceptability	4.33^{b}	4.67^{b}	6.13^{a}

[1] Mean scores followed by the same letter within the same row are not significantly different from each other at $P<0.05$ using LSD.

Color: 1=light brown, 7=golden brown; Aroma: 1=perceivable corn aroma; 7=no perceivable corn aroma; Mouthfeel: 1=dry and crumbly, 7=moist and chewy; Texture (perceived by using the fingers): 1=firm; 7=soft; Sweetness: 1=bland, 7=sweet; Flavor: 1=perceivable corn flavor; 7=no perceivable corn flavor; Aftertaste: 1=perceivable, 7=not perceivable; General acceptability: 1=not acceptable, 7=acceptable

Table 7. Proximate composition of muffins with the most acceptable formulations. APF, all-purpose flour; MCF, mature-white-corn flour; MSCF, milk-stage-white-corn flour.

Composition	Mean value[1]		
	Control (100% APF)	75% APF: 25% MCF	100% MSCF
Moisture, %	28.35 ± 0.16^{b}	24.76 ± 0.06^{c}	29.95 ± 0.08^{a}
Ash, %	2.54 ± 0.19^{a}	2.59 ± 0.13^{a}	2.87 ± 0.12^{a}
Crude fiber, %	6.83 ± 2.28^{a}	7.76 ± 5.31^{a}	8.93 ± 1.25^{a}
Crude fat, %	16.04 ± 2.48^{a}	15.73 ± 1.90^{a}	15.57 ± 1.45^{a}
Crude protein, %	9.79 ± 0.74^{a}	11.10 ± 1.29^{a}	9.02 ± 0.70^{a}
Nitrogen free extract (% NFE)	36.45	38.06	33.66

[1] Mean values followed by the same letter within the same row are not significantly different from each other at $P<0.05$ using LSD.

MSCF had significantly better color, mouthfeel, texture, sweetness, and flavor scores, and significantly lower aftertaste scores, than the other two types of muffin. Muffins with 100% MSCF had the highest mean general acceptability score (6.13) among the three treatments, followed by muffins with 25% MCF (4.67) and controls (4.33).

Muffins with 100% MSCF had a significantly higher moisture content (29.95%) than control muffins (28.35 %) and 25% MCF muffins (24.76%) (Table 7). These results are supported by the results for mouthfeel and texture in the sensory evaluation. Muffins with 100% MSCF were perceived to be moist and chewy, whereas 25% MCF muffins and the controls were somewhat dry. The panelists also described 100% MSCF muffins as softer. Muffins with 25% MCF, on the other hand, had the same firm structure as the controls. The differences in the structures of the muffins may also be explained by differences in the gelatinization behavior of MCF and MSCF. As earlier discussed, MSCF was observed to gelatinize at higher temperatures than MCF and APF.

Our results for MSCF are comparable to those of the study conducted by Johnson (1990) on the characteristics of muffins containing various levels of waxy rice flour: the top surface of the muffins became broader and flatter with increasing levels of waxy rice flour. Johnson also found that muffins containing waxy rice flour were sweeter and significantly moister than standard muffins. Our 100% MSCF muffins, like those containing waxy rice flour, may therefore require a longer baking time or higher temperature compared with the ones with all purpose flour. Moreover, the results of the related study may indicate that MSCF has a higher amylopectin content than MCF and APF. Amylopectin are branched chains in starch that give it characteristic stickiness and may contribute to higher temperature requirement for gelatinization.

We also directly compared the proximate compositions of the APF (control) muffins and the most acceptable MCF and MSCF muffins (Table 7). The ash, crude fiber, crude fat, and crude protein contents did not differ significantly among the three types of muffin. The moisture content was significantly highest in the 100% MSCF muffins and lowest in the 25% MCF muffins. The results of the sensory evaluation and proximate analysis revealed that, in general, as the amount of white-corn flour substituted for APF was increased, the mean scores for the sensory attributes of color, sweetness, and general acceptability, as well as the crude fiber, also increased (Tables 4 and 5). This implies that addition or utilization of cornflour helps to improve the quality of muffins.

Storage stability of MCF- or MSCF-substituted muffins

We examined the effects of substitution of APF with MCF and MSCF on the shelf stability of muffins by determining the changes in moisture content, water activity, pH, TSS, and viable microbial count of samples of the most acceptable muffins during storage (Table 8). Control muffins and those produced from 25% MCF or 100% MSCF were used for storage stability analysis. Muffins were incubated at room temperature (30℃) and sampling was conducted every 2

Table 8. Storage properties of muffins with the most acceptable formulations. APF, all-purpose flour; MCF, mature-white-corn flour; MSCF, milk-stage-white-corn flour.

Treatment	Moisture content (%)	Water activity (A_w)	pH	TSS (°Bx)	Colony count (cfu/mL) Fungi (molds and yeasts)	Total microbial load
100% APF						
Day 0	17.92	0.91	6.05	10	$< 2.5\times10^2$	7.95×10^5
Day 2	21.38	0.92	6.1	10.5	$< 2.5\times10^2$	1.15×10^6
Day 4	21.99	0.93	6.0	12.0	$< 2.5\times10^2$	1.80×10^3
75% APF: 25% MCF						
Day 0	18.35	0.92	5.9	10.5	$< 2.5\times10^2$	7.95×10^5
Day 2	18.28	0.90	5.9	9.5	$< 2.5\times10^2$	1.15×10^6
Day 4	21.78	0.93	5.85	9.5	$< 2.5\times10^2$	1.80×10^3
100% MSCF						
Day 0	18.44	0.92	6.2	9.25	5.65×10^2	8.7×10^5
Day 2	19.9	0.89	6.0	7.0	1.65×10^2	1.41×10^6
Day 4	23.26	0.90	5.95	9.5	1.10×10^2	5.0×10^5

days until visible growth of molds and yeasts was observed.

The moisture content and water activity of the muffins generally increased while pH decreased. These changes supported the data from our microbiological analysis of the muffins. The microbial quality of the muffins was also expected to increase with the progress of storage period. Increases in the moisture content and water activity of foods support the growth of microorganisms, which in turn greatly reduces product shelf stability. Microorganisms require high moisture content and water activity in order to proliferate hence, as these properties increased, increase in the number of microorganisms can be observed. Among the three treatments, muffins with 100% MSCF had the shortest shelf stability, because mold growth was already observable on day 4, whereas no growth was observed in some of the muffins produced from APF until day 4 of storage.

Conclusions and Recommendations

Partial substitution of bread flour with saba flour or sweet potato flour in *pandesal* is nutritionally advantageous because the fiber content is generally increased. However, to compensate for the altered textural properties caused by the low protein content of non-wheat flours, gluten levels must be maintained or the use of additives explored.

Generally, up to 50% substitution of APF with saba or sweet potato flour and up to 25% substitution with MCF and 100% substitution with MSCF was acceptable in the food products tested here. At these levels of substitution, sensory properties such as texture, flavor, taste, aroma, and color were not significantly different from those of the controls. Physicochemical properties such as proximate composition (protein, fats, carbohydrates, fiber and ash), and texture were also comparable to or better than those of the controls. The levels of substitution are likely high enough to increase the utilization of these commodities. Food products from these selected crops are thus of high potential and could be introduced into the study areas as sources of livelihood.

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