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Functional properties of flour substitute from bolo (*Gigantochloa levis*) bamboo shoots and culms

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Abstract

The study aimed to generate flour substitute from the shoots and culms of *Gigantochloa levis*, determine and compare the percent yield of the flour produced between different source parts, and evaluate the functional properties of the shoots flour (SF) and culms flour (CF) in reference to first-class flour (FCF) and third-class flour (TCF). The average yield of the shoots and culm flour were 62.78% and 62.87% respectively. Starch was positively identified via iodine test for both samples. Results indicate that bamboo SF and bamboo CF had the following functional properties respectively; 12.61 and 11.75% moisture, 5.6 and 4.7 pH, 3.1942 and 3.5080 (g/g) water holding capacity (WHC), 1.3879 and 1.2834 (g/g) oil absorption capacity (OAC), 0.6519 and 0.7367 (g/ml) bulk density, 4.1046 and 3.6942 (g/g) swelling power, 20.090 and 24.2342% water solubility, 94 and 95°C gelatinization temperature (GT) and 14% and 16% (g/mL) least gelatinization concentration (LGC). It was revealed from the assessment; functional properties SF and CF are still comparable to the commercial flour with some advantages in other form of products, formulations, and usage. These include dough and pastries, enrichment of high dietary fiber content for bakery products, as flavor retainer, palatability enhancer and shelf-life extender. Based on the findings of this study, it can be inferred that bamboo shoots and culms of *Gigantochloa levis* could be a viable source for production of flour.

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Introduction

Food security is a potential dilemma in the modern world. People currently faced with the challenge of providing low-cost, sustainable and nutritious food for the rapid growing world's population. Food safety is the importance of accessibility, affordability, use and stability this means that financial and natural resources and the ability of people to eat together determine access to food and their rights (Shaheen *et al.*, 2017).

Land degradation, lack of freshwater, overfishing, and global warming are particularly at risk off reducing food supplies. The demand for food is increasing due to the growing population and growing middle class in developing countries. High technology has helped farmers grow, but inequality in the greatest wealth still deprives the poorest people in the world. Food can be produced with availability of energy sources and resources. One of the main alternative energy sources is biomass, which includes trees and other plants, and energy can be integrated into food chain (Shaheen *et al.*, 2017). Converting these resources to produce alternative food and other beneficial products will improve food supply and livelihoods. By providing these alternative resources, consumers who experience significant food shortages can increase food sources, reduce malnutrition, create alternative incomes, and become increasingly important in the eventof natural disaster such as droughts, food crises, market volatility, political unrest and military disputes (Baum *et al.*, 2015).

The main food groups that most people consume are carbohydrates, protein food containing milk and dairy products, fruits and vegetables, fats and sugars. Of the five main groups, carbohydrates provide optimal nutrition for most people with optimal nutrition. More than 55% of all energy comes from carbohydrates of various food ingredients (Asp *et al.*, 1997). Starchy foods considered as hard foods such as pasta, rice, oats, potatoes, noodles, yam, green bananas, sweet potato, millet, couscous, breads, snacks, cereals, barley and rye are the good sources of carbohydrates. Millions of people around the world eat bread and good quality food which were commonly provided. Complex properties of food provide energy, protein, minerals and many other macro and micronutrients. Flour makes an important contribution to industrial use. For example, develop bread, cookies and other pastries, sweets and the common, pasta products. Starch makes up most of the flour (68-76%) and exists in the form of small grains or granules. In general, the main components of white flour are starch 71%, ash 0.5%, lipid 1%, water 2%, moisture 14% and protein 12% (Figoni, 2003).

Bamboo is a subspecies of *Poaceae* (grass family) and is comparable to African napper grass, elephant grass, corn, wheat, millet, and sugar cane. It is also an important grass closely related to human life, housing demand, food, clothing, and many other things. In addition, bamboo known as "the plant of multifunctional uses" because of its wide variety of applications due to the constant growth per unit area and high biomass production (Akinlabi *et al.*, 2017). The shoots are consumed locals as vegetables, but now they offered as delicacies in special markets and restaurants and are processed and stored in various forms, including drying, fermentation, pickling, water soaked, and canned (Chongtham *et al.*, 2011). High nutrient value contributes to the excellent nutritional potential of bamboo shoots mainly consist of fiber, protein, vitamins, minerals, carbohydrates, amino acid and low fat (Akinlabi *et al.*, 2017).

At the upper portion where woody material is located were observed to have high crude fiber content and polysaccharide such as starch and sugar, and during their growth the rhizomes of a 2-3-year-old young culms were know have rich in reserve nutrients (starch and nitrogen) but depending on species and part of culms which also comprises with 40% fibrous tissue and 50% of parenchyma tissue rich in starch (Chongtham *et al.*, 2011; Felisberto *et al.*, 2017).

Since bamboo shoots and culms are rich in nutrients, consisting of fibers, proteins, vitamins, minerals, carbohydrates, amino acid, low fat, fibrous tissue and parenchyma tissue rich in starch hence there can be a demand for new source of starch which also could be a potential substitute for production of flour. Thus, the study intends to produce and evaluate the functional property of alternative flour sourced from bamboo shoots and culms of *Gigantochloa levis*.

Materials and methods

Sample Collection and Preparation

Shoots and culms of *Gigantochloa levis* were randomly collected from Barangay Concepcion, Kabasalan, Zamboanga Sibugay. The sample collection, shoots that were taken was 0.5 inch from its base on ground with an average height around 40 cm and the part of culm that was taken was from its middle part to the top with an average height of around 150 cm. The bamboo shoots sample were hand peeled and bamboo culms were cut from its node to the next line of node resulted to its cylindrical size and were washed by tap water followed by distilled water.

Converting Bamboo Shoots and Culms into Flour

One thousand five hundred (1500 g) of shoots were cut into small dices (approximately 1mm thickness) and 1500 g of cylindrical culm were also cut further into smaller pieces. The small pieces of bamboo shoot and culms were soaked separately in a solution of 0.2% concentration of Sodium metabisulfite (NaMS) for ten (10) minutes. The small pieces of bamboo shoot and culms were drained and sun dried for five (5) days. The dried samples were pulverized separately using Asahi BL-767 blender and were sieved through USA standard testing sieve, size 250 micrometers. The amount yield was quantified, and flour sample was stored for further analyses.

Quality and Functional Properties Assessment of Shoots Flour (SF) and Culms Flour (CF)

Quality and functional characteristics of the produced flour from bamboo shoots and culms were to evaluate and possibly help to predict how new proteins, fat, fiber and carbohydrates may behave in specific systems as well as demonstrate whether or not it can be used to stimulate or replace conventional flours. The evaluation in this study involved the assessment and the comparison of the quality and functional characteristics of SF and CF of *Gigantochloa levis* (Bolo) in reference to FCF and TCF. The properties involved were moisture content, pH, water holding capacity, oil absorption capacity, bulk density, swelling power, water solubility, gelatinization temperature, and least gelatinization concentration.

Percent Moisture Determination

Five (5) grams sample was placed in a previously dried and tared crucible and was placed in the oven for 2 hours at 130°C with the cover slightly ajar. The crucible with sample was removed after 2 hours, was cooled in the desiccator, and was weighed. The crucible was placed back in the oven at 30 minutes until constant weight was achieved (Food Safety and Standards Authority of India, 2016). The percent moisture was calculated by the formula:

$$Percent\ Moisture = \frac{(W_1 - W_2)}{(W_1 - W)} x100\% \text{ (Eq.1)}$$

w_1 = Weight in grams of the dish with the material before drying

w_2 = Weight in grams of the dish with the material after drying

w = Weight in grams of the empty dish

Potential hydrogen (pH) measurement

The determination of pH was done by approximately weighing 1g of sample in 100 ml beaker and was added with 50ml of distilled water. The mixture was thoroughly mixed. The pH of the supernatant liquid was determined by using a pH meter. Before using it was standardized with pH buffer 4.0 and 7.0. The pH and temperature was recorded (Lakshman *et al.*, 2015).

Water Holding Capacity

Water holding capacity was adopted with little modification based on the standard procedure (Gould *et al.*, 1989). One gram flour sample (dried) was weighed into a centrifugal tube, which is added with 10 mL distilled water. This was rotated at 3500 rpm for 15 min in a centrifuge. The supernatant was removed, and the hydrated sample was weighed. The formula that was used in computing for the water holding capacity was:

$$WHC = \frac{[(W_2 - W_1) - total\ flour\ sample\ wt.(g)]}{total\ flour\ sample\ wt.(g)} \text{ (Eq. 2)}$$

w_1 = weight in grams of dry centrifuge tube

w_2 = weight in grams of centrifuge tube + sample after centrifugation and decantation

Oil Absorption Capacity

One gram of the flour sample was weighed, placed in centrifugal tube, added with 10 mL of oil (refined cooking oil) and was mixed. Allowed to be centrifuge for half an hour at 1000 rpm. The supernatant was removed, and the weight of precipitate was measured (Lakshman *et al.*, 2015). The formula that was used in computing for the oil absorption capacity was:

$$OAC = \frac{(W_2 - W_1)}{weight\ of\ original\ sample\ taken} \text{ (Eq. 3)}$$

w_1= weight of tube + sample before centrifugation

w_2 = weight of tube + sample after centrifugation and decantation

Bulk Density

A sample of approximately 15 grams was measured into a 50 ml calibrated measuring cylinder. The bottom of the cylinder was repeatedly tapped and was done until no visible decrease in volume was noticed. The weight and volume the bulk density was determined by the following formula (Chandra *et al.*, 2015):

$$BD = \frac{weight\ of\ the\ sample\ (untapped)}{volume\ of\ the\ sample\ (tapped)} \text{ (Eq. 4)}$$

w = weight of samples in gram (g)

v = volume (mL)

Swelling Power

About 0.25 g (W_1) of sample was taken in a previously weighed centrifuge tube and was weighed and was recorded as W_2. 10 ml (V_e) of distilled water was added, mixed thoroughly and was allowed in a boiling water bath at 100°C for about 30 mins., cooled and centrifuged at 5000 rpm for 10 mins. The supernatant was decanted and was transferred in a test tube and the weight of the centrifuge tube was taken with the swollen material recorded as W_3. The swelling power of the flour sample was calculated by the formula (Butool & Butool, 2015):

$$SP = \frac{(W_3 - W_2)}{W_1} \text{ (Eq. 5)}$$

w_1= weight of flour sample

w_2= weight of the centrifuge tube + sample

w_3= weight of centrifuge tube with swollen material

Percent Water Solubility

Five milliliters (5mL) of supernatant (V_A) was pipetted and transferred to a constant weighed crucible (W_4). The crucibles with sample were dried at 105° C in a hot air oven, cooled in the desiccator, weighed and was repeated until constant weight of crucibles with dry solids were attained (Butool & Butool, 2015).

$$\%\ Solubility = \frac{(W_5 - W_4)}{V_A} x \frac{100}{W_1} \qquad \text{(Eq. 6)}$$

w_1= weight of flour sample

w_4= weight of crucible

w_5= weight of crucible with dry solids

V_A= volume of supernatant take

Gelatinization Temperature (°C)

One-gram flour sample was weighed exactly three times and was transferred to 20 mL screw capped tubes. For each of a sample 10 ml of water was added. The samples were heated slowly in a water bath until they formed a solid gel. At full gelation, the respective temperature was measured and was taken as the gelatinization temperature (Chandra *et al.*, 2015).

Least Gelatinization Concentration

The least gelation concentration (LGC) was evaluated using from Coffman and Garcia method with modifications (Coffmann & Garcia, 1977). Dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, and 30% (w/v) flour were prepared by the addition of 5 mL distilled water and heated at 90 °C for 1 hour in water bath. The contents were cooled under tap water and stored for 2 hours at 10±2 °C. The lowest gel concentration method was defined as the least concentration when the sample from inverted tube did not slip.

Qualitative Determination of Starch in Shoots and Culms Flour

Determination of the presence of starch, about 0.010 g of sample was diluted in 1ml water and two drops of iodine was added to the solution and was followed by the addition of one drop of concentrated sulfuric acid (H_2SO_4). Absence of the formation of blue-black solution indicates a negative result.

Results and discussion

Production of flour from Gigantochloa levis (Bolo) bamboo shoots and culm

Specific shoot and culm length were measured before cutting and processing to flour. The soaking of 0.2% sodium metabisulfite was done to control browning and growth of microorganism. Then it was sun dried for five (5) days to completely remove the remaining moisture. The samples grounded and sieved through USA standard testing sieve, size 250 micrometers to ensure homogeneity and stored in clean zipped lock container.

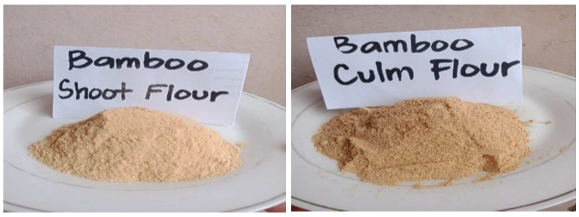

Fig. 1. Bamboo shoots flour (left) and culms flour (right) from *Gigantochloa levis.*

As illustrated in Fig. 1, the appearance of produced shoots flour as bright yellowish and culm flour which of lighter brown color. The obtained yield (Table 1) was relatively modest, and this may be further improved by increasing the efficiency of grinding and sieving process. Smaller particle size is desirable to have good functional properties thus use of a more powerful grinder in par with much finer sieve size is highly recommended.

Table 1. Determination of percent yield on produced flour from bamboo shoots and culms.

Flour sample	Average percent yield	$t_{exp.}$	$t_{crit.}$	Inference
Shoots	62.78±11.40	0.011	4.30	NS
Culms	62.87±3.85			

*not significant (NS)

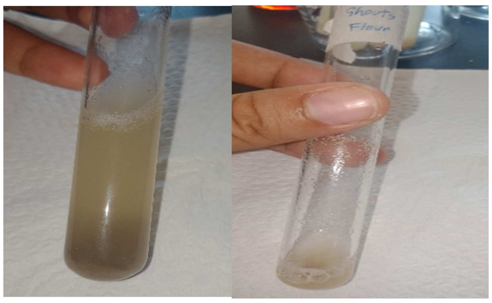

Fig. 2. Determining presence of starch by iodine test of culms (left) and shoots (right) flour samples.

Starch content was qualitatively determined using iodine test. A dark blue-black color indicates presence of starch and based on the Fig. 2, the culms and shoots observed to have a black color at the bottom of the test tube for the CF and a light black-brown color for the SF which indicates the presence of starch.

Functional properties and the comparison of the results of bamboo flour samples with the reference flour samples

Functional property of food is determined by physical, chemical, and/or sensory properties. The functional properties of the bamboo SF and CF samples were evaluated in comparison to commercial FCF and TCF samples. The data obtained could provide useful measure how well is the produced bamboo SF and CF may par with the industrially produced commercial flour especially in its use as raw material for making wide range of foodstuffs.

Moisture and pH

The moisture was determined as the weight lost that resulted from drying to constant weight at 130°C. Moisture content of the four flour samples varies from (11.7519-12.9592)%. CF has the least moisture content (11.9688±0.0289)% as compared to SF (12.9592±0.0756)% as shown in Fig. 3. This suggest that the flour produced from bamboo culms and shoots promising shelf life and storage stability. Moisture content of flours not exceeding to 14% is desirable since it is not susceptible to mold growth and insect infestation. It was noted that bamboo SF and CF were comparable to FCF and TCF.

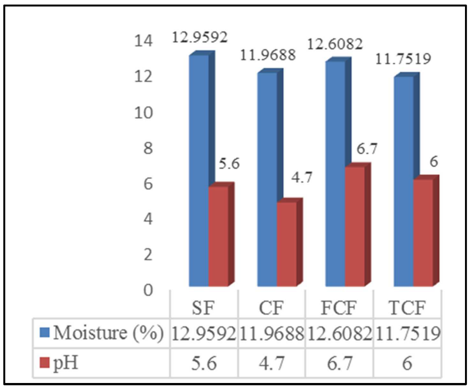

Fig. 3. Percent moisture and pH of shoots and culms flour as compared to FCF and TCF.

Ideally, common commercial flour samples have pH range from 6.0-6.8 (Egan *et al.*, 1981). Fig. 3 illustrates that both CF and SF were slightly acidic than the standard values, (4.7±0.1) and (5.6±0.4) respectively. Much acidic flour may lead to unfavorable palatability. Nonetheless this issue can be easily alleviated to acceptable levels by pre-soaking the bamboo shoots and culms in a sodium bicarbonate solution aside from sodium metabisulfite. The increased acidity may be also due to the storage time of the bamboo flour samples and other constituents present in the bamboo flour samples such as presence of minerals, oxidants and exposure to moisture that needs further study and evaluation.

Water holding capacity and oil absorption capacity

Water absorption capacity (WAC) or water holding capacity (WHC) is define as the ability of a moist material to hold water. Based on the data obtained (Fig. 4), the CF had a WHC of (3.5080±0.3478)g/g, whereas SF had WHC of (3.1942±0.1714)g/g respectively. It was observed that the values were significantly higher as compared to FCF and TCF (0.9144±0.0601) and (0.6781±0.0254)g/g.

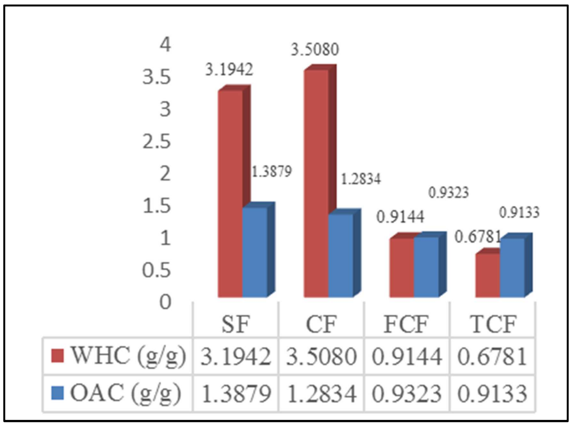

Fig. 4. Water holding and Oil absorption capacity of SF and CF as compared to FCF and TCF.

The large value might be attributed to large number of hydroxyl groups in the fiber structure of CF and SF which may provide a greater water interaction via hydrogen bond formation (Traynham *et al.*, 2007). Different types of food applications have different WHC requirement. Cookies and crackers typically require flow with a low WHC to make the product crispy, but in buns high WHC is required to make the product fluffy and soft (Berggren, 2018).

In terms of oil absorption capacity (OAC), both the produced SF and CF have higher values as compared to FCF and TCF (Fig. 4). The OAC for SF and CF were (1.3879 ± 0.0792)g/g and (1.2834 ± 0.0322)g/g respectively in contrast to (0.9323±0.0657)g/g and (0.9133±0.0219)g/g of FCF and TCF. This might hint that the produced flour from shoots and culms of bamboo had the ability to absorb more oil than the commercial equivalent. The higher the OAC value will lead to further improvement on the quality of the flour since this will translate to longer shelf-life and much improved taste. For bread and meat products, high OAC is favored since the oil as part of its ingredient could act as the flavoring or flavor retainer (Chandra & Samsher, 2013).

Bulk Density

Bamboo CF showed higher bulk density (0.7367±0.0062)g/ml than the bamboo SF (0.6519±0.028)g/ml as depicted in Fig. 5. While bulk density of CF is relatively close to the bulk density of the FCF (0.7534±0.0003)g/ml and TCF (0.7356± 0.0069). Higher bulk density is an indication that it is heavier and would occupy lesser space per unit weight thus packaging cost would be lesser.

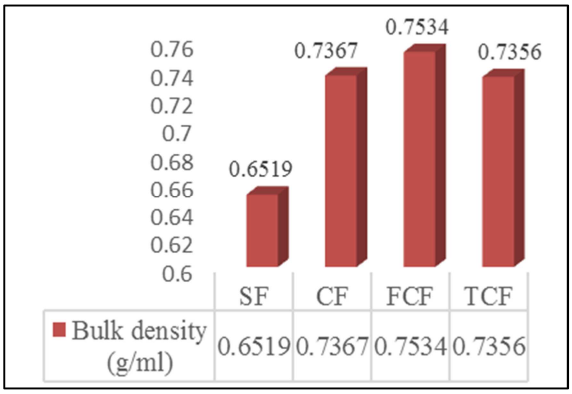

Fig. 5. Bulk density of SF and CF as compared to FCF and TCF.

Moreover, high bulk density as of CF is desirable for greater ease of dispersibility of flour. On the other hand, lower bulk density of SF would still be advantageous in the formulation of specialty provisions like infant food as both calorie and nutrient density is enhanced per weight of feed.

Swelling power and Percent water solubility

The swelling power and the percent water solubility of SF and CF and the reference samples FCF and TCF were shown in Fig. 6. CF had highest solubility at (24.2342±0.0586) % whereas SF (20.0904±0.3752)% is significantly high as well as compared to FCF (8.0858±1.2060)% and TCF (6.7813±0.4055)%. On the other hand, swelling power of SF (4.1046±0.5998)g/g was much higher than the CF (3.6942±1.6814)g/g but were lower the commercial samples FCF (5.6893±0.4705)g/g and TCF (5.0426±0.0549)g/g. SF and CF had higher swelling power and lower percent water solubility as compared to FCF and TCF which suggests that the flour samples produced from bamboo has a low ability to swell due to the fiber content which hinder the penetration of excess water to bind in. Swelling power is a measure of hydration capacity, because the determination is by weight measure swollen and their entrapped water. Swelling power affects products texture thus at high swelling power, products such as noodles, vermicelli and rice analogs can be manufactured.(Norita *et al.*, 2017).

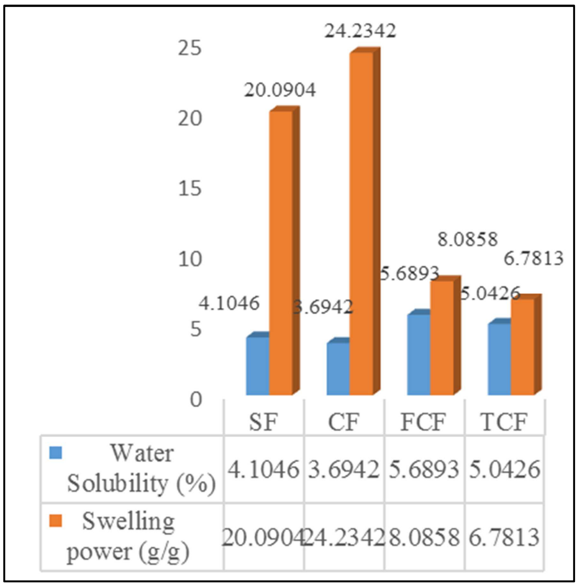

Fig. 6. Percent water solubility and swelling power of shoots and culms flour as compared to FCF and TCF.

The water solubility of SF and CF can be more preferred as substitute material to specially designed foods that requires more fiber. Foods for diabetic patients and those diets conscious are good examples to this. Differences in swelling power and percent water solubility may be attributed to differences in starch structure, morphology, amylose and amylopectin and presence of salts, proteins and other components.

Gelatinization Temperature and Least Gelatinization Concentration

Gelatinization temperature (Fig. 7) of SF and CF were (94±1.0 to 95±1.5) °C whereas (77±1.5 to 79±1.0) °C for FCF and TCF sample. As observed the values for flour from bamboo shoots and culms were much higher compared to the gelatinization temperature of FCF and TCF. This may be due higher energy requirement in order to disrupt the strongly bonded sites in SF and CF leading to swelling and formation of granules to induce gelatinization.

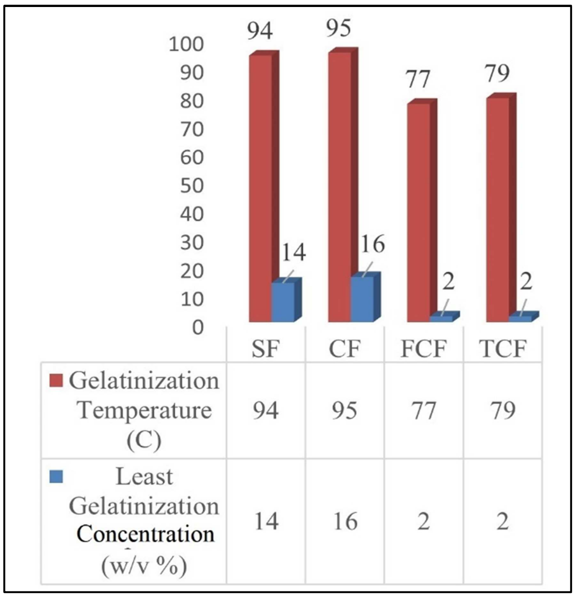

Fig. 7. Gelatinization Temperature and Least Gelatinization Concentration of shoots and culms flour as compared to FCF and TCF.

It was also noted that smaller particle size of commercial flour promotes low gelatinization temperature due to larger surface area for binding of water molecules and easy for heat energy to gelatinize. To further improve the gelatinization temperature of SF and CF, it is recommended to have longer ground time and the use of a finer sieve (<250 microns). Since fiber could be the major component of SF and CF, this had further contributed to higher value obtained. However, high fiber is still advantageous in bakery products since it can improve digestion, regulate blood sugar, prevent diabetes, heart disease, cancer and aid in weight loss.

Presented also in Fig. in 7 the least gelatinization concentration (LGC). Both reference flours had the same least gelatinization concentration of 2% (0.1 g/5mL) heated at 90◦ C, however, for SF 14% (0.7g/5mL) and CF 16% (0.8g/5mL) least gelatinization concentrations were obtained. The concentration for gel formation of SF and CF were higher as compared to the reference samples due to fiber content, hydrophobicity, and area of sulfhydryl protein. Accordingly, the lower the LGC the better the gelation ability but this would be applicable if the flour sample has more amount of starch. Since SF and CF have lower amount of starch in combination of significant fiber thus it is expected to gelatinize at higher concentrations.

Conclusion

This study primarily shows the utilization of shoots and culms of *Gigantochloa levis* (Bolo bamboo) as flour substitute which have comparable functional properties to the reference standard flour samples, the first-class flour (FCF) and third-class flour (TCF).

Having a modest yield and based on the evaluated functional properties, the flours produced from bamboo shoots and culms were advantageous especially formulation of foods such as in sausage, dough, cheese and bakery products, flavor retainers, fat absorbent to some meat products due to high water holding and oil absorption capacity. In addition, the significant fiber content if incorporated to bakery products will be an added advantage it will supplementary benefits such as digestion improvement, blood sugar control, and weight loss aid.

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