Thermal, Functional, and Pasting Characteristics of Flours from Selected Millet Varieties in Nigeria

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ABSTRACT

Background: *Africans have found millet as a source of plant-based protein and energy. Substitution of other high demand cereals with millets can prove useful as they can improve health and decrease the risks of diseases..*

Objective: *Proximate, thermal, functional, and pasting properties of millet flours from selected varieties (pearl, finger, kodo and teff) were investigated using standard analytical methods to provide information on their functionalities.*

Methods: *Pearl, finger, kodo and teff millets were sourced from local markets and processed into flours. The flours were produced using standard procedures, and their samples were analyzed in the laboratory. The results of the analyses were subjected to Analysis of Variance at a significance level of 5% using SPSS.*

Results: *The proximate composition of the flour samples from the varieties ranged between 5.83-6.87% for moisture content, 1.23-2.50% ash, 2.00-5.33% crude fat, 7.66- 10.29% crude protein, 0.61- 0.81% crude fibre, and 76.50-81.57% carbohydrate. Thermophysical properties of the flours values were specific heat capacity (171.73-172.43 kJ/kg°C), thermal conductivity (25.11-25.96 W/m°C) and thermal diffusivity (0.11-0.13 m^2/s). Functional properties of the millet flour were bulk density (1.11-1.31 g/ml), oil absorption capacity (57.00-80.60%), water absorption capacity (0.80-0.94 g/g), dispersibility (37.67-40.3%), swelling power (8.12-9.41%) and solubility (12.67-16.00%). The pasting properties of millet flours were peak viscosity (1126-1946 RVU), trough (903-1848 RVU), final viscosity (1212-1958 RVU), setback viscosity (110-390 RVU), pasting time (6.43-6.93 minutes) and pasting temperature (78.80-90.58°C), respectively.*

Conclusion: *The quality characteristics of the flours showed good nutrient composition, potential for value addition and improved functionality of millet-based food products.*

Keywords: millet, proximate, thermal, functional, pasting

Doi: https://dx.doi.org/10.4314/njns.v45i1.2

INTRODUCTION

Millets are cereals from the Poaceae grass family often regarded as one of the ancient cultivated food crops. According to Devi et al. (1), cereals are very important diet in our society as the human race relies on various plant based sources of food. It is worthy of note that cereals have proved to be of more importance than other food crops. They are reputed for their richness in energy, low-cost source and high nutritional values (2). Some of the examples of cereals are rice, wheat, maize, sorghum, barley, and millet. On the global stage, they have been popularly adopted as staple food. Among the cereals, sorghum and millet are unique in terms of their nutritional characteristics, they do not contain gluten. They are very rich in calories, good source of dietary fibre, phenolic compounds, and high mineral content.

The two common and popular varieties of millet are pearl millet (Pennisetum glaucum) and finger millet (Eleusine coracana). They are often used in human food and animal feed (3). Millets could grow under unfavourable weather conditions like low rainfall and relative sunshine, thus, they are important foods in sub-Saharan Africa (SSA). Millet constitutes a reputable source of energy, and protein for a large African populace. The nutritional benefits of millet have been widely reported Obilana and Manyasa (4, 5). Adding value to cereals has been achieved at the traditional and industrial scale with a high record of success (1). The human dependence on cereal and its products is huge and not very likely to be reduced due to its abundance and nutritional benefits.

In our industries, cereal crops have been utilized in the production of foods such as breakfast meals, snacks, and ready-to-eat food. Most of the cereal-based products are mostly from wheat, sorghum, and, maybe, maize. It is imperative that we need to look inward at what other cereal grains that has been underutilized could do. While understanding the need to look at the benefits other cereals can proffer, it is also important to know the challenge of food insecurity recently as our population increase is resulting in more demands for foods that are high in fibre, energy, and protein. It is therefore of more importance to look for sustainable cereal substitutes such as millet.

However, Shobana and Malleshi (6) reported millet to be endowed with excellent nutritional qualities especially with major and minor-nutrients, protein and amino acid. It contains resistant starch, readily and non-readily dissolved dietary fibre, minerals, and antioxidants (7). Also, it is a good source of food remedies that can fight microbial, viral, inflammatory and cancerous activities in human body (8). Millets were tagged "nutri-cereals" as a result of their propensity to provide humans with vitamins and sulphur containing amino acids with a low glycemic index of 52.7 (a medium value and lower than the value for maize, refined wheat flour, and rice) and zero-gluten, and allergy free food making it a good choice for patients with an immune reaction to eating gluten as a result of gluten intolerance. Knowledge and information of the proximate, thermal, functional and pasting characteristics of millet flours is required by Nigerian processors and equipment fabricators to perform the various heat transfer calculations required in the development of food processing, food equipment and design processes for heating or drying of millet based foods. This article was to provide inherent technological properties of millet flours, some of the Nigerian cultivars of millet flours that can be gotten in large quantities from Borno, Yobe, Kano, Sokoto and Jigawa states in Nigeria.

The frantic demand on other cereals such as maize and its uses in multiple industries and traditionally have merited the search for alternative grains to ease the pressure which millet can easily provide when fully utilized. This current effort is a step towards driving value addition for millet in Nigeria.

MATERIALS AND METHODS

The four different varieties of millet used for this research work were purchased from the Kano grain market, Kano, Kano state, Nigeria. The other analytical materials were sourced from the Food Preparation and Culinary Laboratory of Food Science and Technology Department, Federal University of Agriculture, Abeokuta, Ogun state.

Millet Flour Preparation

The technique described by DeVries et al. (9) was used in the production of the millet flours (Figure 1). The millets were cleaned manually, washed in clean water and then decanted by sedimentation, drained, and dried in cabinet dryer at 50°C for 6 hours. The dried millets were then comminuted into flour by attrition and sieved to pass through a 0.22 mm mesh.

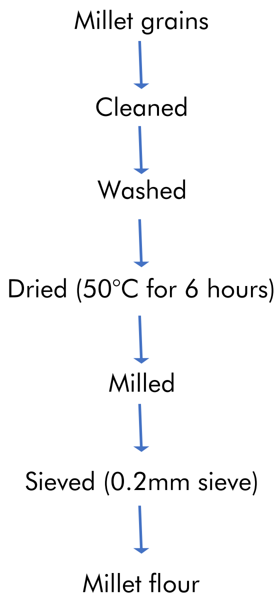

Figure 1: Preparation of Millet into flour

Proximate Composition Analyses

The millet flour samples produced were subjected to proximate composition analyses using Association of Official Analytical Chemists method Nos. 32-10, 46-10 and others (10) as summarized below. 2g of finely ground samples were weighed accurately in a dish cooled in desiccator and weighed soon after reaching room temperature. Cover was loosened and heated at 110°C in hot air oven for 2 hours. The cover was immediately tightened on the dish, transferred to desiccator, and weighed soon after reaching room temperature. The resultant losses in weight were calculated as percentage moisture content on dry basis

Approximately 5g of flour samples were weighed and transferred into a pre-weighed porcelain crucible. The weighed sample was then burned till smoke ceases. The crucible was then transferred to the muffle furnace maintained at 550oC and incinerated until light grey ash was obtained. The crucible was then cooled in desiccator and weighed. The result was reported on dry weight basis.

Ash % = $[(W_1 - W_2) \times 100] \div W$

W = Weight of sample

W_1 = weight of sample + weight of crucible.

W_2 = Weight of ash + weight of petri dish (after ashing)

A grounded 5 g sample was weighed accurately and transferred to the thimble and defatted with petroleum ether in Soxhlet apparatus for 6-8 hours at 80°C. The residue was procured, and ether was removed by evaporation. The loss in weight of thimble was estimated as loss of lipids from sample and expressed as percentage lipids in sample.

Fat % = [loss in weight of sample × 100] ÷ weight of sample

The crude protein content was estimated according to the Kjeldahl's method. Approximately 2g sample was weighed and put into the digestion tube. Twenty millilitres of concentrated sulphuric acid (98%) and 2 tablets of digestion mixture as catalyst were added into the digestion tube. The digestion was carried out for 3-4 hour (till the digested contents attained transparent colour). The digested material was then allowed to cool at room temperature and diluted to a final volume of 50 ml. The ammonia trapped in H_2SO_4 was liberated by adding 40% NaOH solution through distillation and collected in a flask containing 4% boric acid solution, possessing methyl indicator and titrated against standard 0.1N H_2SO_4 solution. The factors 6.25 and 5.70 were used for the conversion of percent nitrogen into crude protein contents of the flour.

The crude fibre was estimated according to the procedure as outlined in method No. 32-10. It was carried out by taking 3 g of each fat free flour sample and digested first with 1.25% H_2SO_4, washed with distilled water and filtered, then again digested with 1.25% NaOH solution, washed with distilled water and filtered. Then sample residue was then ignited by placing the digested samples in a muffle furnace maintained for 3-5 hours at temperature of 550-650 °C till grey or white ash was obtained. Carbohydrate content was calculated for the millet flour by difference method on dry basis using the following formula:

Total carbohydrate = 100 – (fat + fibre + ash + protein)

Thermo-physical Analyses

The proximate composition based mathematical models were used to determine the thermal properties. The specific heat capacity was calculated using Choi and Okos (11) method by using the various mass fraction derived from the proximate composition of the samples.

$$C_p = 4.180X_w + 1.711X_p + 1.929X_f + 1.547X_c + 0.908X_a \quad (1)$$

Cp is specific heat capacity in kJ/kg and X are the respective mass fraction of water, protein, fat, carbohydrate, and ash present in the flour.

The thermal conductivity was calculated using Sweat (12) method and the thermal diffusivity was calculated using the method of Nwanekezi and Ukagu (13). The thermal conductivity was obtained by substituting the various proximate composition of the sample in the expression:

$$K = 0.25X_c + 0.155X_p + 0.16X_f + 0.135X_a + 0.58X_w \quad (2)$$

Where K is the thermal conductivity (w/m°C) and X is the respective mass fraction of carbohydrate, protein, fat, ash, and water in the flour.

The thermal diffusivity of the samples was calculated using the expression:

$$(\sigma) = \frac{K}{PCp} \ (m^2/s) \qquad (3)$$

ρ = density.

Functional Analyses

The millet flour samples were subjected to the following functional analyses: bulk density, dispersibility, solubility index, water absorption capacity, swelling capacity and oil absorption capacity.

Bulk density

Bulk density was determined by using the standard protocols described by Nwanekezi and Ukagu (13). Flour sample (10 g) was measured into a graduated measuring cylinder (50 ml) and lightly tapped on the workbench (10 times) to attain a constant height. The bulk density was recorded and expressed as grams per millilitre.

Bulk density [g/ml] = Weight of sample ÷ Volume of sample.

Dispersibility

The method reported by Kulkarni (14) was used for the determination of the dispersibility. About 10 g of the sample wasdispersed in a measuring cylinder (100 ml), and distilled water was added up to the 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 hours. The volume of settled particles was noted, and the percentage of dispersibility calculated as:

Dispersibility (%) = (50 − volume of the settled particle)50×100

Solubility index

The solubility index of the flours was determined using the protocols reported by *Takashi* and *Seib* (15). One ml of the sample was weighed into 50 ml centrifuge tube. 50 ml of distilled water was added and mixed gently. The sample was heated in a water bath at 90°C for 50 mins. During heating, the sample was stirred gently to prevent clumping. On completion of 15 mins the tube containing the paste was centrifuged at 3000 rpm for 10 minute using Eppendorf, centrifuge Germany. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The moisture content was determined to get the dry matter content of the sample

Solubility index (%) = Weight of dry solid after drying x 100

Water absorption capacity

The water absorption method (WAC) of the flour was obtained according to the procedure reported by Oyeyinka *et al.* (16). Flour sample of 1 g was weighed into a clean pre-weighed dried centrifuge tube and mixed adequately with 10 ml distilled water by vortexing after which the suspension was allowed to stand for 30 minutes and centrifuged (Thelco GLC- 1, 60647: Chicago, USA) at 3500 rpm for 30 min. The supernatant was decanted after centrifugation, with the tube and, the sediment weighed. The weight of water (g) retained in the sample was reported as WAC.

Oil absorption capacity

Flour sample (1 g) was suspended in 5 ml of vegetable oil in a centrifugal tube, after which the slurry was shaken on a platform tube rocker for 1 min at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was decanted and discarded. The adhering drops of oil was removed and reweighed. The oil absorption capacity (OAC) was expressed as the weight of the sediment/initial weight of the sample (g/g) (17)

The pasting properties

Rapid Visco Analyser (RVA TECMASTER, Perten Instrument) as described by Newport Scientific (18) was used in determining the pasting properties of the flours. The sample was turned into slurry by mixing 3g of the sample with 25 ml of water inside the RVA can. The can was inserted into the tower, which was then lowered into the system. The slurry was heated from 50°C to 95°C and cooled back to 50°C within 14 min. Parameters estimated were peak, trough, final, breakdown and setback viscosities, pasting temperature, and time to reach peak viscosity.

Data Analysis

The data obtained from this study was subjected to analysis of variance (ANOVA) using SPSS version 21.0 and the differences between significant mean values were separated at 5% level of significance using Duncan's Multiple Range Test.

RESULTS

Proximate composition of Different Varieties of Millet Flour

Moisture, ash, protein, fat, crude fiber, and carbohydrate contents of flours are as shown in Table 1. The moisture content of varieties of millet flour ranged from 5.83-6.87% with teff millet (TM) flour having the lowest and finger millet (FM) flour had the highest. Ash content of the millet flour ranged from 1.23-2.50% with TM flour having the lowest and pearl millet (PM) flour having the highest. Result showed that PM flour was significantly different ($p<0.05$), while TM, FM and *Kodo* millet (KM) suggested no significant differences from each other. Fat content of the millet flours ranged from 2.00-5.33% with FM flour having the lowest while TM had the highest. Result showed that KM, TM and FM showed significant differences from each other. KM and PM were not significantly different ($p>0.05$) between each other, also pearl and teff showed no significant differences ($p>0.05$). Protein content of millet flour ranged from 7.66- 10.29% with TM having the highest and FM having the lowest. KM and TM were not significantly different between each other ($p>0.05$). PM showed significant difference between the millet varieties and FM also showed significant difference between the millet varieties. Fibre content of millet flour was between 0.61% and 0.81% with KM and TM having the highest and FM had the lowest. KM and TM samples showed no significant difference between each other ($p>0.05$). PM and FM showed significant difference between the millet varieties. Carbohydrate content of millet flours ranged from 76.50-81.57% with KM having the lowest and FM having the highest. All the varieties showed no significant difference between each other ($p>0.05$). FM showed significant difference with other varieties.

Thermo-physical characteristics of the flours

The thermo-physical characteristics results of the flours are as shown in Table 2. The specific heat capacity of the millet flours ranged from 171.73-172.43 J/g°C, with TM recording the highest value and KM recording the lowest value. No significant difference ($p>0.05$) was observed between the millet varieties. The thermal conductivity of the millet flours ranged from 25.11-25.96 W/m°C, with FM recording the highest value and TM having the lowest value. There were no significant differences ($p>0.05$) between TM and KM and between PM and KM. Significant difference ($p<0.05$) was observed in FM when compared with other millet varieties. The thermal diffusivity of the millet flours ranged from 0.11-0.13 m^2/s with PM recording the highest value and TM recording lowest value. There were no significant differences ($p>0.05$) between FM, TM and KM, and between the PM, KM and FM.

Functional properties of Different Varieties of Millet Flour

Table 3 shows the results of the functional properties of the flours. The bulk density of millet flour ranged from 1.11- 1.31 g/ml with FM having the highest and KM having the lowest value. PM, KM and TM did not suggest any significance ($P>0.05$), same for KM, TM and FM. The WAC of the millet flours were between 0.80-0.94 g/g with FM having the highest and TM getting the lowest value. PM, KM and TM were not significantly different ($P>0.05$) from each other. Meanwhile, FM was differently significantly ($P<0.05$) from the rest. SI of the millet flours values were between 12.67-16.00% with PM possessing the highest and leaving FM with the lowest value. PM, KM and TM were not significantly different ($P>0.05$). The SP of the millet flours ranged from 8.12-9.41% with FM obtaining the highest and PM having the least value. The results of OAC of the millet flours was 57.00-80.60% with FM obtaining the highest and TM having the lowest value once more. PM and FM were significantly different ($P<0.05$) from the other varieties. The dispersibility of the millet flours ranged from 37.67-40.33% with FM having the highest and PM having the lowest value. PM and TM were not significantly different ($P>0.05$) from each other. FM and KM were not significantly different ($P>0.05$).

Pasting Properties (RVU) of Different Varieties of Millet Flour

Table 4 gives the results of the pasting properties of the millet cultivars. The PKT ranged from 6.43-6.93 minutes, with FM had the highest and PM had the lowest. FM was significantly different ($p<0.05$) with

Table 1: The Proximate composition of millet flour produced from the cultivars

Sample	Moisture %	Ash %	Protein %	Fat %	Crude fibre %	CHO %
PM	6.33±0.29	2.50±0.00	7.78±0.03	4.67±0.58	0.62±0.00	78.11±0.48
KM	6.33±0.29^a	1.60±0.36^a	10.24±0.04^c	4.33±0.58^b	0.81±0.00^c	76.68±1.09^a
TM	5.83±0.76^a	1.23±0.25^a	10.29±0.04^c	5.33±0.58^c	0.81±0.00^c	76.50±1.40^a
FM	6.67±0.58^a	1.50±0.00^a	7.66±0.04^a	2.00±0.29^a	0.61±0.00^a	81.57±0.54^b

Means with different superscript in the same column are significantly ($p<0.05$) different.
Legend: pearl millet (PM), finger millet (FM), *kodo* millet (KM) and teff millet (TM).

Table 2: Thermo-physical characteristics of the flours

Sample	SHC (J/g°C)	TC W/m°C	TD (m^2/s)	Density Kg/m^3
PM	171.88±0.68[a]	25.48±0.13[b]	0.13±0.02[ab]	1.19±0.14[ab]
KM	172.43±0.71[a]	25.33±0.08[ab]	0.13±0.01[b]	1.11±0.06[a]
TM	171.73±2.11[a]	25.11±0.21[a]	0.11±0.01[a]	1.28±0.05[ab]
FM	172.31±1.52[a]	25.96±0.20[c]	0.12±0.01[ab]	1.31±0.10[b]

Means with different superscript in the same column are significantly ($p<0.05$) different.
SHC = Specific Heat Capacity, TC = Thermal Conductivity, TD = Thermal diffusivity
Legend: pearl millet (PM), finger millet (FM), *kodo* millet (KM) and teff millet (TM).

Table 3: Functional properties of flour produced from different varieties of millet

Sample	WAC g/g	SI %	SP %	OAC %	DIS %	BD g/ml
PM	0.85±3.51[a]	16.00±2.00[b]	8.12±0.05[a]	63.67±3.21[b]	37.67±0.56[a]	1.19±0.14[ab]
KM	0.88±7.58[ab]	14.00±2.00[ab]	8.24±0.35[a]	57.33±2.31[a]	40.00±0.00[b]	1.11±0.06[a]
TM	0.80±2.09[a]	14.67±1.15[ab]	8.28±0.52[a]	57.00±2.00[a]	38.33±0.58[a]	1.28±0.05[ab]
FM	0.94±2.52[c]	12.67±1.15[a]	9.41±0.06[b]	80.67±1.53[c]	40.33±0.58[b]	1.31±0.10[b]

Means with different superscript in the same column are significantly ($p<0.05$) different.
Legend: pearl millet (PM), finger millet (FM), *kodo* millet (KM) and teff millet (TM)
WAC = Water Absorption Capacity,
SI = Solubility Index,
SP = Swelling Power,
OAC = Oil Absorption Capacity,
DIS = Dispersibility,
BD = Bulk Density

the other millet varieties. There was no significant difference ($p>0.05$) between the other varieties. The PKV of the flours ranged from 1126-1946 RVU, with FM recording the highest value and TM having the lowest value. FM was significantly different ($p<0.05$) with the other millet varieties, there was no significant difference ($p>0.05$) between TM and PM. The TGV of the millet flours ranged from 903-1848 RVU, with FM recording the highest value and PM recording the lowest value. FM was significantly different ($p<0.05$) with the other millet varieties, there was no significant difference ($p>0.05$) between TM and PM. The BDV of the millet flours ranged from 98-247 RVU, with KM recording the highest value and FM recording the lowest value. KM was significantly different ($p<0.05$) with the other millet varieties, there was no significant difference ($p>0.05$) between FM and PM.

FLV of the millet flours ranged from 1212-1958 RVU, with FM recording the highest value and TM recording the lowest value. TM was significantly different ($p<0.05$) with the other millet varieties, FM was also significantly different ($p<0.05$) with the other millet varieties, there was no significant difference ($p>0.05$) between PM and KM. The SBV of the millet flours ranged from 110-390 (RVU), with KM recording the highest value and FM recording the lowest value. TM was significantly different ($p<0.05$) with the other millet varieties, FM was also significantly different ($p<0.05$) with the other millet varieties, there was no significant difference ($p>0.05$) between PM and KM.

The pasting temperature of the millet flours ranged from 78.80-90.58°C, with KM recording the highest value and FM recording the lowest value. TM was significantly different ($p<0.05$) with the other millet varieties, KM was also significantly different ($p<0.05$) with the other millet varieties, there was no significant difference ($p>0.05$) between PM and FM.

DISCUSSION

Results obtained in this study showed that there are no significant differences between the moisture content (MC) of the flours. The MC of these samples were not more than 10% being an acceptable limit for storage of flour similar with the report of

Onimawo and Akubor (19). The MC met the Nigeria Standard Organization specification of 10-12% for flour products. The lower MC of the millet flour samples shows that they can be stored for a long period. The ash (2.50%) for PM was higher than the 2.2% in the report of Geervani and Eggum (20). The ash (1.50%) for FM flour was lower compared to the 2.20% in the report of Thilagavathi et al. (21). The ash content (1.60%) of KM flour was higher and up to 1.39% in the account of Strilekha (24). The ash (1.50%) for TM flour was lower when compared to 2.20% in the work of Eke-Ejiofor and Oparaodu (22). The variations in the ash content may be due to the varietal influence. The fat content (4.67%) of PM flour was found to be low when compared to 4.86% for PM flour reported by Taylor et al. (23). The fat content (4.33%) of KM flour was observed to be lower than 1.24% for KM documented by Strilekha (24). The fat content (5.33%) for TM flour in this work was higher compared to 0.50% reported by Eke-Ejiofor and Oparaodu (22). The fat content (2.00%) for FM flour was lower when compared to 2.73% in the report of Abah et al. (25) for same variety. The variations in the fat content may be due to the blending effect. Flours that are high in fat content are better in augmenting flavour and improving foods according to Aiyesanmi and Oguntokun (26). The high-fat content of flour is important for pastries because it helps to create a tender texture. The protein content (7.78%) of PM flour was found to be less than 11.80% for PM flour in the report of Eke-Ejiofor and Mbaka (27). The protein content (10.24%) of KM flour was found to be higher than 7.60% for KM in the work of Strilekha (24). The protein content (10.29%) for TM flour was within range to 10.90% in the report of Eke-Ejiofor and Oparaodu (22). The protein content (7.66%) for FM flour was a little higher than 7.30% in the report of Thilagavathi (21). The carbohydrate content (78.11%) of PM flour was found to be higher than 73% in the work of Eke-Ejiofor and Mbaka (27). The carbohydrate content (76.68%) of KM flour was within range with the report of 76.04% for KM by Strilekha (24). The carbohydrate content (76.50%) for TF flour was found to be higher when compared to 73.1% reported by Eke-Ejiofor and Oparaodu (22). The carbohydrate content (81.57%) for FM flour in this work was higher than 74.46% reported by Eke-Ejiofor and Mbaka (27). The millet varieties used are considerably high in carbohydrate. The high carbohydrate content of the millet flour is important for confectionery making because it gives the energy.

The specific heat of millet flour means the quantum of heat energy required to raise 1 kg of millet flour by 1^{0}C. Thus, specific heat becomes an important coefficient of the heat energy investigation of a food process, or the heat and mass transfer equipment used for the heating or cooling of food (28). The capacity of an engineering material to allow easy passage of heat through it is referred to as thermal conductivity. Bodies with high heat conduction rate will allow rapid heat transfer from a hotter body or transferring heat to a colder body. Therefore, the high thermal conductivity value for FM makes it suitable for operations requiring heat transfer. Food materials with a high thermal diffusivity will rapidly heat or cool.

However, formulating complementary foods requires low bulk density, thus becoming an advantage property (27). Observations from this work shows that FM flour could be best used in

Table 4: Pasting properties of millet flours from selected cultivars.

Sample	PKV (RVU)	TGV (RVU)	BDV (RVU)	FLV (RVU)	SBV (RVU)	PKT (min.)	Peak Temp (°C)
PM	1119±8.49^{ab}	968±5.66^{ab}	231±2.82^{ab}	1334±8.49^{b}	366±2.82^{c}	6.43±0.14^{a}	80.15±0.07^{a}
KM	1279±16.26^{b}	1032±17.68^{b}	247±1.41^{c}	1423±31.11^{b}	390.5±13.44^{c}	6.67±0.09^{a}	90.58±1.03^{c}
TM	1126±21.92^{a}	903±19.09^{a}	223±2.83^{b}	1212±38.18^{a}	308.5±19.09^{b}	6.64±0.05^{a}	89.50±0.07^{b}
FM	1946±65.05^{c}	1848±50.91^{c}	98±14.14^{a}	1938±60.81^{c}	110±9.99^{a}	6.93±0.00^{b}	78.80±0.00^{a}

Means with different superscript in the same column are significantly ($p<0.05$) different.
Legend: pearl millet (PM), finger millet (FM), *kodo* millet (KM) and teff millet (TM).
PKV = Peak Velocity,
TGV = Trough Velocity,
BDV = Breakdown Velocity,
FLV = Final Velocity,
SBV = Set Back Velocity,
PKT = Peak Time

confectionery making products which require addition of water to enhance culinary features of the flour. The organoleptic quality of food is directly related with water retention in the starch granules (29). PM, KM and TM were not significantly different (P>0.05). FM was significantly different (P<0.05) among the other varieties. The binding effects of the millet flour proteins with oil-based emulsion emphasize the desirability of the flours in food applications when optimum oil absorption is a target.

It was observed that there was short peak time in the flour and this could be attributed to the reduction in starch content. The results above agree with the report of Adebowale et al. (30). The peak velocity is an indicator of the ability of the flour paste to thicken and hold water during the pasting of the flour. It shows the culinary quality of the food products to be produced according to the reports of Ndie et al. (31). Trough viscosity is the minimum threshold at which the viscosity is attained during heat exchange for cooling or heating. Invariably measuring the tendency of the paste to withstand breakdown when cooled. The noticeably high trough viscosity of FM in this study suggests the likelihood of the flour to breakdown when cooked.

The breakdown velocity in this present research was similar to that of the breakdown velocity of pearl, finger and fonio millet reported by Eke-Ejiofor and Mbaka (27). Also, Adebowale et al. (30) posited that breakdown viscosity depicts how stable a paste would be when processed. At high breakdown viscosity, the flour samples would experience low capacity of the starch to stand shear stress and heating. According to Chavez et al. (32), high breakdown value gives a proportional failing of the swollen starch granules versus hot shearing with low breakdown values indicating that the starch have cross-linking tendencies.

The setback velocity predicts the extent of steady retrogradation of the starch granules and its characteristic tendencies when cooled or stored of the TM flour starch paste. The outstandingly low setback velocity of the millet flours relate to retrogradation of amylase and suggests that millet flours level of retrogradation is lower than that of other cereals. The low retrogradation capacity in the millet flours would make them to be considered in products formulation (33). The pasting temperature in this work was higher to that of the pasting temperature of pearl, finger and fonio millet reported by Eke-Ejiofor and Mbaka (27). High pasting temperature of starch-based flour is an indicator of better propensity to hold water, excellent gelatinization ability, and less swelling property, the high pasting temperature of KM makes it suitable for varying purposes.

CONCLUSION

The nutritional composition of the four varieties showed that millet can be used as a diet and still provide the basic nutrients needed for human growth. Despite each millet variety being superior in a particular nutritional composition, the values of each millet variety are close to each other, and on average each variety of millet stands out and can be used as a staple food. The thermal properties of each millet variety have shown that millet flour can undergo manufacturing processes using heat energy. Either they are used as a supplementary ingredient, or it is the main ingredient they can perform well. The functional properties of the millet varieties showed different characteristics under different conditions which implies that each millet variety can be used in different ways depending on the function it's used for. Most pasting properties were higher in the FM, an indication of greater potential for its processing and value addition. Millet flours from pearl, finger, kodo and teff varieties either whole or as composites are recommended for the production of cookies, pastries, and other confectionery products due to their excellent properties.

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