

# Effects of Steeping Duration on the Physical, Chemical, Microbial and Sensory Properties of Steeping Water and Ndaleyi (A Nigerian Fermented Pearl Millet Grain Flour)

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## ABSTRACT

The ancient technique of fermenting grains prior to utilization is also practiced by the Kanuri tribe of Northeastern Nigeria for the production of ndaleyi from pearl millet, through extended steeping time. This practice seemed completely eroded with the passage of time and the emergence of modernity, almost a forgotten food legacy. In this study, pearl millet grains were subjected to varying soaking times (0-220h), soaked, washed, wet ground, wet sieved, the bottom lying white sediment (ndaleyi) sun dried and reground to produce ndaleyi flours, the experimental control for reference was dehulled unfermented pearl millet flour. Sieve analysis showed that the control (decorticated milled pearl millet flour) and 110h ndaleyi had the finest granulation while 55h, 165h, and 220h ndaleyi flours the coarsest indicating the longer the soaking time, the bigger the size of the flour particles with significant effects on functional properties of the ndaleyi flours. There were no significant differences ( $p>0.05$ ) in bulk densities and gelatinization temperatures, and but significant decreases in the water absorption capacities and progressive increase in the oil absorption capacities, swelling powers, water solubilities and viscosities of the various ndaleyi flours with soaking time. The pH (4.1-7.07) and titratable acidity (TTA) of the steeping waters varied with soaking time. The pH of ndaleyi flours were lower (more acidic) with negligible degree Brix. Significant variations ( $p<0.05$ ) were observed in the proximate composition of the various ndaleyi flours. Moisture, total ash, crude fat, crude dietary fibre, crude protein and carbohydrate contents varied significantly: 10.28-12.08%, 1.06-2.04%, 4.24-4.81%, 4.08-4.59%, 9.08-10.20%, and 66.86-70.51% respectively. The Mg, Ca, P, K, Na, Fe and Zn contents in the steeping water declined with soaking time and finally minerals were higher in steeping water than observed in the ndaleyi flours that witnessed greater mineral decrease with fermentation time and varied as follows: Mg 95.12-120.39, Ca 76.33-92.01, P 730.30-1027.18 Na 16.37-63.80, K 23.52-315.22, Fe 2.21-3.01 and Zn 1.22-1.66mg/100g. The steeping water had greater presence of yeast/mould, ( $1.60 \times 10^4$ - $4.20 \times 10^4$  CFU/ml), staphylococcus spp ( $1.40 \times 10^4$ - $2.90 \times 10^4$ ), Coliform ( $8.80 \times 10^3$ - $2.08 \times 10^4$  CFU/ml) and therefore total plate counts (TPC) ( $1.48 \times 10^5$ - $2.36 \times 10^5$  CFU/ml) were observed to be higher than observed in the various ndaleyi flours where insignificant counts of the same investigated bacteria were recorded and TPC was  $5.90 \times 10^3$ - $1.22 \times 10^4$  CFU/g. The evaluation of sensory attributes of tuwo (ndaleyi cooked stiff dough) indicated that 165h ndaleyi tuwo had the best sensory attributes better than 220h and the control tuwo had the poorest sensory attributes. Therefore, ndaleyi flours/tuwo had better sensory properties which was achieved at the expense of the reduced nutritive value in terms of decreased proximate and mineral composition as a result of prolonged fermentation.

**Keywords:** Pearl millet; Bambara groundnut; Grain fermentation; Leaching; Ndaleyi; Tuwo.

## 1.0. Introduction

Ndaleyi is fermented pearl millet grain flour, stiff dough of this flour called Bri-ndaleyi was formerly a popular food item produced and consumed along with traditional soups by some of the tribes of the northeastern Nigeria especially the Kanuri sub nationality that inhabits Borno and Yobe States. It was a preserve of the upper class, the choice meal eaten during cultural and religious festivities for the royalty. According to Nkama (1994), ndaleyi is prepared by firstly soaking the grains for 6-9 days, the long soaking duration induces lactic acid fermentation, the wetted grains are washed, wet milled and wet sieved, allowed to settle by gravity, the clear water is decanted to expose the two bottom layers, the upper gluten layer (chir) is carefully separated from the lower layer called ndaleyi, which is now dewatered and sun dried.

Ndaleyi production process is similar to ogi also called akamu, the most popular breakfast gruel in Nigeria. Ndaleyi production and consumption has faded and almost disappeared from the tables to the extent the youths and urban dwellers scarcely remember such food item existed or have scanty knowledge of its production or preparation process. The long process involved in its production is partly responsible for its disappearance, a laborious process

which urban dwellers cannot stand, moreover the availability of maize or wheat based semolina in Nigeria markets has further eclipsed its production. Sadly, urbanisation and the associated rural to city migration has further inspired the disappearance of many indigenous food cultures like ndaleyi, many of which are yet to be documented. Pearl millet is the most popular millet species in terms of production and spread, the topmost producers are India and Nigeria (Shweta, 2015) and other arid and semi- arid tropical regions of the world.

Estimated production in 2020 in Nigeria was put at 2 million tons (Anonymous, 2020) and mostly consumed in form of thin and thick porridges mainly as *kunu* ( cereal-based beverages) and *tuwo* (stiff cooked dough). Nutritive value of pearl millet is not far removed from those of wheat, maize and sorghum, the dry matter, proteins, fat, ash, fibre, and carbohydrate contents are 92.5%, 13.6%, 7.8%, 2.1%, and 63.2% respectively (Abah et al., 2020). Millet provides both nutritional and functional ingredients in the diets of the peasants in the semiarid regions of Asia and Africa (Patni and Agrawal, 2017). During processing of cereals for food through many of the traditional techniques such as roasting, steeping, decortication, germination, fermentation etc, some proportion of the nutrients are lost or modified. Carbohydrates are converted to sugars firstly and later to alcohols and further to acids which brings about the modification or reduction of food reserve through the activities of enzymes elaborated by invading micro-organisms.

Fermentation is the oldest method of food preservation and commonly used in Africa to detoxify, modify, enhance, create novel food products or extend their shelf life. Extended soaking of grains leads to fermentation during which inhibitory factors are eliminated and nutrients modified for enhanced bioavailability and at the same time useful nutrients leach into the soak water. Pearl millet flour or the meal has objectionable appearance that can repel those not accustomed to it but soaking of pearl millet whiten the kernels and the resulting flour through the loss of grey coloured pigments which are located on the outer coats of the kernels. Therefore, the objectives of the present study were to evaluate the effects of variable steeping periods on the steeping water and quality attributes of ndaleyi flours or their *tuwo*.

## 2.0. Materials and Methods

### 2.1. Source of Raw Materials

Pearl millet (*Pennisetum glaucum*) used for the study were from family stock of previous harvest (2019/2020) stored in sacks waiting utilization.

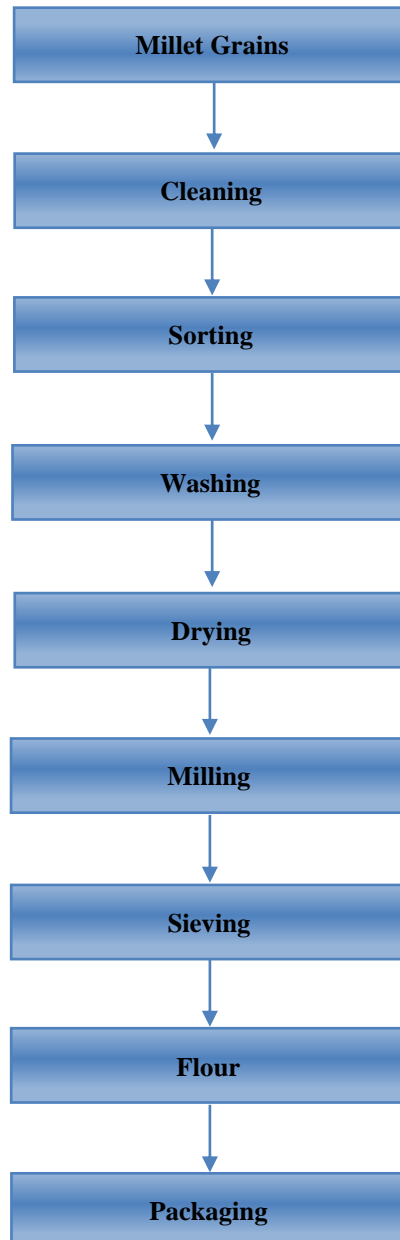
#### 2.1.1. Equipments and Reagents

Part of the equipment and reagents used for this study were obtained from the Department's Food Lab, University of Maiduguri and Chemistry Lab, Yobe State University. Chemicals used were assume to be of the AnalaR grade.

### 2.2. Preparation of Raw Material

#### 2.2.1. Millet Flour Production

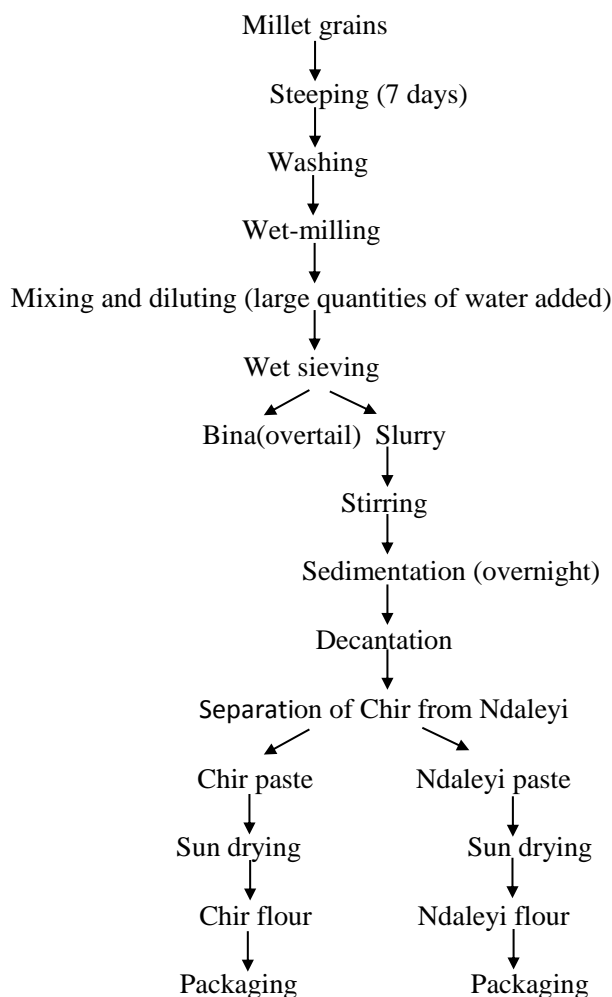
A portion of the millet grains (2kg) was manually cleaned, winnowed and washed. The millet was sun dried, milled and sieved (0.4mm mesh) to yield flour. The flour was then packed in an air tight container (labelled MF0) and stored for and analysis.



**Figure 2.1.** Steps involved in the production of pearl millet flour

### 2.2.2. Ndaleyi Flour Production

Four portions of millet grains, each 3Kg were cleaned and placed in plastic containers labelled N55, N110, N165 and N220. About 9 litres of tap water was added to each and steeped for 55 hours, 110 hours, 165 hours and 220 hours respectively, at room temperature. During fermentation, the water lost by evaporation and seepage was made up by adding fresh water daily. At end, a portion of the steeping water from each sample was collected and stored for analysis. Steeping waters were drained, the wet grains were washed with fresh water and wet milled using Hammer mill. The slurry was wet sieved using a cheese cloth and the filtrates were transferred into different containers, violently stirred, covered and allowed to settle undisturbed overnight, and the excess water was decanted. The starchy deposit was found in two strata, the top layer locally known as chir ndaleyi and the bottom solidly compacted layer, ndaleyi. Both the chir and ndaleyi were carefully separated and sundried for 14 h. The dried products were pulverized, packed separately in airtight containers and kept for use.



**Figure 2.2.** Steps involved in the production of ndaleyi

## 2.3. Physico-Chemical Analysis

### 2.3.1. pH Determination

The pH of ndaleyi (10% suspension), unfermented millet flour, zero hour fresh water, and steeping waters were measured by the method of Ojokoh and Bello (2014). Before pH were taken, the sample slurries were thoroughly stirred to homogenize the mixture and achieve uniformity. The pH electrode was dipped in each of the slurries and measurements were taken using a HANNA pocket-size pH Meter.

### 2.3.2. Total Titratable Acidity

The total titratable acidity (TTA) of ndaleyi (fibrate of 10% suspension) and steeping waters were determined by the method of Chinenye et al. (2017). Aliquot (10 ml) each of the samples was pipetted into an Erlenmeyer flask, and then 2 drops of 1% phenolphthalein were added. This was titrated using 0.1 N NaOH until a faint pink colour appeared. The titre volume was noted and used to calculate TTA which was expressed in lactic acid on basis.

$$\% \text{Lactic acid} = A \times 0.9 \times 100/V;$$

where A = ml of 0.1NaOH required for the titration; and

V = ml of sample taken for titration, 0.09=milli equivalent weight of lactic acid.

### **2.3.3. Brix determination**

The Brix value of steeping waters and flour suspension filtrates were determined. Few drops of the sample were placed on the prism surface of the refractometer (RFM 340 Refractometer, Bellingham + Stanley Limited Code 25-340, England) and the brix read.

### **2.4. Particle Size Distribution Analysis**

The particle size distribution of each ndaleyi flour was determined by placing 100g of each flour sample on a tier of sieves of decreasing aperture (1000, 850, 710, 500, 425, 300, 200, 150, 63 $\mu$ m and a base pan) on a laboratory test sieve shaker (Endecotts, England). The shaker was operated for ten min each time and the retention on each sieve was weighed and expressed as percentage retention as described by Nishita and Bean (1982). The percentage coarse and fine particles were calculated according to the method of Suresh et al. (2013).

### **2.5. Proximate Analysis**

The crude protein, ash, crude fibre and crude fat contents of all the samples (millet flour and four ndaleyi flours) were analyzed using the standard methods of AOAC (2000).

### **2.6. Mineral Composition**

The official method of AOAC (2005) was adopted for the mineral analysis of the samples. The samples were previously ashed in a furnace for 5 h at 600°C, mixed with 50ml 20% hydrochloric acid and boiled. The cooled mixture was filtered into a 100 ml standard flask, the filtrate was made up to the mark with deionised water. Sodium (Na) and potassium (K) levels in the samples were determined using a flame emission photometer (Model 4100, Sherwood Scientific, Cambridge) with NaCl and KCl as standards. All other metals were determined using atomic absorption spectrometer (Perkin Elmer Model 3300) excluding P determined using vanadomolybdate spectrophotometric method and absorbance taken at 420nm.

### **2.7. Functional Properties of the Ndaleyi Flours**

Functional properties of millet flour and four Ndaleyi flours were evaluated as follows:

#### **2.7.1. Water Absorption Capacity (WAC)**

The method of Lin et al. (1974) was used to determine WAC of ndaleyi flours and the control. One gram of the sample was weighed and placed into a weighed centrifuge tube. Ten ml of distilled water was added to the tube and mixed thoroughly. The mixture was then allowed to stand for 30 minutes at room temperature. It was centrifuged at 3500 rpm for 30 minutes. The supernatant was decanted and the residue in the test tube was inverted over an absorbent paper (tissue pad). It was allowed to drain completely before the tube and its content were weighed. Results were expressed as gram of water held per gram of flour used

#### **2.7.2. Oil Absorption Capacity (OAC)**

A modification of the method described by Ogunyike et al. (2016) was used to determine OAC of each sample. Five hundred milligram (0.5 g) of the sample was added to 5.0 ml of soybean oil in a 10 ml graduated centrifuge tube.

The mixture was mixed with a vortex mixer for 2 min, left to stand at room temperature for 30 min, and later centrifuged at 3500 rpm for 20 min. The volume of the supernatant was read directly and converted to grams using the density of the oil, the result expressed as gram oil absorbed per gram of sample used.

### 2.7.3. Bulk Density (BD)

The bulk density of flour was determined as described by Agbara et al. (2018). Ten grams of each flour sample was placed into 100 ml graduated measuring cylinder. It was taped gently on a Lab bench to obtain constant flour volume, which was noted. BD was reported as weight of flour per unit volume of graduated cylinder.

### 2.7.4. Swelling Capacity

The swelling capacity was determined by suspending one gram flour in 20 ml distilled water in a 50 ml centrifugal tube and was mixed gently. The slurry was heated in a water bath at 80°C for 30 min and later centrifuged at 3000 rpm for 10 min. The supernatant was decanted and the weight of the paste was taken and expressed as weight of paste per weight of flour (g/g) (Agbara et al., 2018).

### 2.7.5. Gelatinization Temperature (GT)

A method described by Chandra et al. (2015) was used to determine the gelatinization temperature of the ndaleyi flours. One gram of the sample was introduced into a screw capped tube containing, 10ml of distilled water, mixed with glass rod and heated in a water bath until it started to become cloudy (onset of gelatinization) until completion of gelatinization, the final temperature was recorded.

### 2.7.6. Viscosity

The viscosity of the sample slurry were determined as described by Quinn and Beuchat (1975). 20% slurry (dry weight) of each flour was heated to 100°C with constant stirring. They were then cooled to 23-25°C. Viscosity was then determined using Brookfield Synchro-electric Viscometer, using RVT Spindle No. 4 at constant speed of 100rpm. The reading indicated on the red pointer was recorded and this was converted to centipoise (cP).

### 2.7.7. Solubility of Ndaleyi flours and the Control

Solubility was determined by the method of Onwulaka et al. (1998). One gram of each sample was weighed into porcelain dish and hydrated with 10ml of distilled water. The hydrated flour was heated in a water bath at 95°C for 30 min and allowed to cool at room temperature. After centrifuging at 3500 rpm for 30 min., the supernatant placed in the crucible was evaporated to dryness, cooled in a desiccator and reweighed to obtain weight of dissolved solute. Solubility was the weight of dissolved solute expressed on a percentage basis.

### 2.8. Microbial Status of Ndaleyi Flours and Steeping Waters

The method described by Harigan and Mc Cance (1976) was adopted to determine the microbiological status of the steeping waters and ndaleyi flours. Pour plate techniques involving Potato dextrose agar, Nutrient agar, Mannitol Salt agar and Eosine Methylene Blue agar were prepared and used for the microbiological evaluation of the samples. One gram of sample was suspended in 9 ml of sterile water for a ten-fold dilution that was then further diluted to a  $10^4$  dilution. One ml (1ml) of each  $10^4$  dilution was plated on 18 ml each agar in duplicate. Plates for

bacterial enumeration were incubated at 37°C for 24-48 h and 30±2°C, 5 days for yeast-mould count. Colonies were counted using a digital colony counter. The results were reported as colony forming unit per gram (CFU/g ndaleyi flours) or CFU/ml of steeping water.

## 2.9. Sensory Evaluation of Various Ndaleyi Tuwo

Ndaleyi tuwo was prepared by reconstituting 200g of each flour in 200ml of water. In a clean pot, 400ml of water was boiled and the reconstituted flour was added while constantly stirring with a wooden spatula until a thick gruel was formed. Ndaleyi was continuously stirred on very low heat and 30ml of oil was added. On the addition of the oil, ndaleyi was observed to separate clean from the pot. It was stirred for another 10 minutes until the separated thick gruel re-joined again. Ndaleyi was then dished out on a previously oiled tray so as to avoid sticking, allowed to cool and then served. Test panellists were selected from among the students of the Department (FST) who were familiar with Bri Ndaleyi made from pearl millet.

The panellists were then served with the prepared samples on coded disposable plates and spoons. The containers with the coded samples were presented to the panellists randomly and the attributes evaluated were aroma, colour, taste, mouth-feel, smoothness, aftertaste, texture and overall acceptability of each tuwo on a 9- point Hedonic scale as described by Larmond (1977). Warm water was provided for mouth gargling to help distinguish the different tastes.

## 2.10. Statistical Analysis

All data generated were subjected to analysis of variance (ANOVA) using computer assisted software (Statistical Tool for Agricultural Research, STAR) version 2.0.1. Significant means were separated using Duncan's Multiple Range Test (DMRT) at p-value of 5%.

## 2.11. Results and Discussions

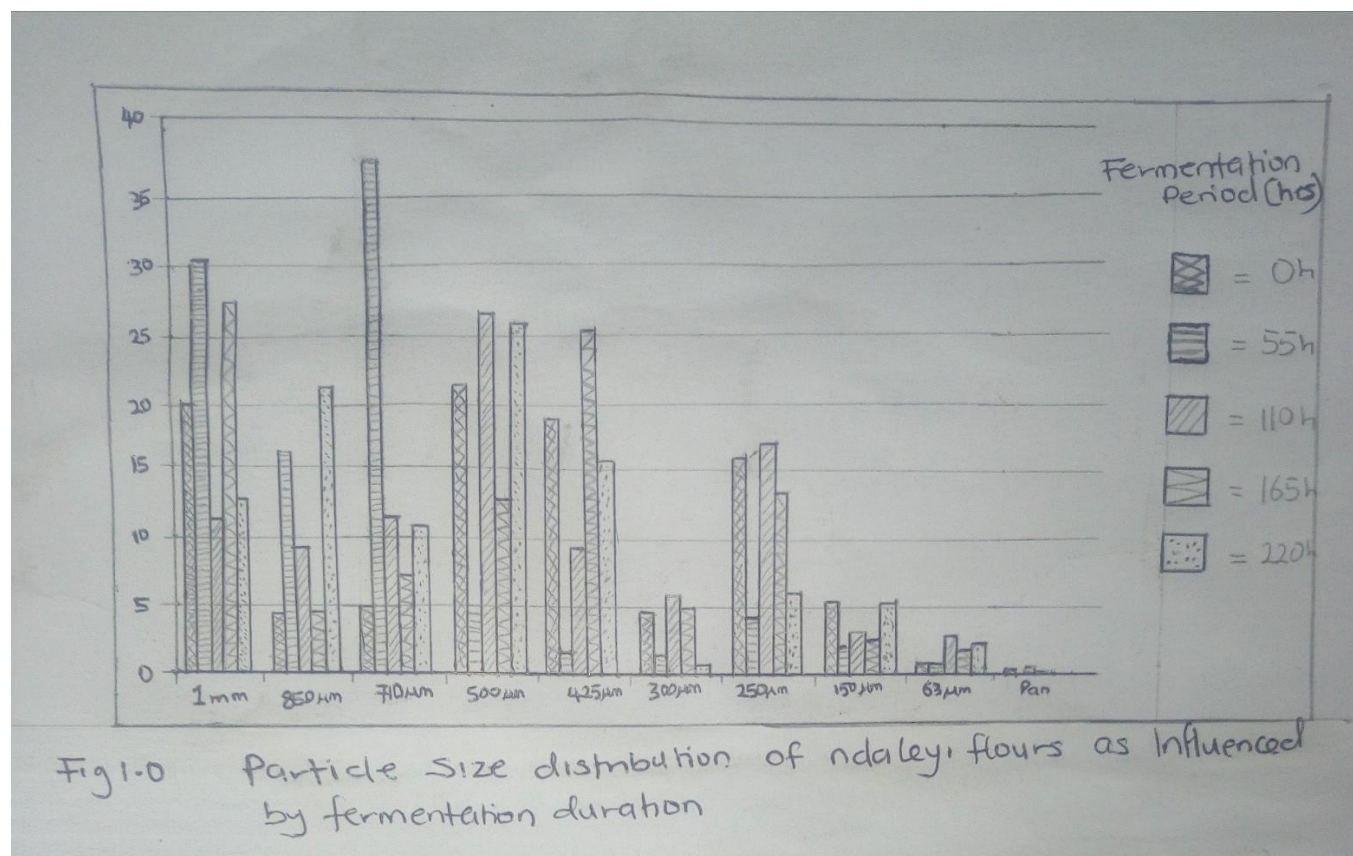
### 2.11.1. Effect of soaking time on the particle size distribution of various ndaleyi flours

At the end of sun drying, the clumped dried ndaleyi were pulverized, the wet grinding and the regrinding the dried stuff was responsible for the particle size distribution of the ndaleyi flours. The PSD of the various ndaleyi flours subjected to different soaking duration is presented in **Figure 1**.

**On 1mm sieve:** the order of retention on sieves was 55h>165h>control>220h>110h. Ndaleyi soaked for 55h and 165h had greater portion of coarse particles (>1mm) than others, and 220h and 110h ndaleyi with the smallest proportion of coarse particles therefore the finest granulation. **On 0.85mm sieve,** the order was 220h>55h>110h>control=165h, ndaleyi flour soaked for 220h and 55h had greater portion of coarse particles (>0.85mm), the control and 165h ndaleyi had finest granulation. **On 0.71mm sieve:** the order of retention on sieves: 55h>>>110h~220h>165h>control. Also on this sieve, 55h ndaleyi again and 110h ndaleyi had greater coarse particles (>0.71mm). **On 0.5mm sieve:** the order was: 220h=110h>control>165h>55h indicating ndaleyi soaked for 220h and 110h had greater proportion of flour particles greater than 0.50mm and 55h and 165h ndaleyi had the least, indicating finer granulation. **On 0.425mm sieve:** 165h>220h>control>110h>55h, 165h and 220h ndaleyi had greater proportion of flour particles greater than 0.425mm and 55h again and 110h had the finest granulation on this



sieve D). **On 0.30mm sieve:** the differences in size of the particles were hardly noticeable, except in 110h ndaleyi flour, others had more or less the same proportion of flour particles of size >0.30mm. **On 0.25mm sieve:** the difference in the sizes of the flour particles were spaced out again now moderately, the order was 110h > control > 165h > 220h > 55h, meaning the proportion of ndaleyi flour particles greater than 0.25mm were greater, again on this sieve, 220h and 55h were the finest. **On 0.150mm sieve:** the differences in the size of the flour particles were small again barely noticeable. The particle size of control and 220h ndaleyi were bigger and similar than others. A similar scenario was observed **on 0.063mm sieve** although 110h instead of control and 220h ndaleyi had slightly greater proportion of flour particles greater than 0.063mm. Summary: ndaleyi soaked for 55h (2 days, 7h) had the highest retentions on 1mm, 0.85mm and 0.71mm sieves and more or less the least retention on the lower sieves (0.5mm-0.063mm) indicating presence flour particles greater than 0.7-1.0mm and another set of particles less than 0.50mm. Knowledge of flour granulation characteristics of the ndaleyi is important because it determines its hydration properties for preparation of ndaleyi tuwo and gruel as well as the textural characteristics of the same. Flour particle sizes from the fermented ndaleyi were all greater than those of the control (dehulled unfermented pearl millet flour.), which in turn impacted on the flour functional properties especially solubility, swelling power, water or oil binding capacities. Except 55h and 165h ndaleyi, others were well represented on particle size of 0.50mm and above as further exposed in **Table 1**, here 90.06% of N550h, 86.12% of N220h, and 77.14% of N165h ndaleyi (N) respectively were not able to pass through sieves with size greater than 0.425mm indicating coarse granulations against 70.16% of control and 70% of N110h. N55h had the coarsest granulation next was N220 and N165 in that order collaborating the assertion made earlier that 55h & 220h soaking time yielded ndaleyi flour with the greatest proportion of coarse flour particles.





**Table 1.** Percentage coarse and fine particles in the various Ndaleyí flour samples

Steeping time	%Retention/Coarse (1000µm-425µm)	% Thorough/Fine (<300µm)
MF00h	70.16	29.06
N55h	90.87	9.06
N110h	70.00	29.98
N165h	77.14	22.84
N220h	86.34	13.88

MF00=dehulled millet flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N = ndaleyí flour.

### 2.11.2. Effects of steeping time on functional Properties of ndaleyí flours and the control

There were no significant differences in the bulk densities (BD) (0.55-0.58g/ml) of the various ndaleyí flours, comparable to 0.53-0.55g/ml reported by Apotiola (2013) for ogi powder produced from sorghum under varying soaking period. Steeping duration had no significant impact on the bulk density of the ndaleyí flours. (**Table 2**). BD reflects the porosity of the samples, and particle size dependent. Smaller BD values as obtained here indicates the flours were voluminous or porous, small amount occupy big volume especially the control and 55h ndaleyí earlier revealed by sieve analysis as highly coarse granulated. This has implications on cost of packaging, distribution and storage (Kulkarni et al., 1991). Water absorption capacities (WACs) decreased (2.9-1.75g/g) linearly with soaking time, this might be due to partial hydrolysis of starch and protein into shorter units and decreased availability of hydrophilic groups of protein and starch that are able to interact with water (Kulkarni et al., 1991). Ndaleyí flour will be suitable for thinner gruels because of reduced WAC. Apotiola (2013) contrarily reported increase in WAC of ogi powder with soaking duration. Oil absorption capacities (OACs) (1.80-2.10g/g) followed opposite trend to WAC, in this case the control had the least (1.80 g/g). Decreased hydrophilic groups means increased availability of lipophilic groups in oil and protein molecules for complexing with hydrophobic chains in oil. Swelling power (2.15-5.10 g/g) increased with soaking time evidence to show pure starch availability, the granules were intact unaffected by longer fermentation, therefore greater associative force within the starch granules (Singh, 2001), so 165h and 220h ndaleyí had starch granules with greater tendency to swell or it could be due to observed progressive increase in protein content with soaking time. Woolfe (1992) linked swelling power to combine effects of starch and protein molecules. Viscosity of 10% cold paste of the various ndaleyí increased with soaking time (134.66-876cps) as well as the solubility (2.53-4.43%), and the gelatinization temperature values were statistically not significantly different, indicating soaking time positively correlates with solubility, viscosity and swelling power and barely noticeable effect was observed on gelatinization temperature despite longer fermentation. Increase in viscosity with soaking time can be linked to enhanced starch and protein contents therefore enhanced viscosity with the progress of fermentation. Onweluzo and Nwabugwu (2009) reported decrease in viscosity with fermentation time for both fermented millet and pigeon pea grains, in that study, the fermented grains were not subjected to wet milling and wet sieving. Walls and Moges (2017) reported that blends with high carbohydrates

content leads to higher viscosity. High swelling power, viscosity, solubility and WAC are needed for better tuwo preparation.

**Table 2.** Functional properties of Ndaleyi samples and control

Sample	BD(g/ml)	WAC(g/g)	OAC(g/g)	SP(g/g)	Visco(cPs)	Solubility (%)	GT(°C)
M0	0.56±0.01 <sup>a</sup>	2.00±0.14 <sup>a</sup>	1.80±0.00 <sup>b</sup>	2.15±0.07 <sup>d</sup>	134.66±1.53 <sup>d</sup>	2.53±0.30 <sup>c</sup>	75.50±0.71 <sup>a</sup>
N55	0.55±0.04 <sup>a</sup>	1.95± 0.35 <sup>a</sup>	1.80±0.00 <sup>b</sup>	3.05±0.21 <sup>c</sup>	154.33±2.08 <sup>d</sup>	3.48±0.41 <sup>bc</sup>	71.50±2.12 <sup>a</sup>
N110	0.57±0.02 <sup>a</sup>	1.85±0.07 <sup>b</sup>	1.95±0.07 <sup>ab</sup>	4.45±0.35 <sup>b</sup>	675.00±6.55 <sup>c</sup>	3.70±0.25 <sup>b</sup>	71.50±0.71 <sup>a</sup>
N165	0.58±0.00 <sup>a</sup>	1.75±0.07 <sup>bc</sup>	2.10±0.14 <sup>a</sup>	5.10±0.28 <sup>a</sup>	708.33±8.08 <sup>b</sup>	4.03±0.15 <sup>b</sup>	71.00±1.41 <sup>a</sup>
N220	0.57±0.03 <sup>a</sup>	1.80± 0.00 <sup>b</sup>	2.05±0.07 <sup>a</sup>	4.20±0.28 <sup>b</sup>	876.00±3.60 <sup>a</sup>	4.43±0.28 <sup>a</sup>	72.00±1.41 <sup>a</sup>

Values are mean±SE (n=3). Values in the same column with different superscripts are significantly different (P<0.05). M0=dehulled millet flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N = ndaleyi flour. WAC/OAC,=Water/Oil absorption capacity, BD=bulk density, SP=swelling power, Visco=viscosity, GT=gelatinization temperature.

### 2.11.3. Physico-chemical Properties of Steeping Water, Ndaleyi and the Controls

The physico-chemical properties of zero hour steeping water and the steeping waters from each fermentation period are presented in **Table 3**. The pH levels of steeping waters were observed to decrease significantly (p<0.05) as steeping time increased. S220 with highest duration of steeping had the least pH of 4.10 or the highest TTA of 1.54%. The TTA of steeping water also increased linearly (0.22-1.54) as fermentation progressed due to the dominance of the environment by lactic acid bacteria which degrades carbohydrates resulting in formation of soluble organic acids that leached into the medium. According to Banigo and Muller (1972), sorghum, maize and millet were subjected to equal soaking time, it was observed that millet seeds had more disruptions than others, this indicates more soluble solids from millet seeped into water but some pearl millet varieties are said to possess corneous endosperm (Hadmani and Malleshi, 2001). Therefore, degree Brix (gram solute per 100g sample) of steeping water (kadal) increased with steeping time 3 for S220 and not detectible in the zero hour water (S00) for obvious reasons.

**Table 3.** Physico-chemical properties of steeping water

Sample code	pH	Brix (°)	TTA (% lactic acid)
S00	7.07±0.15 <sup>a</sup>	0.00± 0.00 <sup>d</sup>	0.00±0.00 <sup>d</sup>
S55	5.10± 0.10 <sup>c</sup>	1.00±0.00 <sup>c</sup>	0.22±0.01 <sup>c</sup>
S110	5.53± 0.11 <sup>b</sup>	2.03±0.05 <sup>b</sup>	0.68±0.01 <sup>b</sup>
S165	5.23± 0.05 <sup>c</sup>	2.33±0.05 <sup>b</sup>	0.78±0.01 <sup>b</sup>
S220	4.10±0.00 <sup>d</sup>	3.00±0.00 <sup>a</sup>	1.54±0.03 <sup>a</sup>

Values are mean $\pm$ SE (n=3). Values in the same column with different superscripts are significantly different (P<0.05). Steeping water (S): 00h, 55 h, 110 h, 165 h, 220 h. TTA= Total Titratable Acidity. With regard to ndaleyi flours, the TTA (% lactic acid basis) (0.23-0.55%) were observed to be at its peak in N55 and N110 ndaleyi, this could be due to the dominance of the environment at that period by lactic acid bacteria which degrades carbohydrates, resulting to acidification. A significant (p<0.05) decline was observed in N165 and N220 as fermentation progressed but still were higher than observed in the control. The PH (6.25-3.63) of the 10% suspension of the various ndaleyi flours decreased linearly with soaking time (**Table 4**), the unfermented control was slightly acidic (6.25), the progressive decline of pH or slight increase in titratable acidity is linked to utilization of soluble substrates for metabolism mainly by lactic acid bacteria(LAB) and yeast and formation of organic acids. Omemu et al.(2018) observed that LAB was active throughout 48h steeping and 48h souring phase of ogi production, a pH and TTA of 3.74-4.27 and 0.47-0.54% respectively were reported. Single cereal grain akamu powders from maize, pearl millet and sorghum were reported by Obiegbuna et al.(2019) to have pH that ranged between 5.83 and 6.30, which is slightly higher but comparable to the values obtained here. The decrease in degree Brix with fermentation time indicates soluble substrates mainly simple sugars were utilized, completely utilized to the extent it could not be detected in 165h and 220h ndaleyi, the foregoing indicates that ndaleyi is acidic which aid its protein and starch digestibility, therefore more digestible than the control.

**Table 4.** Physico-chemical Properties of Ndaleyi samples and Control

Sample code	pH	Brix(°)	TTA (% lactic acid)
M0	6.25 $\pm$ 0.07 <sup>a</sup>	0.50 $\pm$ 0.00 <sup>a</sup>	0.23 $\pm$ 0.00 <sup>d</sup>
N55	3.83 $\pm$ 0.05 <sup>b</sup>	0.30 $\pm$ 0.00 <sup>b</sup>	0.52 $\pm$ 0.01 <sup>a</sup>
N110	3.63 $\pm$ 0.05 <sup>c</sup>	0.13 $\pm$ 0.05 <sup>c</sup>	0.55 $\pm$ 0.00 <sup>ab</sup>
N165	3.83 $\pm$ 0.05 <sup>b</sup>	0.00 $\pm$ 0.00 <sup>d</sup>	0.45 $\pm$ 0.01 <sup>b</sup>
N220	3.70 $\pm$ 0.00 <sup>c</sup>	0.00 $\pm$ 0.00 <sup>d</sup>	0.41 $\pm$ 0.01 <sup>c</sup>

Values are mean $\pm$ SE (n=3). Values in the same column with different superscripts are significantly different (P<0.05). M00=dehulled millet flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N = ndaleyi flour.

#### 2.11.4. Proximate Composition of Ndaleyi flour and the Control

Significant variations (p<0.05) were observed in the proximate composition of the various ndaleyi flours as affected by steeping duration, the results are presented in **Table 4**. Moisture contents (11.09-12.08%) were comparable and slightly increased with fermentation period, 220h ndaleyi flour had the highest and the unfermented control the least (10.28%) the lower moisture or higher dry matter is indicative of high storage potential. Flour with moisture content less than 13% are more stable from moisture-dependent deterioration (Bello et al., 2017). There were marginal increase in protein content (9.08-10.20%), dietary fibre (4.08-4.59%), ash (1.63-2.04%) and fat (4.41-4.81%) and decreased carbohydrate (70.51-66.88%) contents with increase in soaking time suggesting higher nutritive value of ndaleyi than the control. Observed protein increase might be linked to additional nitrogen from bacterial biomass because most filamentous fungi serve as commercial source of single cell protein. It could have arisen from in-vitro

synthesis of protein by metabolizing microorganisms using available substrates in the fermenting medium. Ene-Obong and Ohizoba (1996) observed that fermentation did not significantly change total protein and amino acid composition of substrates. Onweluzo and Nwabugwu (2009) observed that the protein of unfermented millet was higher while the protein of the fermented flours decreased initially and later increased yet was lower than the value in the control. The least carbohydrate content mainly starch perhaps with higher glycemic index was recorded for 220 flour, (66.86%) indicating carbohydrates were the main source of energy for the microorganisms. Dietary energy decreased (333.03-325.57 %kcal) slightly with fermentation time and statistically the observed decreases were not statistically significant ( $p>0.05$ ). Ndaleyi with reduced dietary energy will serve as a better food source for patients with weight issues, however its supposedly higher glycemic index prohibits it as a food in the menu of diabetics. Ash content of the control (1.63%) decreased initially and later started climbing up and climaxed in 220h ndaleyi flour, the highest (2.04%). Ash reflects the mineral elements present in a biological material after incineration that removes the organic materials. The increase after the initial decrease in ash could be due to liberation of elements complexed by phytates and tannins with progress of fermentation (Samtiya et al., 2021). Fat content was observed to increase with increase in soaking time still ended up with the least value in 220h flour (4.24%). Osman (2011) reported that 24 h fermentation did not significantly change the protein and lipid contents of pearl millet for preparation of lohoh. A similar case was observed here even in prolonged fermentation. Bottom line is that the observed increases in the proximate values are not statistically significant, even with prolonged grain soaking time but losses during wet sieving and separation of sediments could lead to reduction in nutritional value.

**Table 5.** Proximate Composition of Ndaleyi flours and control (g/100g)

Sample	MF00	N55	N110	N165	N220
Moi	10.28±0.01 <sup>d</sup>	11.15±0.05 <sup>c</sup>	11.09±0.02 <sup>c</sup>	11.24±0.03 <sup>b</sup>	12.08±0.03 <sup>a</sup>
Fat	4.41±0.00 <sup>b</sup>	4.58±0.00 <sup>ab</sup>	4.61±0.01 <sup>ab</sup>	4.81±0.01 <sup>a</sup>	4.24±0.01 <sup>c</sup>
Ash	1.63±0.00 <sup>b</sup>	1.06±0.01 <sup>c</sup>	1.58±0.00 <sup>c</sup>	1.50±0.00 <sup>d</sup>	2.04±0.00 <sup>a</sup>
Fibre	4.08± 0.00 <sup>c</sup>	4.20± 0.01 <sup>d</sup>	4.32±0.01 <sup>c</sup>	4.39±0.00 <sup>b</sup>	4.59±0.00 <sup>a</sup>
Protein	9.08± 0.00 <sup>e</sup>	9.34±0.02 <sup>d</sup>	9.60±0.01 <sup>c</sup>	9.75±0.01 <sup>b</sup>	10.20±0.02 <sup>a</sup>
CHO	70.51±0.01 <sup>a</sup>	69.66±0.06 <sup>b</sup>	68.81±0.04 <sup>c</sup>	68.30±0.0 <sup>d</sup>	66.86±0.01 <sup>e</sup>
Energy(kcal)	333.03±0.08 <sup>a</sup>	325.57±0.28 <sup>b</sup>	327.86±0.14 <sup>d</sup>	325.73±0.20 <sup>c</sup>	326.57±0.15 <sup>d</sup>

Values are mean±SE (n=3). Values in the same column with different superscripts are significantly different ( $P<0.05$ ). M=dehulled millet flour. Steeping time: 00, 55 h, 110 h, 165 h, and 220 h. N = ndaleyi flour. Moi=moisture, CHO=carbohydrate.

#### 2.11.5. Mineral Composition of Steeping Water, Ndaleyi flours and Controls

##### Minerals in steeping waters

Mineral contents of the steeping waters decreased significantly ( $p<0.05$ ) from the highest level observed in the 0 h water, the variations presented in **Table 5** are as follows: (mg/100g) Mg.128.21-112.12, Ca 71.86-61.58, P

1093.39-955.87, K 204.75-179.01, Na 14.21-12.43, Fe 2.52-2.21 and Zn 1.76-1.54, the only reason for the general decrease of the mineral elements in steeping water with soaking time was the diffusion of the steeping waters' minerals into the microbial cells and fermenting seeds, one would have expected an increase due to leaching from the soaked seeds into the steep water, anyway diffusion occurs from the higher to the lower concentration. It is worthy to note that in S110 (4.58 days) water, the concentration of the mineral in the steeping water reached a minimum and began to rise until the end of steeping time, however the final concentrations in S220 (9.17 days) water were yet below the initial starting level and also below the level in S165 (6.88 days) meaning that lower mineral in S220 steeping water equates to higher mineral in the N220 flour. In fact there was initial diffusion out of the steeping water into the grains that caused the initial decline of minerals for those soaked for shorter time (55h, 110h) and for longer time leaching occurred from grain into the water which was responsible for the later increase in minerals in 165 h and 220h waters.

**Table 6.** Mineral composition (mg/100ml) of the various steeping waters

Mineral	S00	S55	S110	S165	S220
Mg	128.21±0.00 <sup>a</sup>	109.59±0.07 <sup>c</sup>	107.14±0.00 <sup>d</sup>	101.30±0.00 <sup>e</sup>	112.12±0.02 <sup>b</sup>
Zn	1.76±0.04 <sup>a</sup>	1.50±0.02 <sup>c</sup>	1.29±0.02 <sup>d</sup>	1.61±0.02 <sup>b</sup>	1.54±0.03 <sup>b</sup>
Fe	2.52±0.01 <sup>a</sup>	2.15±0.00 <sup>d</sup>	1.85±0.00 <sup>c</sup>	2.29±0.01 <sup>b</sup>	2.21±0.01 <sup>b</sup>
P	1093.39±2.90 <sup>a</sup>	932.56±1.78 <sup>d</sup>	803.04±1.54 <sup>e</sup>	994.50±1.15 <sup>b</sup>	955.87±1.83 <sup>c</sup>
K	204.75±0.98 <sup>a</sup>	174.65±0.65 <sup>d</sup>	150.39±0.56 <sup>e</sup>	186.27±0.54 <sup>b</sup>	179.01±0.66 <sup>c</sup>
Na	14.21±0.39 <sup>a</sup>	12.12±0.16 <sup>c</sup>	10.43±0.04 <sup>d</sup>	12.95±0.12 <sup>b</sup>	12.43±0.16 <sup>c</sup>
Ca	71.86±0.81 <sup>a</sup>	56.54±7.93 <sup>cd</sup>	52.73±0.36 <sup>c</sup>	65.24±0.22 <sup>b</sup>	61.59±1.86 <sup>c</sup>

Values are mean±SE (n=3). Values in the same column with different superscripts are significantly different (P<0.05). M0=dehulled millet flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N = ndaleyi flour.

### Mineral in various ndaleyi flours

The mineral contents of the various ndaleyi are shown in **Table 6**. Significant differences were observed in the mineral content of the various ndaleyi flours similar to the observation made for the steeping waters, the same trend was repeated, the levels decreased for shorter fermentation/soaking time in 55 h and 110 h from the highest observed in the control (M0) and thereafter started to increase yet lower in the N220h for some, leaching occurred in the flours that received shorter fermentation and reabsorption from steeping water for longer fermented flours. The observed variations were as follows (mg/100g): Mg 120.39-105.28, Ca 97.01-93.95, P 1027.18-1138.38, K 315.22-275.58, Na 19.18-63.80, Fe 3.01-3.68 and Zn 1.66-1.45. There were however exceptions, Na content slightly decreased in 55h and increased heavily in longer fermented flours reaching levels higher than in the control, others such as Fe, Zn, Ca and P decreased initially and reached minimum levels in 110 h flour, then began to increase in longer soaked flours like 165h and 220h yet their concentrations never reached the levels in the unfermented flour, perhaps reabsorption of the minerals already leached out was not sufficient enough to reach the



level of the control. Reported overall mineral levels in pearl millet akamu fermented 72 h (Obiegbuna et al., 2019) were found to be considerably smaller than obtained in this study for either 55 h and 110h flours or those soaked for longer periods. However, the mineral composition of unfermented pearl millet flours reported by Abdelrahman et al.(2005) and Fasasi (2009) are comparable to values recorded for the control, (dehulled pearl millet flour) used as control in this study.

**Table 7.** Mineral compositions of ndaleyi flours (mg/100g)

Mineral	MO	N55	N110	N165	N220
Mg	120.39±0.00 <sup>a</sup>	102.9±0.03 <sup>c</sup>	100.60±0.00 <sup>d</sup>	95.12±0.00 <sup>b</sup>	105.28±0.01 <sup>c</sup>
Zn	1.66±0.02 <sup>a</sup>	1.41±0.01 <sup>d</sup>	1.22±0.01 <sup>e</sup>	1.51±0.01 <sup>b</sup>	1.45±0.01 <sup>c</sup>
Fe	3.01±0.01 <sup>b</sup>	2.56±0.00 <sup>d</sup>	2.21±0.00 <sup>e</sup>	2.73±0.00 <sup>c</sup>	3.68±0.01 <sup>a</sup>
P	1027.18±1.18 <sup>b</sup>	875.96±0.68 <sup>d</sup>	730.30±0.57 <sup>e</sup>	934.00±0.35 <sup>c</sup>	1138.38±0.84 <sup>a</sup>
K	315.22±0.91 <sup>a</sup>	268.86±0.57 <sup>d</sup>	231.52±0.49 <sup>e</sup>	286.72±0.39 <sup>b</sup>	275.58±0.59 <sup>c</sup>
Na	19.18±0.53 <sup>d</sup>	16.37±0.21 <sup>e</sup>	63.80±0.72 <sup>a</sup>	50.20±7.04 <sup>b</sup>	46.81±0.32 <sup>c</sup>
Ca	97.01±1.09 <sup>a</sup>	76.33±10.71 <sup>e</sup>	80.94±5.76 <sup>d</sup>	87.39±0.41 <sup>c</sup>	93.95±1.46 <sup>b</sup>

Values are mean±SE (n=3). Values in the same column with different superscripts are significantly different (P<0.05). M00=dehulled millet flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N = ndaleyi flour.

#### 2.11.6. Microbial Status of Steeping Waters

Microbiological status of steeping waters for pearl millet grains is presented in **Table 6**. The total plate counts (TPC) and yeast mould counts (YMC) in the steeping water increased with soaking time, while staphylococcus sp and coliform counts in soaking water decreased progressively with soaking time, probably due to succession of bacteria in the course of fermentation. TPC ranged between  $3.28 \times 10^4$  and  $3.36 \times 10^5$  CFU/ml, the zero hour steeping water had the least and 110h steep water the highest, since the tap water is assumed to be partially sterile, the microorganisms must have originated from the pearl millet grains. Yeast/mould counts varied from  $4.20 \times 10^3$  to  $90 \times 10^4$  cfu/ml, zero hour steep water had the least and again 110h the highest and there after decreased and increased further to  $2.40 \times 10^4$  in 220h steeping water. Perhaps bacterial cell death was responsible for the decrease increase phenomenon as a result of prolonged soaking time.

The staphylococcus spp counts ranged between  $2.40 \times 10^4$  and  $2.90 \times 10^4$  (cfu/ml), the zero hour steep water (few hours after adding the grains to fresh water) and S220 water had the highest. After the zero hour population there was a decrease, later increased and reached highest count in 220h steep water. The coliform counts decreased from the highest population of  $2.08 \times 10^4$  cfu/ml recorded for zero hour steep water and decreased progressively to the level observed in 220h steep water ( $1.80 \times 10^4$  cfu/ml) still lower than recorded for other steep waters. Coliform presence indicates fecal contamination. E. coli and other members of enterobacteriaceae should be absent in drinking water therefore in this case they probably originated from the grains or from handling or food surface containers.

**Table 8.** Microbiological status of the steeping water (CFU/ml)

Sample Code	Total Plate Count (NA)	Yeast (PDA)	Staphylococcus sp (MSA)	Coliform (EMBA)
S00	$1.48 \times 10^5$	$1.60 \times 10^4$	$2.40 \times 10^4$	$2.08 \times 10^4$
S55	$2.89 \times 10^5$	$2.70 \times 10^4$	$1.80 \times 10^4$	$1.52 \times 10^4$
S110	$3.36 \times 10^5$	$3.90 \times 10^4$	$1.40 \times 10^4$	$8.80 \times 10^3$
S165	$3.20 \times 10^5$	$4.20 \times 10^3$	$2.10 \times 10^4$	$1.10 \times 10^4$
S220	$3.28 \times 10^4$	$2.40 \times 10^4$	$2.90 \times 10^4$	$1.80 \times 10^4$

Steeping waters (S)=00h, 55h,110h,165h, 220h. CFU= Colony Forming Unit.NA= Nutrient Agar. PDA= Potato Dextrose Agar. MSA= Mannitol Salt Agar. EMBA= Eosine Methylene Blue Agar.

### Microbiological status of the various ndaleyi flours

**Table 9** clearly indicates that ndaleyi flours were microbiologically safe considering the counts obtained which was influenced by sun drying operation aimed to lower the water activities of the various flours. TPC varied from  $5.90 \times 10^3$  to  $1.24 \times 10^3$  CFU/g, yeast and staphylococcus spp counts were insignificant but coliform was initially not detectable in zero hour flour and there after increased with progress of fermentation ( $1.30 \times 10^2$ - $7.20 \times 10^2$  CFU/g). Presence of Coliform suggests possible fecal contamination and the possibility of pathogenic bacteria presence. Absence of coliform in the control suggests steeping water was the source of contamination or from post processing handling. Omemu et al.(2018) noted that TPC increased till the end of steeping (48h), a range of log 5.70 and log 6.04 cfu/g for wet maize ogi indicating the beneficial effect of drying for longer storage.

**Table 9.** Microbiological status (cfu/g) of ndaleyi flours and the Control

Sample Code	Total Plate Count (NA)	Yeast count (PDA)	Staphylococcus spp. (MSA)	Coliform count (EMBA)
MF00	$1.23 \times 10^4$	$1.00 \times 10^2$	$8.00 \times 10$	ND
N55	$8.20 \times 10^3$	$1.00 \times 10$	$8.00 \times 10$	$1.30 \times 10^2$
N110	$9.30 \times 10^3$	$3.00 \times 10^2$	$2.00 \times 10$	$6.90 \times 10^2$
N165	$1.06 \times 10^4$	$8.00 \times 10$	$1.00 \times 10$	$1.60 \times 10^2$
N220	$5.90 \times 10^3$	$3.00 \times 10$	$1.10 \times 10^2$	$7.20 \times 10^2$

M00=dehulled millet flour 55= 55 hours steeping ndaleyi flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N= ndaleyi flour. NA= Nutrient Agar, PDA= Potato Dextrose Agar, MSA= Mannitol Salt Agar, EMBA= Eosine Methylene Blue Agar.

### 2.11.7. Effect of soaking time on sensory characteristics of ndaleyi tuwo

On a 9-point hedonic scale, the sensory attributes of the various ndaleyi tuwo were compared with the control (unfermented pearl millet flour tuwo) **Table 7**. The overall picture indicates that 165h (6.88 days) ndaleyi tuwo

out-scored others in terms of the attributes under investigation, followed closely by 220h (9.17 days) tuwo, the control tuwo had better aroma (6.47) than 55h and 110h tuwo; the taste (5.87-8.07) and after taste scores (5.80-7.93) of the control were not significant different ( $p<0.05$ ) from the taste of 55h and 110h two. The control tuwo had the poorest mouth feel (5.27-8.07), smoothness (4.13-8.47) which are indicators of texture (4.73-8.33), and the least overall acceptability (5.07-8.53). The control and N55 had the least colour score (4.93). M00 (Control) and N55 appeared darker as millet flour is naturally greyish in colour and moreover chir did not separate cleanly from N55 ndaleyi as in others therefore responsible for its unique behaviour. The desirable attributes climaxed in 165h (6.88 days) ndaleyi two and thereafter started to decline. The texture, smoothness, colour, mouth feel, taste etc. were enhanced with longer fermentation time which climaxed in 165h ndaleyi tuwo instead of 220h tuwo.

**Table 10.** Sensory evaluation of Ndaleyi tuwo and Control tuwo

Sample	MF00	N55	N110	N165	N220
Aroma	6.47±2.00 <sup>c</sup>	6.33±1.63 <sup>c</sup>	6.27±2.34 <sup>d</sup>	7.67±1.88 <sup>a</sup>	7.33±1.50 <sup>b</sup>
Colour	4.93±2.28 <sup>c</sup>	5.00±2.17 <sup>c</sup>	6.13±2.13 <sup>b</sup>	8.53±0.52 <sup>a</sup>	7.07±1.39 <sup>b</sup>
Taste	6.07±2.15 <sup>c</sup>	5.87±1.85 <sup>c</sup>	6.00±2.33 <sup>c</sup>	8.07±1.39 <sup>a</sup>	7.40±1.72 <sup>b</sup>
Mouthfeel	5.27±2.09 <sup>d</sup>	5.67±1.84 <sup>c</sup>	5.67±2.26 <sup>c</sup>	8.07±1.03 <sup>a</sup>	6.87±1.81 <sup>b</sup>
Smoothness	4.13±2.00 <sup>c</sup>	6.80±1.66 <sup>b</sup>	6.60±1.92 <sup>b</sup>	8.47±0.64 <sup>a</sup>	8.00±0.85 <sup>a</sup>
Aftertaste	5.80±2.31 <sup>c</sup>	5.80±1.61 <sup>c</sup>	6.07±2.09 <sup>c</sup>	7.93±1.75 <sup>a</sup>	7.27±1.39 <sup>b</sup>
Texture	4.73±2.22 <sup>e</sup>	6.47±1.36 <sup>d</sup>	7.07±1.71 <sup>b</sup>	8.33±0.72 <sup>a</sup>	7.93±1.03 <sup>c</sup>
Acceptability	5.07±1.71 <sup>e</sup>	5.27±2.22 <sup>d</sup>	6.27±1.79 <sup>c</sup>	8.53±0.83 <sup>a</sup>	8.00±0.85 <sup>b</sup>

Values are Mean±SE (n=3). Values in the same column with different superscripts are significantly different ( $P<0.05$ ). M00=dehulled millet flour. Steeping time: 55 h, 110 h, 165 h, and 220 h. N = ndaleyi flour.

### 3.0. Conclusion

Ndaleyi flour is obtained by soaking pearl millet (6-9days) followed by wet milling, wet sieving, sedimentation, dewatering and drying. Soaking for 165h yielded ndaleyi with better swelling power and reduced water absorption capacities, however the 165h ndaleyi had the best sensory attributes achieved at the expense of lower mineral and proximate composition than unfermented pearl millet flour. Greater levels of mineral and bacteria were located in the steeping waters than in the ndaleyi flours.

### Declarations

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### Competing Interests Statement

Authors have declared no competing interests.



### Consent for Publication

The authors declare that they consented to the publication of this research.

### Appendix



**Plate 1.** Millet Flour



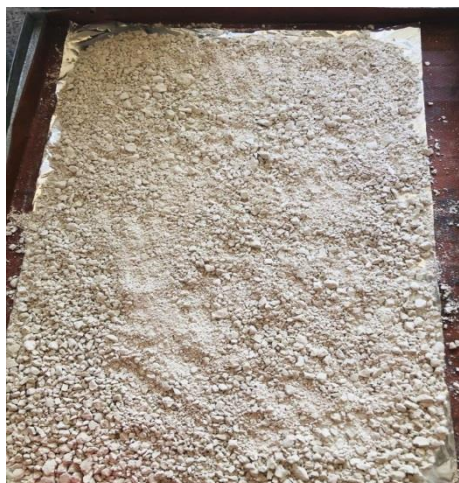
**Plate 2.** Pearl Millet



**Plate 3.** Steeping Water



**Plate 4.** Steeped Pearl Millet



**Plate 5.** Dried N55



**Plate 6.** Dried Chir and Ndaley



**Plate 7.** Ndaleyi and Chir



**Plate 8.** Separated Ndaleyi and Chir



**Plate 9.** Ndaleyi reconstituted in Water



**Plate 10.** Bri-Ndaleyi Preparation (cooked dough)

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