QUALITY EVALUATION OF CO-FERMENTED PEARL MILLET AND BAMBARA GROUNDNUT NDALEYI.

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Abstract: Ndaleyi flour is traditionally produced from fermented pearl millet (M) grain. It is used for the preparation of thin and thick porridges. The outcome of prolonged fermentation/soaking involved in the preparation of ndaleyi is reduced nutrient density of both the ndaleyi flour and ndaleyi-based foods. Enhancement of the nutritive value of ndaleyi is the focus of the present study. Ndaleyi was fortified through co-fermentation of decorticated(d) whole pearl millet with whole or decorticated bambara groundnut (B) in the ratio of 85:15 and 75:25 (M:B).There were eight blends and the control (traditional ndaleyi flour from 100% pearl millet), the eight blends were code named: M8 (5:15), MB75:25), MdB (85:15), MdB (75:25), MBd(85:15), MBd(75:25), MdBd (85:15), MdBd (75:25) and M(100:00). After 7 days of cofermentation, each blend was washed, wet-ground, wet-sieved, allowed to settle and decantation followed and separation of brown of upper gluten layer (chir) from the underlying cream-colured starchy layer (ndaleyi), each was dewatered and sun-dried and the clumps were pulverized and evaluated for physiochemical and functional properties as well as sensory properties of the various tuwo using standard procedures. The result revealed that the control ndaleyi flour was more acidic with the least pH of 3.19, and highest titratable acidity (TTA) (1.26%) than the pH of the treated (4.0-4.8) and TTA (0.55-0.97%). The observed differences in the bulk density (0.67-0.75) were not significant although higher in the fortified. Water solubility (2.25-7.25%) and water absorption capacities (117-185%) were higher in the fortified. Reduced swelling power (2.10-2.97g/g).were observed in the treated. Crude protein 8.69-11.63%, crude fat 3.98-5.55, total ash 1.95-3.09% and crude fibre 2.84-3.56% were greater in the treated ndaleyi flours. Carbohydrate content was higher in the control and moisture contents were generally low after drying. , The calorific values were low and not significantly different. The investigated mineral elements were lower in the control and higher in the fortified especially those 75:25 blend containing whole grains and the concentrations of mineral elements varied significantly ($p=\leq 0.05$) as follows : Na 21.04-36.12, K 57.26-129.04, Ca 31.32-55.01, Mg 55.04-107.19, P 94.85-153.11, Zn 0.87-1.26, Fe 1.46-2.87 and Mn 0.15-0.23 mg/100g. Formulations MdB and MBd had the least of these minerals and were greater in MdBd and cofermented whole millet and whole BGN. Traditional ndaleyi tuwo had better sensory attributes which deteriorated with inclusion of BGN, however in many cases the sensory scores of the control and the treated were not significantly different especially at the level of 15% inclusion of decorticated Bambara groundnut, this later observation justified the fortification of starchy ndaleyi with any of the common pulses for greater nutritive value.

Key Words: Ndaleyi, Pearl millet, Fermentation, Bambara groundnut, *Tuwo*

Introduction

Ndaleyi is a fermented grain flour obtained through steeping of pearl millet for 6-9days, after which the starch is extracted and dried for shelf stability. A slurry of this flour stiired into hot water and cooked, produces a stiff dough called bri-ndaleyi which is consumed alongside with one of the various local soups. A sweetened gruel produced from ndaleyi serves as breakfast cereal similar to *akamu* or *kunu*. Ndaleyi is majorly produced and consumed by the Kanuri ethnic sub-nationality that inhabits Borno and Yobe States of northeastern Nigeria, a semi-arid environment that supports the cultivation of pearl millet (pennisetum glaucum). This grain is a major member of the millet family, a group of small seeded cereals, and an unfailing drought tolerant crop that survives the harshness of the environment (Bidinger and Hash, 2003). Previously, Nigeria is the second leading producer after India (Shweta, 2015). Northern Nigeria is the epicenter of pearl millet production in Africa, the annual production between 2014 and 2016 ranged from 1.15 to 1.55 million tons which positioned Nigeria currently as the third largest producer after Niger and India (Ajeigbe *et al*., 2020). Ndaleyi is produced by steeping the grains, there after follows wet-milling and wet-sieving and the resulting starchy suspension is allowed to settle, the sediment is recovered by decantation of the clear water, leaving behind two layers of sediments, the brownish upper layer (gluten layer or the chir) and the cream coloured bottom layer (wet ndaleyi), both are sun dried and used for their respective purposes. (Nkama, 1994). In former times, ndaleyi was the desired meal consumed by the upper class especially during religious and cultural festivities, priced for its excellent organoleptic properties unlike unfermented pearl millet flour or its steamed stiff dough *(towu*) Regrettably, ndaleyi production and consumption is currently subdued by availability of cereal-based semolina, especially from wheat and maize, consequently the youths are scarcely aware of the availability of this worthy food legacy driven underground by many factors not excluding the laborious production process of ndaleyi, rural-urban migration and the era of fast foods or availability of ready to eat or cook foods, as well as rising health and nutrition consciousness with the attendant emphasis on consumption of functional foods.

Akamu and ndaleyi preparations are similar, the difference lies in long steeping period (6-9 days) associated with ndaleyi preparation, and therefore greater leaching of minerals and health giving neutraceuticals, greater modification of the nutrients and without extended fermentation chir will not separate from the ndaleyi. Fermentation is one of the methods of food preservation techniques in Africa, and according to Kadajdova and Karovicova (2017), fermentation is a desirable process of biochemical modification of primary food matrix brought about by microorganisms and their enzymes; a process that enhances the bio-accessibility and bioavailability of nutrients (Holz and Gibson 2007), a process which also improves the organoleptic properties as well as extending the shelf life of fermented foods (Chaves et al.,2014). The prolonged fermentation, wet-sieving and dewatering process renders ndaleyi nutrient deficient hence the need for fortification of ndaleyi flour with one of the common pulses in Nigeria. Bambara groundnut (BG) is of West Africa origin, the third most important food legume after peanut and cowpea in terms production and consumption (Mkandawire, 2007). BGN is regarded as a complete food containing 3.0-5.0% ash, 4.5-7.5% fat, 18-24% protein with adequate lysine and relatively sufficient methionine, 3-12% fibre,, 51-70% carbohydrate in balanced amounts in addition to presence of micro nutrients (Mahazib et al., 2013,; Saleh et al.,2013). Fortification of ndaleyi with BGN will enhance through complementation the lysine deficient pearl millet protein as well as improving the overall nutritive value of ndaleyi. Grain decortication helps improves the sensory properties of food products as well reduce the anti-nutritional factors such as tannin and the phytate but also it leads to loss dietary fibre, minerals, and non-nutrient phytochemicals which are mostly located in the in grain pericarp (Babiker et al.,2018). Food preparation practices such as dehulling/decortication, soaking, fermentation, germination and others reduce the level of antinutrients and modify nutrients for greater bioavailability. Therefore, the present study was premised on the effects of grain decortication on the quality of ndaleyi produced from the fermentation of pearl millet and Bambara groundnut grains.

Materials and Methods

Procurement of Raw Materials:-

Raw material such as pearl millet and Bambara nut and working tools such as cloth bags, muslin clothes for wet sieving; plastic buckets with lids, cups etc. were purchased at Maiduguri Monday market

Decortication of Grain

Sorted and cleaned millet grains were portioned into two, one portion was decorticated using a local attrition mill after tempering. The same treatment was given to bambaragrounut(BGN) but manually done using mortar and pestle after soaking overnight, the decorticated BGN were parboiled for 10 min.

Formulations for Millet-BGN Ndaleyi

Table1: Traditional Ndaleyi and modified Ndaleyi formulations

Sample Code	Peal millet (%)	Bambara groundnut (%)
M	100	00
MBd	85	15
MBd	75	25
MdB	85	15
MdB	75	25
MB	85	15
MB	75	25
MdBd	85	15
MdBd	75	25

M=millet, Md=decorticated millet, B=Bambara groundnut, Bd=decorticated Bambara groundnut.

Preparation of Ndaleyi

A modification of the method described by Nkama (1994) was adopted to prepare the various modified ndaleyi. Cleaned millet grains were portioned into two, one portion was decorticated in a local attrition mill. The same treatment was given to one portion of cleaned bambara groundnut (B) but manually dehulled, and parboiled (10 min). Millet decorticated or whole (Md or M) were blended with whole or dehulled bambara groundnut in the prescribed ratios shown in **Table 1** above. Whole millet (100%) used for preparation of traditional ndaleyi, served as the experimental control. There were nine formulations including the control. Each portion was soaked in portable water (1:3, W/V) in transparent labeled plastic buckets for 7 days. At end, the steep water was removed and the fermented grains were washed with tap water and wet milled using attrition mill and wet-sieved. The over tail (Bina) was kept aside for drying, and the starchy suspension stirred vigorously with the hand and allowed to sediment by gravity settling. After 18 h, the clear water atop was decanted. The top layer (millet gluten or chir) was separated from the bottom whitish layer (wet ndaleyi), these two layers were separately sun-dried on plastic trays and further pulverized in an electric blender to obtain chir and ndaleyi flours. **Figures 1& 2** illustrate further the preparation of the traditional and modified ndaleyi flours

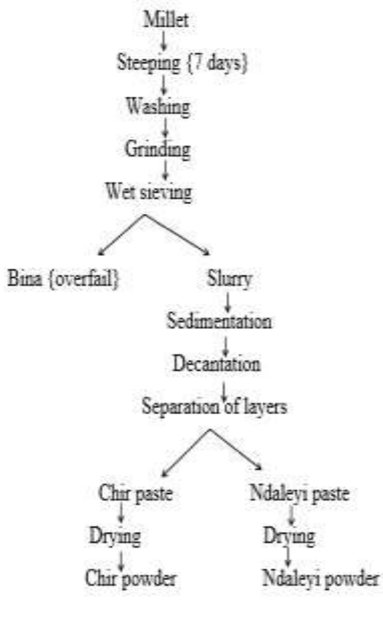

Fig 1. Process diagram for ndaleyi preparation (a modification of Nkama (1994)

Fig.2. Process diagram for Pearl millet-Bambara Groundnut (BGN) Ndalayi flour.

Physical and Functional Properties Analysis

Bulk Density

Bulk density was determined according to the method of Anderson et al. (1969). The flour samples were transferred into a 10 ml graduated cylinders that were previously weighed. The cylinder was tapped gently at the bottom on a laboratory bench several times until no diminution of the sample level was observed. Bulk density was calculated as the weight of the sample per unit volume of the sample (g/ml).

Determination of water absorption capacity

Water absorption capacity (WAC) was determined by modifying the method of Philips et al.(1998). One gram (dry weight basis) of the sample was dispersed in 10 ml distilled water, vortexed intermittently for 10 minutes and centrifuged at 3500 rpm for 20 minutes. The aqueous supernatant obtained after centrifuging was decanted and the test tubes inverted and allowed to drain for 5 minutes on a towel. By weighing the residue, water absorption capacity was calculated as a percentage of a gram of water absorbed per gram of sample.(gram of water absorbed was the difference wet weight and dry weight of the sample).

Swelling and solubility

Swelling power and solubility patterns were determined as described by Ahmed et al. (2010). About 0.5 g was suspended in 10 mL of distilled water and placed in a water bath maintained for 30 min at a temperature of 90 °C, the mixture was centrifuged at 2000 rpm for 15 min, the clear supernatant was drawn off by suction unto a pre-weighed porcelain dish, oven dried at 105°C for 5hr, cooled and weighed. The wet sediment was also weighed after inverting the tube unto a tissue paper to drain for 60 min. The difference in weight of the soluble starch and sample was regarded as the solubility expressed in percentage. Swelling power was the weight of the sediment divided by sample weight, dry basis.

Determination of titrable acidity

About 5g of sample was suspended in 20ml of distilled water, mixed and allowed to stand for 30 min and filtered after, the titrable acidity was determined by the method described by AOAC (2005). Approximately 5 ml of the filtrate was taken and titrated with 0.1 N NaOH (N = normality) using 0.5 ml 1% phenolphthalein as indicator. Titration continued until pink end point. (TV).The titration was repeated to get the average value and blank titre (Bv) deducted.

$$\%\,Titrable\ acidity = \frac{Tv - Bv \times Equivalent\ weight\ of\ acid}{Volume\ of\ sample} \times 100$$

Equivalent weight of lactic acid = 0.09.

pH determination

The pH of the filtrate was determined according to the method of AOAC (AACC, 2000). 10 g of the sample was added to 50 ml of distilled water and stirred for 10 min. The pH of the sample was determined by dipping the electrode of the Kent pH meter in the mixture. Duplicate determination was made in all cases. The pH meter was calibrated using pH 4.0 and 9.0 standard buffers.

Proximate composition

After bringing the samples to Uniform size, they were analyzed for moisture, crude protein, crude fat, total ash, crude fiber and nitrogen free extract according to established procedures of AOAC (2010). Carbohydrate content was determined by 'difference', subtracting from 100 the sum of the percentages of moisture, ash, protein and fat. %Carbohydrate =100 - (%Moisture + %Ash + %Fat + % crude fiber + %Protein).

Mineral determination

Established procedures of AOAC (2010) were used to determine the minerals. Ca, Mg, Fe, Zn, Mn were determined using atomic absorption spectrometer (Perkin-Elmer, Model 3100, USA), Na and K were determined using flame atomic emission photometer, and P was determined using a spectrophotometer (Pye-Unicam UK, Model S99). About 1.0g of the powdered sample was placed in digesting glass tube for wet digestion. Twelve milliliters (12ml) of HNO_3 was added to the sample, kept overnight at room temperature. Then 4.0 ml Perchloric acid ($HClO_4$) was added to this mixture and was kept in the fume block for digestion. The temperature was increased gradually, starting from 50^0C and increasing up to 250-300 C. The digestion completed with the appearance of white fume Cooled mixture was made up to mark (100ml) with deionised water in a volumetric flask. Aliquotes of the digest were used for elemental analysis of the samples, and concentration of each was obtained by extrapolation from the respective standard calibration curves.

Sensory Evaluation of the various millet -BGN ndaleyi and control tuwos

On a 9-point Hedonic scale ranging from like extremely (9) to dislike extremely (1), neither liked nor disliked (5). Fifty-man panel was used for the exercise. Taste, aroma, colour, texture and acceptability of the various tuwo were evaluated these panelists were selected among students both within and outside the faculty, University of Maiduguri especially students from Kanuri ethnic group who are familiar with the product. Disposable plates with coded samples were presented to the 20 test panelists consisting of (8 males and 12 females), two sections were conducted, without and with local soup. Average sensory scores were presented.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) and means separated using Duncan multiple range test, significance difference was accepted at 5% probability ($p<0.05$). Results are presented as mean±standard error of the mean (n=2).

Results and Discussion

The physicochemical and functional properties of co-fermented millet Bambara groundnut ndaleyi flours.

The physicochemical and functional properties of bambara groundnut (BGN) fortified millet ndaleyi flours shown in Table 1. Unmodified millet (100%) ndaleyi flour had significant higher titratable acidity (TTA) 1.26%, greater than the TTA of fortified ndaleyi flours, perhaps as a result of the partial replacement of starchy millet with higher protein BGN. Among the blends, the TTA varied from 0.50% to 0.97% but these reductions of the TTA of the enriched ndaleyi corresponded with the pH of 3.7-4.8, with little variations between them. MdB (85.15) had the highest pH or least acidity, and M(100%), MdB (75.25), MB (85:15), MB(75:25) and MdBd (85.15) were more acidic but the control was the highest. It goes to show that pH or acidity is influenced by the greater presence of starch from millet whole or decorticated providing soluble substrates for metabolizing actions of microorganisms and their enzymes which convert sugars to organic acids. Omemu reported a similar trend, higher TTA in 100% maize ogi (0.54%, pH 3.74)) and lower in maize-pegron pea ogi TTA <0.54%, pH 4.07-4.27). The acidic nature of ndaleyi could have preservative effect and aids the enhancement of sensory properties as well as the digestibility of tuwo (ndaleyi cooked stiff dough). (Pranoto et al., 2013) The bulk density (BD) values were comparable, a range between 0.65 and 0.75 g/ml, MdB had the least and MdBd the highest; however there were no significant difference between the BD of the control and some of the fortified blends. BD is greatly influenced by flour particle size, those with higher coarseness are bulkier, therefore low BD, meaning little material stuff is sufficient to occupy or fill a unit volume which is indicative of higher cost of packaging, handling and storage (Kulkarni et al., 1991). Higher BD is associated with greater degree dispersiblity or reconstitution ability needed during tuwo preparation. Decortication, parboiling of BGN and blend ratio were the factors which perhaps cooperatively influenced the solubility (2.25-7.25%), swelling power (2.10-2.97g/g) and water absorption capacity (95-180%) of the various ndaleyi flours. Parboiling must have caused BGN protein denaturation which in turn reduced its solubility and water affinity (Padmashre *et al.,* 1987) but increased its protein digestibility. Co-fermentation of decorticated millet or BGN or decorticated millet and BGN had greater influence on the functional parameters, and but the effect of blending ratio is not clear-cut however greater proportion of BGN than millet would provide more protein with greater hydrophilic groups capable of binding with water molecules and thereby improve water absorption, which in turn influenced both swelling power and solubility, both parameters determine ability to gain and retain water in an environment where water is limited (Singh, 2001). Millet ndaleyi flour had the highest swelling power (2.97 g/g) which decreased in the treated, reduced swelling is indicative of starch with greater associative force within the starch granules but other authors link swelling power as a function of both starch and protein presence (Woolfe, 1992). This could be true because Ibrahim et al. (2021) reported greater WAC and swelling power in millet-BGN flour blend than in millet flour. Ndaleyi flours with high water absorption and swelling power are desirous because it could improve tuwo yield, two tenderness and reduced tendency to harden on cooling or in storage. Solubility values are influenced by factors such as flour particle size, temperature, ionic strength of the medium or the pH (Elkhalid et al., 2012), and flour hydration properties are dependent on flour solubility.

Table:1 Effect grain decortication and blend level on the physicochemical properties of millet-BGN ndaleyi flours

Sample Code	T.T.A (%)	pH	Bulk Density(g/ml)	Solubility (%)	Swelling power (g/g)	WAC (%)
M (100%)	$1.26^{a} \pm 0.00$	$3.7^{d} \pm 0.1$	$0.69^{a} \pm 0.08$	$2.97^{d} \pm 1.27$	$2.97^{a} \pm 0.14$	125^{d}
MBd(85:15)	$0.51^{d} \pm 0.00$	$4.4^{ab} \pm 0.1$	$0.69^{a} \pm 0.02$	$4.76^{ab} \pm 0.11$	$2.82^{a} \pm 0.28$	165^{b}
MBd(75:25)	$0.55^{d} \pm 0.01$	$4.5^{a} \pm 0.2$	$0.71^{a} \pm 0.02$	$7.25^{a} \pm 0.35$	$2.65^{ab} \pm 0.21$	130^{d}
MdB(85:15)	$0.56^{d} \pm 0.01$	$4.8^{a} \pm 0.5$	$0.65^{ab} \pm 0.04$	$5.82^{ab} \pm 0.00$	$2.34^{c} \pm 0.42$	180^{a}
MdB(75:25)	$0.97^{b} \pm 0.03$	$4.0^{c} \pm 0.1$	$0.65^{ab} \pm 0.07$	$4.76^{ab} \pm 1.08$	$2.52^{b} \pm 0.44$	140^{c}
MB(85:15)	$0.72^{bc} \pm 0.00$	$4.1^{c} \pm 0.1$	$0.72^{a} \pm 0.05$	3.44c±0.00	$2.63^{ab} \pm 0.22$	140^{c}
MB(75:25)	$0.85^{bc} \pm 0.07$	$4.0^{c} \pm 0.1$	$0.72^{a} \pm 0.05$	2.25e±0.1	$2.33^{c} \pm 0.52$	125^{d}
MdBd(85:15)	$0.72^{bc} \pm 0.06c$	$4.2^{c} \pm 0.02$	$0.70^{a} \pm 0.08$	4.25b±1.06	$2.25^{d} \pm 0.10$	130^{d}
MdBd(75:25)	$0.84^{bc} \pm 0.13$	$4.6^{a} \pm 0.1$	$0.75^{a} \pm 0.04$	$2.80^{d} \pm 0.00^{e}$	$2.10^{d} \pm 0.11$	95^{e}

Values are presented as Mean±SE(n=2). Mean values in a column bearing similar superscripts are significantly not different ($p<0.05$). M = millet, Md = decorticated millet, B = Bambara Groundnut (BGM), TTA = Titratable acidity, WAC = Water Absorption Capacity.

4.2 Effect of grain decortication and blend level on the proximate composition (%) of millet-BGN Ndaleyi flours.

Table 2 reveals that millet-BGN ndaleyi flours with higher blend ratio (75.25) had greater nutrient density than 85:15 blend.. Moisture contents of the BGN fortified ndaleyi flours ranged from 7.37 to 9.04%, values that were not significantly different, the low moisture of the flours after drying indicates higher dry matter, and higher storage potential. Fortification of pearl millet with BGN improved nutritive value of the treated, the traditional ndaleyi flour used as the control had protein content of 9.58% and there were protein enhancements in the treated (10.09-11.63%) so that MB 85:15 and MB 75:25 (both whole grains) had the highest protein, fat, ash and fibre (g/100g), 11.26-11.63, 5.13-5.55, 2.65-2.88, 3.56-3.62 respectively and the least carbohydrate content (67.55 -68.55) but when millet and

BGN were both decorticated, the resulting ndaleyi flours had slightly lower nutritive value in terms of protein, fat, ash, fibre and higher carbohydrate contents still higher than the values recorded for traditional ndaleyi. Onweluzo and Nwabugwu (2009) reported millet grains fermented for 0-96h witnessed initial decrease in protein and final increase to 9.5% at 72 h, and observed an increase in ester extract with progress of fermentation, an increase in fat observed at 24h and 72h.. Whole millet and decorticated BGN yielded ndaleyi flours with nutritive value higher than that of ndaleyi flour produced using decorticated millet and whole BGN, indicating that removal of outer bran layers of millet had more profound effect on the proximate composition of fortified ndaleyi flours than decorticated BGN. Co-fermentation of millet and BGN both decorticated caused a pronounced reduction of the protein, ash, fibre and fat contents of the ndaleyi flours. Babiker et al.(2018) reported that decortication decreases ash, protein, oil, fibre and increased moisture and carbohydrates of millet.

Table: 2 Effect of grain decortication and blend level on the proximate compositions (%) of millet-BGN ndaleyi flours.

Sample	Mosture	Crude Protein	Crude Fat	Total Ash	Crude Fibre	Corbohydrate	Energy value (kcal)
M(100%)	$8.95^{ab}\pm0.01$	$9.58^{d}\pm0.02$	$4.63^{c}\pm0.01$	2.17d±0.01	$2.78^{d}\pm0.01$	$71.90^{a}\pm0.04$	$367.59^{a}\pm0.62$
MBd (85:15)	$8.89^{ab}\pm0.01$	$10.09^{c}\pm006$	$4.74^{bc}\pm0.02$	$2.38^{c}\pm0.03$	$2.96^{d}\pm0.01$	$70.96^{a}\pm0.03$	$366.86^{a}\pm0.70$
MBd(75:25)	$9.04^{a}\pm0.01$	$10.88^{bc}\pm0.02$	$4.88^{b}\pm0.00$	$2.78^{b}\pm.0.01$	$3.11^{b}\pm0.1$	$69..34^{ab}\pm0.03$	$364.48^{ab}\pm0.79$
MdB (85:15)	$8.17^{b}\pm0.08$	$10.65^{bc}\pm0.09$	$3.98^{e}\pm0.04$	$1.95^{f}\pm0.02$	$2.34^{f}\pm0.01$	$72.93^{a}\pm027$	$370.14^{a}\pm0.95$
MdB (75:25)	$8.28^{b}\pm0.01$	$10\ 97^{bc}\pm0.08$	$4.24^{d}\pm0.02$	$2.23^{c}\pm0.05$	$2.50^{e}\pm0.03$	$71.78^{a}\pm0.15$	$369.16^{a}\pm0.88$
MB (85:15)	$8.90^{ab}\pm0.01$	$11.26^{b}\pm0.07$	$5.13^{b}\pm0.02$	$2.65^{b}\pm0.24$	$3.56^{a}\pm0.01$	$68.55^{ab}\pm0.14$	$365.21^{a}\pm0.61$
MB (75:25)	$8.83^{ab}\pm0.00$	$11.63^{a}\pm0.43$	$5.55^{a}\pm0.11$	$2.88^{b}\pm0.05$	$3.62^{a}\pm0.08$	$67.55^{ab}\pm0.85$	$366.67^{a}\pm0.79$
MdBd (85:15)	$8.82^{ab}\pm0.00$	$10.69^{bc}\pm0.01$	$4.87^{b}\pm0.00$	$2.87^{b}\pm0.01$	$2.92^{d}\pm0.03$	$69.85^{ab}\pm0.03$	$365.99^{a}\pm0.80$
MdBd (75:25)	$8.90^{ab}\pm0.00$	$10.97^{bc}\pm0.02$	$4.93^{b}\pm0.05$	$3.09^{a}\pm01$	$2.96^{d}\pm0.00$	$69.18^{ab}\pm0.40$	$364.97^{ab}\pm0.72$

Values are presented as Mean±SE(n=2). Mean values in a column bearing similar superscripts are significantly not different ($p<0.05$). M = millet, Md = decorticated millet, B = Bambara Groundnut (BGM), TTA = Titratable acidity, WAC = Water Absorption Capacity.

Effect of grain decortication and blend level on the mineral contents of Millet-BGN ndaleyi flours.

There was significant enhancement in the mineral contents as influenced by grain decortication and BGN fortification of millet ndaleyi. A glance at T**able 3** provides the obvious information of higher mineral content in the fortified ndaleyi flours than in the traditional millet ndaleyi, and among the treated ndaleyi flours 75:25 flour blends had greater concentration of the investigated dietary elements. MdBd (both decorticated grain) and MB (both whole grains) had greater concentration of the minerals but lower in blends where one of the grains, either millet or BGN was decorticated as in MBd or MdB. The range of concentrations of Na, K, Ca, Mg, P, Zn, Fe, and Mn obtained were, 21.04-36.11, 57.26-129.04, 31.32-55.01, 55.04-107.19, 94.85-153.11, 0.87-1.26, 1.46-2.87 and 0.15-0.23 mg/100g, respectively and the Ca/P and Na/K ratios were 0.23-0.38 and 0.19-0.23 respectively. Reduced Ca and increased P intake indicates low Ca:P ratio, a subject of worldwide concern, a value of 1.3:1.0 is suggested for maintenance of bone health (Pereira et al.,2013). On the other hand, significant increase in the risk of cardiovascular diseases is associated with higher ratios of sodium to potassium in the human plasma which is influenced by Na/K ratio in the diets.. The order of abundance of the elements was P>K>Mg>Ca>Na>Fe>Zn>Mn. Mineral concentration reported by Oko et al. (2018) in akamu from single cereals (maize, sorghum and pearl millet) given 72 h fermentation were smaller compared with the values of the same minerals obtained here for the control (100% pearl millet ndaleyi four) that received longer fermentation period. Reported mineral composition of unfermented pearl millet flour provided by Abdelrahman et al. (2005) and Fasasi (2009) are higher indicating the effect of leaching on the mineral contents of traditional ndaleyi flour or the fortified blends.

Table: 3 Effect of grain decortication and blend level on the mineral composition (mg/100g) of millet-BGN ndaleyi flours

Sample	Na	K	Ca	Mg	P	Zn	Fe	Mn	Ca/P	Na/K
M100	$25.39^{d}\pm0.11$	$74.36^{f}\pm0.50$	$33.26^{e}\pm0.20$	$66.41^{g}\pm0.168$	$94.85^{a}\pm0.20$	$1.00^{d}\pm0.00$	$1.90^{e}\pm0.00$	$0.18^{b}\pm0.00$	0.36	0.34
MBd 85:15	$28.20^{c}\pm0.13$	$88.27^{e}\pm0.71$	$38.82^{d}\pm0.28$	$77.76^{f}\pm0.30$	$111.10^{g}\pm0.00$	$1.07^{c}\pm0.00$	$2.20^{b}\pm0.01$	$0.19^{b}\pm0.00$	0.35	0.32
MBd 75:25	$33.84^{b}\pm0.44$	$119.43^{c}\pm2.61$	$51.09^{bc}\pm1.02$	$81.84^{e}\pm0.97$	$136.46^{cd}\pm1.78$	$1.18^{bc}\pm0.01$	$2.68^{ab}\pm0.03$	$0.22^{a}\pm0.00$	0.37	0.28
MBd 85:15	$21.04^{ef}\pm0.46$	$57.26^{g}\pm1.74$	$31.32^{e}\pm0.88$	$55.04^{h}\pm0.91$	$130.21^{d}\pm2.47$	$0.89^{f}\pm0.01$	$1.46^{g}\pm0.03$	$0.15^{c}\pm0.00$	0.24	0.37
MdB 75:25	$21.62^{e}\pm0.47$	$116.16^{cd}\pm4.28$	$45.93^{cd}\pm1.58$	$91.20^{cd}\pm1.72$	$138.18^{c}\pm1.37$	$0.87^{f}\pm0.01$	$1.55^{f}\pm0.01$	$0.15^{c}\pm0.00$	0.33	0.19
MB 85:15	$33.11^{bc}\pm3.25$	$113.72^{d}\pm2.39$	$48.94^{c}\pm8.55$	$87.73^{d}\pm1.41$	$133.10^{d}\pm7.16$	$1.21^{b}\pm0.01$	$2.62^{ab}\pm0.14$	$0.22^{a}\pm0.00$	0.37	0.29
MB 75:25	$36.00^{a}\pm0.59$	$129.04^{a}\pm3.73$	$55.01^{a}\pm1.44$	$93.59^{c}\pm5.63$	$146.17^{b}\pm2.48$	$1.26^{a}\pm0.05$	$2.87^{a}\pm0.05$	$0.23^{a}\pm0.02$	0.38	0.28
MdBd 85:15	$33.73^{b}\pm1.51$	$122.24^{bc}\pm9.57$	$51.99^{b}\pm3.694$	$102.14^{b}\pm2.51$	$145.65^{b}+3.15$	$1.07^{c}\pm0.09$	$1.65^{e}\pm0.03$	$0.22^{a}\pm0.01$	0.51	0.28
MdBd 75:25	$36.12^{a}\pm0\ 08$	$124.78^{b}\pm0.4$	$53.64^{b}\pm0.17$	$107.19^{a}\pm0.08$	$153.11^{a}\pm0.09$	$1.10^{c}\pm0.02$	$1.73^{d}\pm0.00$	$0.23^{a}\pm0.00$	0.50	0.29

Values are presented as Mean±SE(n=2). Mean values in a column bearing similar superscripts are significantly not different($p<0.05$).M=millet, Md=decorticatedmillet, B=bambaragroundnut(BGN). Bd=decorticated BGN.

Effect of grain decortication and blend level on the Sensory attributes of millet-BGN ndaleyi tuwo

The mean score texture, aroma, taste, colour, and overall acceptability of the traditional millet-based ndaleyi tuwo was rated by the sensory panelist as having better sensory attributes than the fortified tuwo. Considering the fact that the various ndaleyi flours were given equal fermentation time as well as other processing events, such as not replacing the steeping water during fermentation, therefore the only operating variables that affect the physicochemical and sensory properties of the ndaleyi tuwo were grain decortication, blend ratio and BGN parboiling of which the later had greater influence. Additionally, lack of natural separation that usually occur at the end of fermentation between the chir (gluten) and the ndaleyi did not take place in some treated and this was responsible for the observed differences in the various ndaleyi flours or tuwo. Added BGN caused a reduction of the sensory attributes of the treated ndaleyi. Ndaleyi containing either decorticated millet or BGN possesed sensory attributes not significantly different from the traditional tuwo followed closely by ndaleyi tuwo which contained both decorticated millet and BGN which were taught to have performed more than the other treated tuwo considering the fact tuwo produced from cofermented whole millet and whole BGN had the poorest sensory attributes among the treated tuwo.Texture of traditional ndaleyi is usually soft and pliable, texture scores (7.00 8.33) were generally high, and the control had the best texture significantly not different from those with 85:15 blend ratio. Extended soaking time usually yield softer texture and added BGN reduced swelling capacity of ndaleyi flours and some of the sensory properties of ndaleyi tuwo. Intense amoniacal aroma among the 75:25 blends might be due to increase in proteins from BGN which upon extended soaking time needed to induce the separation of chir from ndaleyi which slso led to putrefaction and exudaton of intense ammonical or fermented odour which was responsible for lower aroma scores (6.0-7.73) of the treated especially the whole millet and BGN mix and by extension the tuwo aroma, although the aroma scores were not significantly different among the treated but different from the traditional tuwo, which had the highest mean aroma score (7.80), fermented aroma of ndaleyi is usually the first objection express by first timers to ndaleyi meal. Ndaleyi flours or tuwo is acidic naturally because of long steeping especially the control (100% millet ndaleyi) which had the highest taste score (8.07) because the all millet provided more carbohydrates for acid production by fermenting micro-organisms than can be provided by millet-BGN blends, therefore the taste scores (6.20-7.67) of the treated were lower and in some cases significantly not different among them. The natural colour of ndaleyi flour is off-white or cream, added BGN reduced the cream-colour of the treated, therefore the lower mean colour score of the treated (6.13-7.78). The acceptability scores (6.67-7.93) among the treated were lower, however they were all acceptable with different degrees of acceptance influenced by grain decortication and blending ratio and in most cases significantly similar with the traditional tuwo. Poorer sensory scores of the whole grain mix indirectly suggests that decortication of millet is needed to produce ndaleyi of superior sensory quality but at the expense of nutritive value.

Table: 4 Effect decortication of grain on the Sensory properties of millet-BGN ndaleyi tuwo

Sample	Texture	Aroma	Taste	Color	Overall acceptability
M(100:00)	8.33±0.72ᵃ	7.80±1.42ᵃ	8.07±1.28ᵃ	8.40±0.74ᵃ	8.47±0.64ᵃ
MBd(85:15)	7.93±1.34ᵃ	7.20±1.21ᵃᵇ	7.67±1.54ᵃᵇ	7.87±1.31ᵃ	7.93±0.79ᵃ
MBd(75:25)	7.67±1.45ᵃ	7.33±1.88ᵃᵇ	7.73±1.39ᵃᵇ	7.73±1.22ᵃ	7.80±1.08ᵃ
MdB(85:15)	7.67±2.02ᵃ	7.20±1.94ᵃᵇ	6.73±1.62ᵃ	7.47±1.06ᵃᵇ	7.53±1.13a
MdB(75:15)	7.13±1.89ᵃᵇ	6.00±1.92ᵇ	6.20±1.97ᵃᵇ	6.13±2.29ᵃᵇ	6.67±1.84ᵃᵇ
MB(85:15)	7.20±1.47ᵃᵇ	6.00±1.28ᵇ	6.20±1.97ᵃᵇ	6.13±2.29ᵇ	6.67±1.84ᵃᵇ
MB(75:25)	6.87±1.41ᵃᵇ	6.40±1.12ᵃᵇ	6.47±0.92ᵃᵇ	6.27±1.87aᵃᵇ	7.20±1.15ᵃᵇ
MdBd(85:15)	7.67±1.05ᵃ	6.67±1.67ᵇ	7.00±1.17ᵃᵇ	7.00±1.55ᵃᵇ	7.47±0.99ᵃ
MdBd(75:25)	8.00±1.36ᵃ	7.00±1.93aᵃᵇ	7.60±1.45ᵃᵇ	7.53±1.41ᵃᵇ	7.67±1.05ᵃ

Values are presented as Mean±SE(n=2). Mean values in a column bearing similar superscripts are significantly not different($p<0.05$).M=millet, Md=decorticated millet, B=bambara groundnut(BGN). Bd=decorticated BGN.

Conclusion

Long steeping period depletes the nutritive value of ndaleyi through leaching and the answer to this dilemma is fortification with one of the common pulses present in Nigeria. Therefore, ndaleyi produced from cofermented millet and BGN grains had greater nutrient density than the traditional ndaleyi. Decortication of either one or both grain did not adversely affect the mineral contents of the treated, instead they were higher than in the control. Swelling power of the treated decreased but the water absorption capacity increased as well as a slight drop in the acidity level of the treated due to starch reduction. Although the traditional tuwo had better sensory attributes but in most cases they were statistically similar with fortified ndaleyi tuwo. Ndaleyi is similar to Ohio, a starchy stuff that needs fortification because of the leaching that occurred due to extended fermentation.

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