Global Scientific JOURNALS

GSJ: Volume 11, Issue 11 November 2023, Online: ISSN 2320-9186

www.globalscientificjournal.com

RHEOLOGICAL, MICRONUTRIENTS AND MICROBIAL QUALITY OF IDLI PRODUCED FROM BLENDS OF RICE (*Oryzasativa*), AFRICAN YAM BEAN (*Sphenostylissternocarpa*) AND PIGEON PEA (*Cajanuscajan*)

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ABSTRACT: This study investigated the micronutrient and microbial qualities of idli from blends of rice, African yam bean and pigeon pea. Pigeon pea and African yam bean (AYB) whole seeds were cleaned, soaked in hot water (80 °C for 30 minutes), manually dehulled and sundried to obtain dhals. The processed dhals, black gram dhals (control) and rice were washed and soaked in water separately for 5 hours at room temperature (29 ± 2 °C). The dhals were wet-milled separately into a smooth batter, while the rice was ground to a coarse batter. The rice and dhals were blended in the ratio 2:1. One gram of common salt was added to the blended batters, mixed and allowed to ferment for 14 hr at room temperature (29 ± 2 °C). The fermented batters were placed in idli moulds with cup-like depressions and steamed for 15 minutes in idli steaming pot to obtain idli. The micronutrients and microbial qualities of the flours and idli samples were analysed using standard methods. The Calcium varied from 36.75 to 51.64 mg / 100 g, magnesium 84.21 to 156.33 mg / 100 g and vitamin B_2 0.48 to 0.89 mg / 100 g. Lactic acid bacteria count increased from 1.0 to 2.8 × 10^5 cfu/g, yeast from 1.0 to 6.0 × 10 cfu/g in the idli batters and no mould was observed in the steamed idli products. Quality idli can be produced from blends of rice, African yam bean and pigeon pea.
Keywords: Idli, African yam bean, Pigeon pea, micronutrients, microbial

Introduction: Globally, cereal-legume-based foods are important sources of affordable dietary energy and nutrients (Agrawal et al., 2000). From a nutritional perspective, it is beneficial to consume mixtures of cereals and legumes as it provides a balance in diet (Nout, 2009). One cereal grain that is crucial to human nutrition is rice, which accounts for 95% of all cereals consumed; it is primarily used at the household level, where it is boiled, ground, fried, and eaten with soup or stew. While rice is rich in cysteine and methionine, it lacks some essential amino acids, such as lysine, and is therefore not able to provide all the nutrients required for adequate nutrition (Oko and Ugwu, 2011).To attain a better nutritional balance, these components are used in many traditional recipes around the world (FAO, 2002). Put another way, rice has been mixed with various legumes to create rice-based dishes like idli, dhokla, masa, and dosa, among others (Nkama et al., 2011). Among the dishes made from cereals and legumes, "idli," a fermented steamed product, is a native dish of Sri Lanka and India that is eaten for breakfast and dinner three to four times a week (Manickavasagan et al., 2013). Because of its nutritional value, spongy texture, look, mouthfeel, flavor, and aroma, it is favored by many people worldwide (Iyer andAnanthanayan, 2008). Both adults and children typically eat idli with sides like chutney and sambar (Sharavathy et al., 2001).

Black gram (Phaseolusmungo), a legume, and rice (Oryzasativa), a cereal, are traditionally used to make idli (Gosh and Chattopadhyay, 2011). Since idli is an auto-fermented food, fermentation usually occurs without the addition of an inoculum. This is due to the fact that it has been discovered that the ingredients naturally contain the necessary microorganisms, such as lactic acid bacteria (mainly *Leuconostocmesenteroides, Lactobacillus delbrueckii, Streptococcus faecalis, and Pediococuscerivisiae*) and yeast (*Pichiasilvicola*and *Saccharomyces cerevisiae*) (Nagarjuna and Manohar, 2000). There haven't been many studies done on substituting African yam bean and pigeon pea for black grams to determine its micronutrients quality. Thus, it's necessary to look for easily accessible, high-quality protein sources like pigeon pea and African yam beans, rich in micronutrients.

Ene-obong (1995) claims that the African yam bean, sometimes referred to as ijiriji or okpodudu in south-eastern Nigeria, is an underutilized legume that is not commonly consumed in Nigeria. It is well recognized for having high protein content and for including the majority of the necessary amino acids, including leucine and lysine. Conversely, pigeon peas, also known as fio-fio, agbugbu, or otile (Enwere, 1998), are an excellent source of proteins, minerals, vitamins, and carbs.It lacks the sulfur-containing amino acids cystine and methionine, although it is abundant in lysine. It is combined and consumed with vegetables, oil, salt, and pepper, as well as maize (Ayaraya) and dry cocoyam grits (achicha). However, because they are inexpensive locally and underutilized grain legumes in Nigeria (Azeke et al., 2005), pulses like African yam bean (Sphenostylisstenocarpa) and Pigeon pea (Cajanuscajan) can be used in place of black gram when making idli because of their high nutritional value, which includes protein, carbohydrates, vitamins, and minerals.

Thus, this research aims to enhance the nutritional value of rice proteins by utilizing and complementing less expensive and more accessible plant sources, such as pigeon pea and African yam bean, in place of black gram.This study's primary goal was to create and ascertain the rheological, micronutrient and microbiological compositions of idlis made from blends of pigeon pea (*Cajanuscajan*), African yam bean (*Sphenostylisstenocarpa*), and rice (*Oryzasativa*).

Materials and Methods

Sources of raw materials: The African yam bean grains and whole pigeon pea were purchased from the Ogige market in Nsukka, Enugu State. The black gram (dhals) was bought at Roban stores in Enugu State, Nigeria, while the rice (Faro 44, Faro 52A, and Faro 52B) was obtained from Abakiliki, Nigeria.

Preparation of pigeon pea and African yam bean (AYB) dhals: African yam bean and pigeon pea whole grains were cleaned and separated then weighed using an Ohauz Adventurer Corporation Model AR2130 and then washed. For half an hour, the seeds of African yam and pigeon pea were immersed in hot water at 80 degrees Celsius. The hulls were then manually removed using a motar and pestle to produce dhals. The dhals were kept in airtight receptacles after being sun-dried. Figure 1 displays the flow chart for preparing African yam bean (AYB) and pigeon peas into dhals.

Preparation of idli: Rice/black gram (control), rice/African yam bean, and rice/pigeon pea dhals were all used to make idlis. The ratio for each was 2:1, meaning that 200 g of rice was used for every 100 g of grain legume. The codes for Faro 44, 52A, and 52B were R1, R2, and R3. After washing the rice to remove any remaining dirt or dust particles, the processed dhals and rice were weighed using an Ohauz Adventurer Corporation Model AR2130. The rice was then soaked in 300 ml of water, while the grain legumes were soaked in 150 ml of water separately. This process was carried out for five hours at room temperature (29 ± 1 °C).

Pigeon pea seeds/African yam bean seeds
↓
Cleaning/sorting
↓
Weighing
↓
Washing
↓
Soaking in hot water (at 80°C for 30 mins)
↓
Dehulling
↓
Sun drying
↓
Dhals

Figure 1: Processing of pigeon pea and African yam bean seeds into dhals.(Fasoyiro*et al*. 2010)

Using a home blender, the rice, black gram, African yam bean, and pigeon pea dhals were ground individually while maintaining hygienic conditions. Water was added to the rice and dhals during milling, ranging from 1.5 to 2.2 times their initial dry weight. The dhals were ground into a finely smooth batter and the rice into a coarse batter. The coarsely ground rice batter was combined with every grain legume. After adding one gram of common salt to each batter, the mixture was combined. The batters were left in a covered bowl at room temperature (29 ± 1 ºC) for 14 hours to ferment. Both before and after fermentation, the pH, titratable acidity, and rise in batter volume were determined.After greasing the idli pans and moulds, an equal volume of batter samples were collected, stacked one on top of the other, and steam-cooked for seven to fifteen minutes in an idli pot. Figure 2 displays the idli production flow chart.

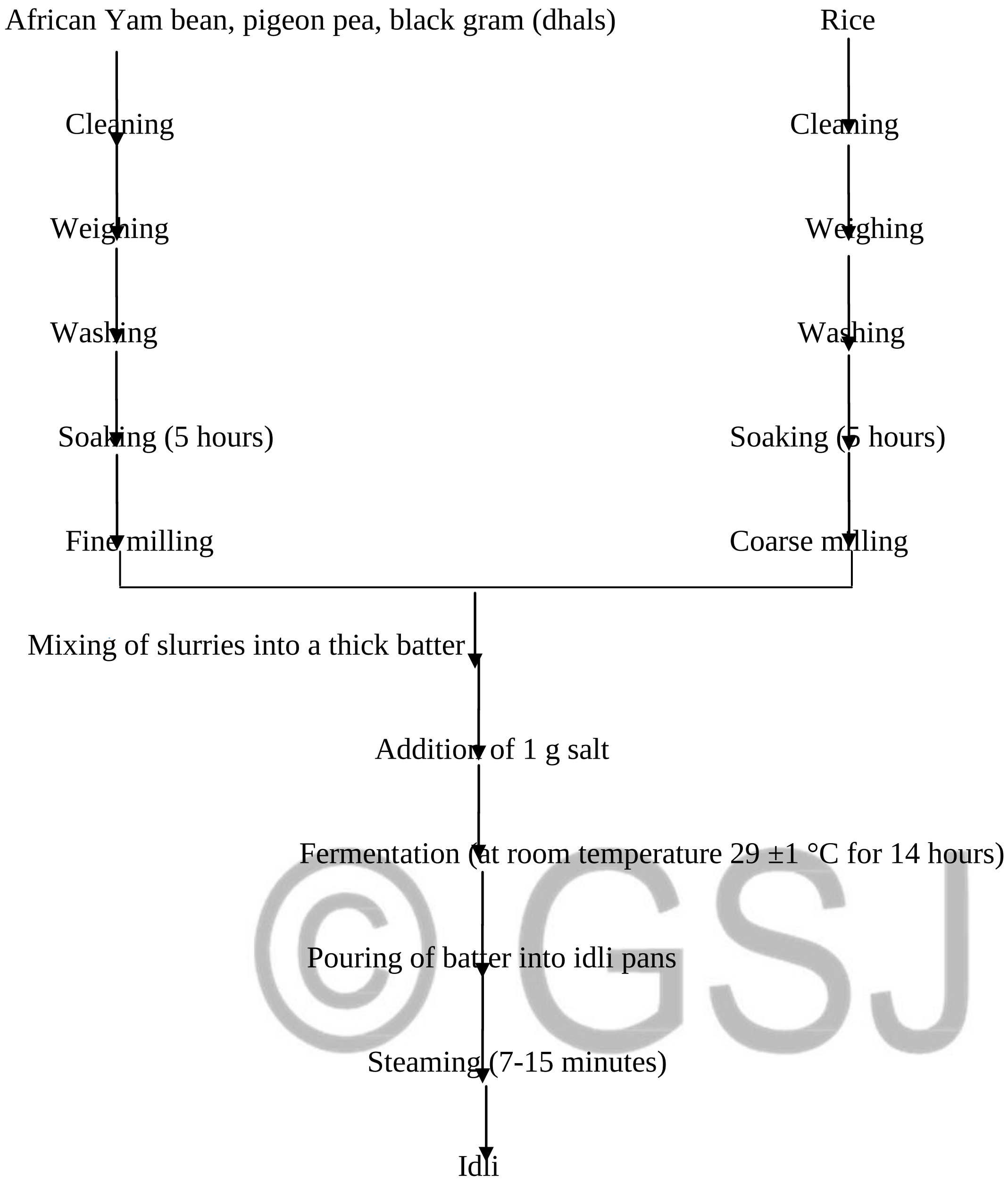

Figure 2: Production of African yam bean, pigeon pea, and black gram idlis

Source: Steinkraus (1988)

Description of idli steaming pot

The idli pot was created and modified based on the standard idli pot, which has four molds with cup-shaped depressions placed one on top of the other and resembles a pot with a perforated cylindrical base. Idli batter is typically poured into the cup-shaped depressions in the idli pot and left to steam for around fifteen minutes. During this time, steam passes through the perforations in the cylindrical base of the idli pot, steaming the idli. In figure 3, the idli steaming pot is displayed.

Figure 3: Idli steaming pot with mould pans stacked above the other.

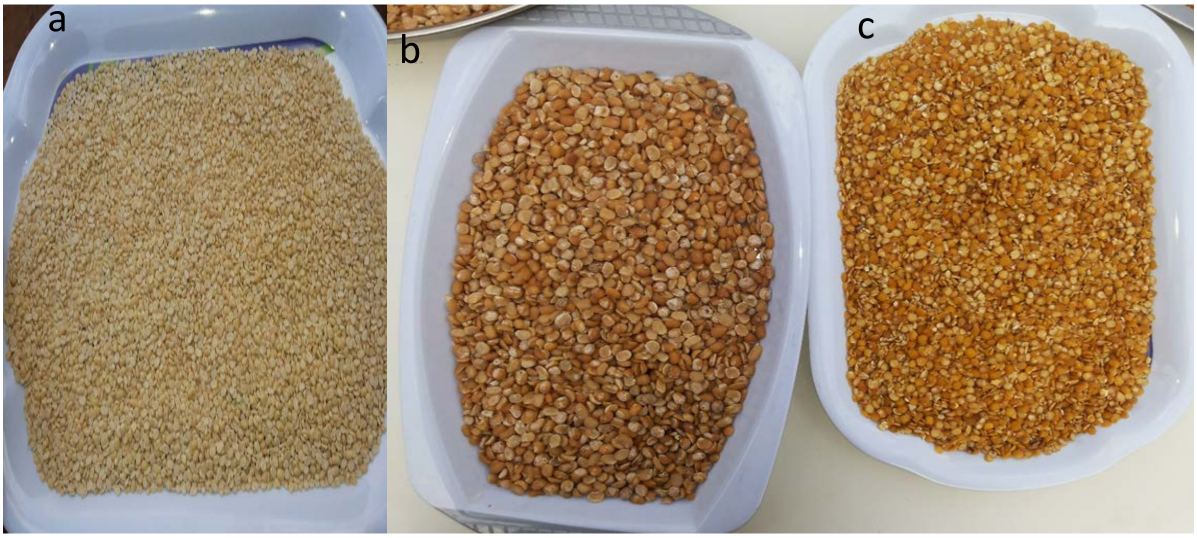

Figure 4: (a)Processed Black gram, (b)African yam bean and (c)Pigeon pea dhals.

Figure 5: Developedblackgram idlis

Figure 6: Coded samples ofAfrican yam bean, pigeon pea and black gram idlis.

Figure 7: DevelopedIdli samples with accompaniment.

Viscosity:A Ferranti Portable Viscometer, type VH, as detailed in Davies, was used for this (1956). High viscosities with the inner cylinder combination are appropriate for the Model VH. In order to guarantee that the location spring rests flat on the shaft's side, the outer cylinder was installed. To lock the inner spindle and insert the guard ring up the inside of the outer cylinder and press it firmly home, turn the knurled knob to the left of the handle in a clockwise direction. The inner cylinder was selected because it was the right size to accommodate the necessary viscosity ranges. When the inner spindle pin was situated on its restraining slot, the inner cylinder was gradually rotated while keeping a light upward after the spindle was placed inside the guard ring.After that, the cylinder was forced home until the retaining spring was engaged by the ball end. After unlocking the inner spindle, 200 milliliters of the test sample batter were poured into the cylinders for immersion. With the liquid barely covering the top of the outer cylinder, determinations were made. There were five distinct gear speeds used, ranging from 1 to 5. They engaged their respective gears. The motor was not stopped while the gears were changed to make the charting of the flow curves easier. Viscosity in poises was calculated at a specific speed and cylinder combination by multiplying the instrument measurement by the suitable multiplier indicated on the calibration chart, as the following equation shows.

$$\mu = IM \text{ ---(1)}$$

where μ is viscosity, I is instrument reading and M is multiplying factor.

Shear stress and shear rate: This was measured using the Universal Testing Machine and the Halek and Paik (1989) technique. A moving probe was positioned between a stationary plate and the 200 ml batter. Stress and shear rate were measured while it was being squeezed. Shear stress in poises/sec at a specific speed and cylinder combination was calculated by multiplying viscosity μ by the relevant shear rate indicated on the instrument's calibration chart, as shown below:

$$\tau = \mu \, {}^{du}/_{dy} \text{ ----------------------------------(2)}$$

Where; τ is shear stress, μ is viscosity and ${}^{du}/_{dy}$is shear rate.

Mineral Contents: We assessed the mineral content of the prepared samples by applying the technique outlined by Adedeye and Adewoke (1992). Each sample was digested using one gram and 2.5 millilitersof 0.03 N hydrochloric acid (HCl). After letting the digest cool to room temperature after five minutes of boiling, it was transferred to a 50 ml volumetric flask and diluted water was added to make up the difference. Whatman No. 1 ashless filter paper was used to filter the final digest. Using an atomic absorption spectrophotometer, the mineral contents of each sample's filtrates (calcium, magnesium, zinc, iron, and phosphorus) were determined. The findings were given as (mg/100g).

Vitamin contents

Thiamin (vitamin B_1): The procedure outlined by AOAC (2010) was followed. 50 milliliters (ml) of distilled water were used to macerate one gram (g) of the sample for five minutes. Then, 2 milliliters of reagents (9% potassium ferricyanide and 10% sodium hydroxide) were added to the filtrate. After one minute, 15 milliliters of isobyte alcohol were added, and the mixture was shaken vigorously for two minutes. The isobyte layer was then collected and dried using a spatula made of anhydrous sodium.

Riboflavin (vitamin B_2): The AOAC (2010) was utilized to ascertain this. After an hour, 5 g of the sample were used to extract the sample extract using 100 ml of ethanol. After adding ten milliliters (10 ml) of potassium permanganate (5 percent) and ten milliliters (10 ml) of hydrogen peroxide (30 percent), the filtered extract was placed in a hot water bath and left for thirty minutes. Two milliliters of 40% sodium sulfate were added to this. The absorbance was measured at 510 nm and the volume was increased to 50 ml.

Niacin (vitamin B_3): The AOAC (2010) was utilized to ascertain this. Three drops of ammonia solution were added to five grams of the sample, which was then treated with fifty milliliters of 1N sulfuric acid and shaken for thirty minutes. The material was then filtered into a fifty milliliter volumetric flask and five milliliters of potassium cyanide were added. This was acidified using five millilitersof 0.02 N sulfuric acid, and the absorbance was measured at 470 nm using a spectrophotometer. A diluted standard niacin solution was made. The solution in ten milliliters was examined. Reagent blank was used to take readings at zero. We'll use the formula below.

$$\text{Niacin (mg/100g)} = \frac{100}{W} \times \frac{AU}{AC} \times C\frac{V_f}{V_a} \times D \text{----------------------------------} (13)$$

Where;

W = Weight of sample analysed, Au = Absorbance of the test sample, As = Absorbance of standard solution, V_f = Total volume of filtrate, V_a = Volume of filtrate analysed

C = Concentration of the standard, D = Dilution factor where application

Microbial Analysis

Total viable count: The procedures outlined by Prescott et al. (2005) were used for this. After the idli samples were crushed in a mortar, 1g was weighed into a test tube that had been sanitized. The test tube was filled with nine (9 ml) of 1/4 strength ringer solution, and it was completely mixed by shaking. The sample solution was then added to the test tube and shaken. Next, 1 ml was pipetted into the second test tube, which held 9 ml of the ringer's solution. Finally, 1 ml of the solution was added to the third test tube, and the serial dilution process was carried out until the last test tube.Subsequently, 0.1 ml of each test tube's contents was transferred to the matching plate, and 15 ml of sterile nutritional agar medium was added. The plates were then rocked to ensure full mixing. Following a 24-hour incubation period at 37 oC with the plates turned upside down, the colonies that developed were tallied and expressed as colony forming units per gram. When possible, the morphological characteristics on the agar plate were used to make a rough identification.

Mould/yeast count: As stated by Prescott et al. (2005), this was carried out. Potato dextrose agar (PDA) was used to cultivate the molds and yeast. A sterile 250 ml flat bottom flask containing 65 g of potato dextrose agar was sterilized in an autoclave set at 15 pressure and 121 °C for 20 minutes. The flask was then allowed to cool in a desiccator. The potato dextrose agar was dissolved in a liter of distilled water. It was transferred into sterilized petri plates and left to cool to room temperature before solidifying. Ringer's tablet was dissolved in 500 milliliters of water in a 500 milliliter flask for the serial dilution 1/4 strength. The flask was then sealed with aluminum foil and cotton wool and autoclaved for 15 minutes at 121 oC with the PDA. For the test, serial dilutions were prepared.

Five sterile test tubes were filled with nine (9 ml) diluents each, and the diluent bottles were sealed with aluminum foil and cotton wool. Next, 2 g of the samples were combined with 1 ml of Ringer's solution in the diluent bottles. Subsequently, 1 milliliter of the sample solution was moved to test tubes 2 and 3, and the process of serial dilution was carried out until the final test tube. Next, 1 cc was extracted from every test tube, transferred into petri dishes along with a little amount of PDA, and vigorously shaken to ensure the bottom was covered. For 48 hours at 30 oC, the petri dishes were incubated upside down.Each plate's colonies of mold and yeast were counted and their numbers were converted to colony forming units (Cfu) per gram of material.

Cfu/g = number of colonies× dilution factor ---(14)

Statistical Analysis: The completely randomized design (CRD) was used. The data generated were analysed using a one-way analysis of variance (ANOVA) using SPSS (Statistical Package for Social Sciences) software version 20 computer program. Mean separation was by Duncan's New Multiple Range test. Significance was accepted at $p < 0.05$.

Experimental Design: The legume dhals (African yam bean, pigeon pea and black gram), were divided into 3 parts each was blended with three different varieties of rice Faro 44, 52A and 52B. The cereal and legume were in the ratio of 2:1. The analysis was carried out according to the experimental layout below.

Table 1: Design of Experiment for Blends of Different Rice Cultivars, Pigeon pea, African yam bean and Black gram.

Cereal (Rice)	Legumes (dhals)	Blend ratio (g)	Sample code
Faro 44(R1)	African yam bean	200:100	AR1
	Pigeon pea	200:100	PR1
	Black gram	200:100	BR1
Faro 52A(R2)	African yam bean	200:100	AR2
	Pigeon pea	200:100	PR2
	Black gram	200:100	BR2
Faro 52B(R3)	African yam bean	200:100	AR3
	Pigeon pea	200:100	PR3
	Black gram	200:100	BR3

Micronutrient Compositions of Rice, Pigeon pea, African yam bean, Black gram Flours

Table 2 displays the results of the micronutrient analysis of flours derived from several rice cultivars, black gram, pigeon pea, and African yam bean. The flours ranged in phosphorus concentration from 36.71 to 375.96 mg/100g. Faro 51A had the lowest amount (36.71 mg/100g), whereas Black gram flour had the greatest value (375.96 mg/100g). Varietal variances may be the cause of these variations in phosphorus concentration. The African yam bean value obtained also agreed with the findings of Oshodi et al. (1997). Phosphorus, which pairs with calcium in many of its functions, is the most ubiquitous mineral in the body after calcium (Oyarekwua, 2011). In plant cells, magnesium is the most prevalent ion. The magnesium concentration of the flours varied significantly ($p < 0.05$), ranging from 65.84 to 247.04 mg/100g. The black gram flour has the highest magnesium level (247.04 mg/100g), as would be predicted, while rice flour has the lowest magnesium content. The raw ingredients could be the cause of these variations. The magnesium concentration of the rice flours showed good agreement with the values found by Oyewole and Ebuehi (2007). The body's more than 300 enzyme systems require magnesium.

Table 2: Micronutrient Compositions of Rice, Pigeon pea, African yam bean & Black gram Flours

Micronutrients	Faro 44	Faro 52A	Faro 52B	PPF	AYBF	BGF
Phosphorus (mg/100g)	$54.52^{b}\pm0.22$	$36.71^{a}\pm0.01$	$36.76^{a}\pm0.06$	$228.00^{c}\pm0.07$	$241.83^{d}\pm0.34$	$375.96^{e}\pm2.63$
Magnesium (mg/100g)	$65.84^{a}\pm0.02$	$68.29^{b}\pm0.06$	$70.76^{c}\pm0.12$	$135.29^{e}\pm0.24$	$112.40^{d}\pm0.20$	$247.04^{f}\pm0.18$
Calcium (mg/100g)	$53.00^{c}\pm0.15$	$51.16^{b}\pm0.07$	$40.48^{a}\pm0.61$	$86.50^{e}\pm0.11$	$63.00^{d}\pm1.00$	$130.50^{f}\pm0.20$
Zinc (mg/100g)	$0.63^{a}\pm0.50$	$0.62^{a}\pm0.01$	$1.20^{a}\pm0.17$	$3.42^{b}\pm0.02$	$4.16^{b}\pm0.01$	$2.76^{b}\pm1.97$
Iron (mg/100g)	$10.36^{c}\pm0.04$	$5.16^{b}\pm0.30$	$5.54^{b}\pm0.10$	$3.60^{a}\pm0.05$	$2.88^{a}\pm0.40$	$2.33^{a}\pm1.59$
Vitamin B_1	$1.00^{a}\pm0.30$	$2.33^{b}\pm0.49$	$1.00^{a}\pm0.02$	$2.02^{b}\pm0.04$	$2.00^{b}\pm0.01$	$1.54^{ab}\pm0.90$

(mg/100g)						
Vitamin B_2 (mg/100g)	1.16^{a}±0.05	1.53^{ab}±0.02	1.24^{a}±0.01	2.26^{b}±0.03	2.13^{b}±0.02	1.60^{ab}±0.96
Vitamin B_3 (mg/100g)	0.22^{a}±0.01	0.48^{b}±0.04	0.48^{b}±0.01	0.23^{a}±0.02	0.22^{a}±0.06	0.50^{b}±0.01

Values are means ± SD (n = 3). Samples with the same superscript in a row are not significantly different ($p > 0.05$).

PPF = pigeon pea flour, AYBF = African yam bean flour, BGF = black gram flour

It plays a crucial role in nerve and muscle function, the synthesis of adenosine triphosphate, and the storage of carbs, lipids, and proteins. The human body is capable of storing magnesium (Oyarekwua, 2011).

The calcium content of the flours varied between 40.48 and 130.50 mg/100g and was significantly ($p < 0.05$) different from one another. Black gram flour has the highest calcium level (130.50 mg/100g), while Faro 52B had the lowest. Arawande and Borokini (2010) observed that the calcium content of pigeon peas was 86.50 mg/100g, which was greater than the figure of 65.00 mg/100g. Black gram's calcium content and Kavitha et al.(2013) calcium content showed good comparisons. According to Balasubramanian and Viswanathan (2007), black grams have higher calcium and magnesium concentrations than several other pulses, including lentils, chickpeas, greengrams, pigeonpeas, and peas. A calcium deficit can cause rickets in children and newborns because calcium is necessary for the production of teeth and bones.

The flours' zinc contents varied from 0.62 to 4.16 mg/100g. African yam bean flour had the highest zinc content (4.16 mg/100g), while rice samples had the lowest zinc content (0.62 mg/100g, identified in Faro 52A). Varietal variations could be the cause of these discrepancies. The results obtained for the legumes were found to be lower than the 10 mg/100g necessary from supplementary foods for older infants and young children, but comparable with British guidelines (4.7 mg/100g) required for complementary foods for 11 to 23 months based on daily consumption (WHO/NUT/98). In chronically malnourished newborns, zinc is a limiting factor in their growth, particularly in underdeveloped nations whose diets are high in phytates and low in animal proteins. Therefore, a zinc shortage may have a detrimental effect on an infant's behavioral development. Diarrhea may also be a cause of zinc loss (WHO/NUT/98).

Between 2.33 to 10.36 mg/100g, the iron content of the flours varied considerably (p 0.05) between samples.Black gram flour had the lowest amount (2.33 mg/100g) and faro 44 had the greatest value (10.36 mg/100g). Between the flours made from African yam beans and pigeon peas, and black gram flour, there was no discernible difference ($p > 0.05$). Varietal variations may be the cause of these variations.

The flour samples' thiamine contents ranged from 1.00 to 2.33 mg/100g. Vitamin B1 values ranged from 1..00 mg/100g in Faro 44 and 52B rice flours to 2.33 mg/100g in Faro 52A rice flour, with pigeon pea coming in second at 2.02 mg/100g. Varietal variations could be the cause of these discrepancies.

The flours had riboflavin contents ranging from 1.16 to 2.26 mg/100g.With 2.26 mg/100g, pigeon pea flour had the highest value, and Faro 44 rice had the lowest, at 1.16 mg/100g. Varietal variations and processing methods could be to blame for this.

The flours' niacin concentration ranged from 0.22 to 0.50 mg/100g. Black gram flour had the highest niacin content (0.50 mg/100g), whereas African yam beans and Faro 44 had the lowest (0.22 mg/100g). Varietal variations and leaching could be the cause of these low niacin amounts. The value found for black gram flour was less than what Singh et al. (1968) found.

Micronutrient Composition of Idlis from Blends of Different Rice Cultivars, Pigeon pea, African yam bean and Black gram

Table 3 displays the micronutrient makeup of fresh idlis manufactured from mixes of African yam bean, black gram, pigeon pea, and several rice cultivars. Idlis varies in phosphorus content from 30.58 to 51.97 mg/100g. The control idlis, BR3 (51.68 mg/100g) and BR2 (51.97 mg/100g), had the greatest phosphorus values, whereas the pigeon pea idli, PR3, had the lowest (30.58 mg/100g). There were noticeable differences ($p < 0.05$).

Table 3: Micronutrient Composition of Idlis from Blends of Different Rice Cultivars, Pigeon pea, African yam bean and Black gram

Micronutrients	AR1	BR1	PR1	AR2	BR2	PR2	AR3
Phosphorus (mg/100g)	32.68^{c}±0.24	45.18^{f}±0.23	36.20^{d}±0.14	36.10^{d}±0.04	51.97^{h}±0.03	31.44^{b}±0.08	37.07^{e}±0.09
Magnesium (mg/100g)	84.21^{b}±0.04	132.39^{f}±0.00	120.21^{e}±0.05	108.29^{c}±0.03	156.29^{g}±0.02	114.36^{d}±0.02	78.62^{a}±0.20
Calcium (mg/100g)	46.78^{c}±0.04	50.13^{e}±0.17	51.64^{d}±0.82	36.75^{a}±0.01	46.70^{c}±0.07	46.73^{c}±0.06	45.45^{b}±0.30
Zinc (mg/100g)	2.59^{b}±0.65	3.56^{ef}±0.05	2.75^{bc}±0.02	3.05^{cd}±0.02	3.25d^{e}±0.01	2.44^{b}±0.35	3.75^{f}±0.01
Iron (mg/100g)	0.76^{a}±0.03	1.14^{b}±0.01	0.90^{ab}±0.01	1.14^{d}±0.02	0.91^{ab}±0.02	1.00^{ab}±0.55	0.84^{ab}±0.05

$VitaminB_1$ (mg/100g)	$0.29^{a}\pm0.10$	$0.41^{abc}\pm0.00$	$0.44^{abc}\pm0.09$	$0.41^{abc}\pm0.10$	$0.53^{d}\pm0.03$	$0.34^{ab}\pm0.02$	$0.35^{abc}\pm0.04$
$VitaminB_2$ (mg/100g)	$0.51^{a}\pm0.16$	$0.59^{a}\pm0.20$	$0.57^{a}\pm0.04$	$0.89^{a}\pm0.63$	$0.53^{a}\pm0.01$	$0.48^{a}\pm0.01$	$0.62^{a}\pm0.03$
$VitaminB_3$ (mg/100g)	$0.13^{a}\pm0.02$	$0.75^{b}\pm0.50$	$0.27^{a}\pm0.03$	$0.18^{a}\pm0.10$	$0.22^{a}\pm0.02$	$0.25^{a}\pm0.15$	$0.28^{a}\pm0.04$

Values are means ± SD (n = 3). Samples with the same superscript in a row are not significantly different ($p > 0.05$). AR1=African yam bean/Faro 44, BR1=black gram/Faro 44, PR1=pigeon pea/Faro 44, AR2= African yam bean/Faro 52A, BR2=black gram/Faro 52A, PR2=pigeon pea/Faro 52A, AR3=African yam bean/Faro 52B, BR3=black gram/Faro 52B, PR3=pigeon pea/Faro 52B.

This might be explained by the possibility that leaching happened during the steaming process, as well as the fact that pigeon pea flour had the lowest phosphorus level of all the legume flours. In an experiment, Sheela and Kowsalya (2013) discovered that fermentation affected the amount of phosphorus in idli, resulting in a 2 mg decrease that was likely caused by phytate breakdown.

Between 78.62 to 156.33 mg/100g, the magnesium content of the idli samples varied substantially ($p < 0.05$). The African yam bean idli AR3 had the lowest amount of magnesium (78.62 mg/100g), whereas the control idlis had the greatest values, with BR3 (156.33 mg/100g), BR2 (156.29 mg/100g), and BR1 (132.39 mg/100g), respectively.This might be the outcome of Balasubramanian and Viswanathan(2007) discovery that black gram has the highest magnesium concentrations among other pulses. Leaching, processing steps, and water dilution may be the source of the African yam bean idlis's lower values.

The idlis's calcium content varied from 36.75 to 50.29 mg/100g. The calcium value for pigeon pea idli (PR1) was 51.64 mg/100g, which was the highest. There were noticeable differences ($p < 0.05$). Varietal variations and high moisture levels could be the cause of this. This result exceeded the figure of 26.76 mg/100g that Nazni and Shalini (2010) found for normal idli.The values of 46.73 mg/100g for the control idli by Hotkar et al. (2015) were well compared with the calcium contents of the newly formulated idlis, AR1, PR2, PR3, and AR3, as well as the control BR2. With 36.75 mg/100g, calcium was discovered to be listed in AR3 idli. This result compared favorably with the one that Nazni and Shalini (2010) found for sorghum idli, which was 31.79 mg/100 g. According to Macrae (1993), a low calcium diet increases the risk of osteoporosis. Calcium also aids in the development of healthy bones and teeth.

The idli samples' zinc levels ranged from 0.26 to 3.75 mg/100g. When it came to zinc content, the control idli (BR3) and AR3 had the greatest values (3.73 mg/100g), whereas PR3 had the lowest (0.26 mg/100g).Differences in the leaching effect could be the cause of these discrepancies in zinc content. Normal growth and development in childhood, adolescence, and pregnancy require zinc. According to Wardlaw and Kessel (2002), it is also necessary for the immune system, healing, and taste perception.

The idli samples had iron concentrations ranging from 0.65 to 1.14 mg/100g. PR3 had the lowest iron content value (0.65 mg/100g), while the control (BR1) and African yam bean (AR2) idlis had the greatest iron content value (1.14 mg/100g), and were found to be equivalent with the value obtained for regular idli (1.16 mg/100g) by Nazni and Shalini (2010).The low iron content readings may be the result of heat degradation and leaching. Among other things, iron is crucial for the production of hemoglobin, body construction, metabolism, and immunity (Wardlaw and Kessel, 2002).

The formulated idlis's vitamin B1 (thiamine) concentrations varied significantly ($p < 0.05$), ranging from 0.29 to 0.53 mg/100g. The control idli (BR2) had the greatest value (0.53 mg/100g), followed by the pigeon pea idli/Faro 52B (PR3), which had a value of 0.50 mg/100g, and AR1, which had the lowest value (0.29 mg/100g). Thiamine's water solubility and heat sensitivity, particularly during steaming, may be the cause of this lower thiamine value.According to Padmashree et al. (2014), the unfermented idli batter's vitamin B1 concentration was measured at 0.24 mg/100 g. He reported that the B1 level had grown to 0.44 mg/100g after 18 hours of fermentation. Their research revealed a significant rise in B1 and B2 contents, which are in line with the findings of Ghosh and Chattopadhyay (2011). The low amount of vitamin B1 in these samples may have resulted from the considerable loss of vitamin B1, which is most heat labile, as noted by Padmashree et al. (2014) after steaming for 15 minutes. Thiamine is essential for the nerve tissues' ability to metabolize carbohydrates. According to Wardlaw and Kessel (2002), the recommended daily intake of thiamine from diet falls between 1.2 and 1.5 mg.

The idli samples' riboflavin (vitamin B2) concentrations varied from 0.48 to 0.89 mg/100g. The African yam bean idli (AR2) had the highest value (0.89 mg/100g), while the pigeon pea idli (PR2) had the lowest value (0.48 mg/100g). After processing, the riboflavin concentration of the idli samples decreased. The B complex vitamins are susceptible to depletion during processing due to their water solubility and heat susceptibility. Ihekoronye and Ngoddy (1985) state that leaching, oxidation of water-soluble nutrients, and thermal degradation are the causes of nutrient losses during steam blanching. According to Padmashree et al. (2014), after fermentation and steaming, the vitamin B2 concentrations of the unfermented batter were 0.26 mg/100 g and 0.30 mg/100 g, respectively. This indicates that the newly prepared idli samples had a greater vitamin B2 content than the declared value of 0.30. According to Wardlaw and Kessel (2002), riboflavin helps produce and grow red blood cells while also protecting the skin, eyes, and nervous system.

The prepared idli samples varied considerably ($p < 0.05$) in their vitamin B3 (niacin) content, ranging from 0.13 to 0.75 mg/100g. AR1 had the lowest value at 0.13 mg/100g, while BR1, the control idli, had the highest value at 0.75 mg/100g. The potential cause of these low niacin values could be the heat degradation of the vitamins.

Microbiological Analysis of Idli batters after 14 hours of natural fermentation and Developed Idlis from Blends of Different Rice Cultivars, Pigeon pea, African yam bean and Black gram

Table 4 displays the microbiological analysis of idli batters during a 14-hour natural fermentation period and developed idlis manufactured from mixtures of black gram, pigeon pea, African yam bean, and various rice kinds. Idli is a food that ferments naturally; typically, no inoculum is required to promote fermentation. This is because it has been discovered that the ingredients contain the necessary microbes. Following a natural fermentation period of 14 hours, the fermented idli batters exhibited lactic acid bacteria counts ranging from 1.0 to 2.8× 105 cfu/g.

Table 4: Microbiological Analysis of Idli Batters after 14 hours of Natural Fermentation and Developed Idlis from Blends of Different Rice Varieties, Pigeon pea, African yam bean and Black gram

Samples	Batters		Idli Products	
	Lactic acid bacteria Count (cfu/g)	Yeast/Mould count (cfu/g)	Total viable count (cfu/g)	Yeast/Mould count (cfu/g)
AR1	1.4×10^5	4.0× 10	2.0×10^5	ND
BR1	2.3×10^5	5.0× 10	2.5×10^5	ND
PR1	2.6×10^5	3.0× 10	2.8×10^5	ND
AR2	1.0×10^5	3.0× 10	1.0×10^5	ND
BR2	1.8×10^5	6.0× 10	2.3×10^5	ND
PR2	2.7×10^5	1.0× 10	2.8×10^5	ND
AR3	2.8×10^5	3.0× 10	2.9×10^5	ND
BR3	1.0×10^5	2.0× 10	8.7×10^5	ND
PR3	1.1×10^5	1.0× 10	1.9×10^5	ND

Values are means ± SD (n = 3). Samples with the same superscript in a row are not significantly different (p> 0.05). AR1=African yam bean/Faro 44, BR1=black gram/Faro 44, PR1=pigeon pea/Faro 44, AR2= African yam bean/Faro 52A, BR2=black gram/Faro 52A, PR2=pigeon pea/Faro 52A, AR3=African yam bean/Faro 52B, BR3=black gram/Faro 52B, PR3=pigeon pea/Faro 52B. ND=Not Detected

The lactic acid bacteria count increased significantly in the batter enriched with AYB/Faro 52B (AR3), while the lactic acid bacteria counts of the pigeon-pea idli batters PR2 and PR1 were determined to be 2.6 and 2.8 × 105 cfu/g, respectively. In comparison to the control idlis, it was discovered that the newly formulated idlis included a higher quantity of lactic acid bacteria. The microorganisms found in African yam bean seeds during their natural fermentation were described by Adewale et al. (2012). Thus, it was discovered that lactic acid bacteria were present when the idli batters fermented. Leuconostocmesenteroids and Enterococusfaecalis are the LAB that are reportedly necessary for the batter's leavening and acid generation during the fermentation of idli batter (Mukherjee et al., 1965). Following the fermentation process, there were more lactic acid bacteria than yeasts in the batter. As a result, the batters' yeast development was inhibited by the presence of LAB. After 14 hours of natural fermentation, the quantity of yeasts/mould in the batter ranged from 1.0 6 to 6.0 ×10 cfu/g. They were found to be lowest in Pigeon pea idlis pigeon pea Faro 52A (PR2) and 52B (PR3), having 1.0 × 10 cfu/g, and greatest in control idlis black gram/Faro 44 (BR1) by 5.0 × 10 cfu/g and 52A (BR2) by 6.0 × 10 cfu/g.

A maximum quantity of microorganisms for fermentation is also provided by black gram (Ghosh and Chattopadhyay, 2011). The control idli black gram/Faro 52B (AR3) had the greatest population of total viable counts (8.7 × 105 cfu/g). The total viable count in the finished product (idli) ranged from 1.0 to 8.7 × 105 cfu/g. African yam bean/Faro 52A (AR2) idli had the lowest amount of TVC, with a microbial population of 1.0 × 105cfu/g. The quantity of microbial loads present throughout the idli batters' fermentation process may be the source of this high TVC population. Additionally, a high TVC in the produced idli indicated the heat resistance of some of the microorganisms.Upon completion, the steamed idli products showed no signs of mold growth. The idli products are therefore considered safe to eat microbiologically, falling within permitted bounds and not resulting in any health issues or food poisoning.

Rheological Properties of Fermented Idli Batters from Blends of Different Rice Cultivars, Pigeon pea, African yam bean and Black gram.

Figure 8 shows the outcomes of the viscosities, shear stress, and shear rates of idli batters prepared from mixtures of several rice kinds, pigeon pea, African yam bean, and black gram. The viscosity values are in the appendix. Figure 8 shows that the viscosities of the idli samples fell from gear 1 to gear 5, and that the gear speed is inversely proportional to the multiplication factors and directly related to the instrument reading.Both the shear rate and the shear stress were found to increase as the gear speed increased; however, the shear stress reading for the control samples was found to be higher and to increase in line with the gear speed increase, while the shear rate reading remained constant for all samples. It was discovered that the freshly formulated idlis AR1, PR1, AR2, PR2, AR3, and PR3 had significantly lower viscosities than the control idlis BR1, BR2, and BR3.This could be explained by the fact that the main ingredient in control idli, black gram, contains ingredients that give it these qualities. According to Koh and Singh (2009), black gram fermentation results in an increase in the apparent viscosity of the cold paste, while mucilaginous polysaccharide composition and rheological changes occur during the fermentation process, which is necessary for the production of leavened meals. It was found that pigeon pea has the lowest viscosities.

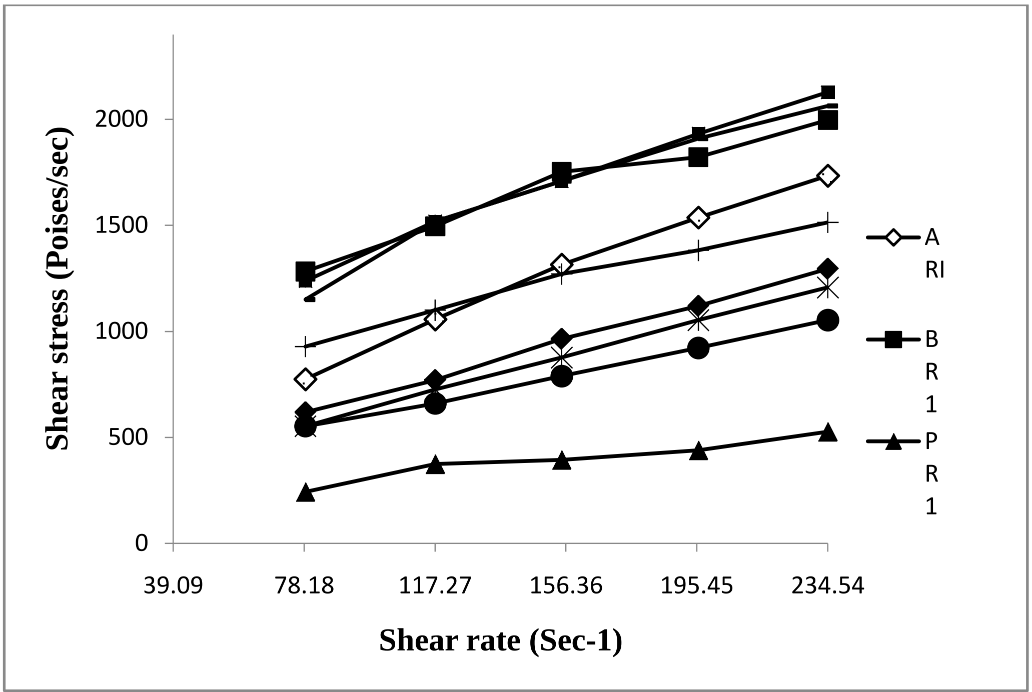

Figure 8. Viscosity of fermented idli batters from different rice varieties, pigeon pea, African yam bean and black gram dhals.

AR1=African yam bean/Faro 44, BR1=black gram/Faro 44, PR1=pigeon pea/Faro 44, AR2= African yam bean/Faro 52A, BR2=black gram/Faro 52A, PR2=pigeon pea/Faro 52A, AR3=African yam bean/Faro 52B, BR3=black gram/Faro 52B, PR3=pigeon pea/Faro 52B.

The reason for this could be the blanching process applied to the legume during dehulling and the fibrous nature of the seeds. This outcome is consistent with Onwuka's (2003) findings, which indicate that viscosity, or parameter μ, is crucial in food processing because it undergoes significant changes during heating, homogenization, and industrial fermentation. According to Onwuka (2003), the viscosity of most gases reduces as temperature rises for all liquids. It has been noted that fermented idli batters have viscosity, which is the resistance to fluid flow. One way to conceptualize the idli batters is as a sequence of steady, stationary layers.When a force (F) is applied to the topmost layer, it flows on a surface and moves at a velocity of u. As the topmost layer moves, it drags the next layer along at the same speed, and so on. Other layers flow slightly faster than u, and so on, until the flow reaches the bottommost layer, which stays stationary. The strain created, which is the velocity gradient over the distance, is known as the shear strain (γ), whereas the force that moves the idli batters and creates a deformation as it flows is known as the shear stress (τ). Rheology, then, is the relationship between shear strain and shear stress.When the fermented idli batters' shear stress was plotted versus their shear rate. It was discovered that as shear rate increased, viscosity dropped. All of the idli batters made with black gram, African yam bean, and pigeon pea displayed the same behavior. They exhibited shear-thinning, or pseudoplastic, activity. This indicates that Newton's law of viscosity is not followed by the idli batters. According to numerous reports, food pastes with delicate structures and hydrocolloid solutions frequently experience this phenomena (Awonorin, 1993). The shear rate rose as the shear stress increased, according to the shear stress-shear rate connection. At various fermentation times and blend ratios, Balasubramanian and Viswanathan (2007) noticed a shift in the flow behavior of the idli batter that suggested a strong non-Newtonian fluid behavior (pseudo plastic). Figure 8 shown that the viscosities of the control and other idli batters are higher. AR1, AR3, and AR2 were the African yam bean idli batters that came after. Pigeon pea idli batters PR3, PR2, and PR1 exhibited the lowest viscosity, in that order. One possible explanation for the low viscosities in pigeon pea could be the flour's high crude fiber content.

Conclusion: This study has demonstrated that instead of using black gram dhals, which have a lower nutritious quality, mixes of African yam beans, rice, and pigeon peas can be used to make idli. It was discovered that African yam and pigeon pea beans, when used to make idlis, are great sources of calcium, phosphorus, magnesium, zinc, iron, and vitamins B1 and B2. The African yam bean/Faro 52B and pigeon pea/Faro 52A idlis had the maximum concentration of the microorganisms needed for fermentation, while the control idli had the lowest concentration, according to the results of the microbiological analysis.Since there was no sign of mold growth, all of the idli items were safe to consume. The rheological properties of idli batters showed that the batters behaved in a way that violated Newton's law of viscosity when shear stress was plotted against shear rate. In addition to the control idli's high viscosity, African yam bean idli batter was visceral than pigeon pea idli batters. Thus, our study demonstrates that pigeon pea or African yam bean can be substituted for Indian black gram to enhance idli, a wholesome breakfast food. Thus, the introduction of idli in Nigeria will be crucial for diversifying the product line.

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