



## Research Article

# Comparative study on Physicochemical and Microbiological Assessment of Combined Sprouted/Fermented Sorghum (*S. bicolor*) blended with Cowpea (*Vigna unguiculata*) and Groundnut (*Arachis hypogea*)

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### ABSTRACT

Cereal grain (Sorghum, millet, and maize) and legumes (beans, soya beans, and groundnut) are the agricultural raw materials used both commercially and traditionally in the production of weaning foods, particularly in developing countries. A variety of cereals (sorghum) are used singly or in combination to produce several fermented and sprouted weaning foods using simple processing methods. The study investigated the effect of sprouting and fermentation on some functional properties and microbiological quality of the food formulations prepared from sorghum (*S. bicolor*), cowpea (*Vigna unguiculata*), and groundnut (*Arachis hypogea*) in a ratio of (70:20:10). Viscosity, functional properties, and microbiological assessment of the food formulations were evaluated using standard laboratory methods of analysis. Sprouting, fermentation singly and in combination significantly ( $P < 0.05$ ) decreased gruel viscosities ( $1978 \pm 25.1 \text{cps} - 225.0 \pm 19.4 \text{cps}$ ) for red sorghum and ( $19520 \pm 22.9 \text{cps} - 2300 \pm 18.6 \text{cps}$ ) for white sorghum variety. The results of ranged bulk density from ( $0.70 \pm 0.01 \text{g/ml} - 0.60 \pm 0.02 \text{g/ml}$ ) for red sorghum and ( $0.71 \pm 0.02 \text{g/ml} - 0.60 \pm 0.02 \text{g/ml}$ ), while increasing water absorption capacity in sprouted and fermented sorghum samples for (FCR  $6.47 \pm 0.00 \text{g/ml}$ , FCW  $5.43 \pm 0.01$ ) and SCR  $6.03 \pm 0.00 \text{g/ml}$ , SCW  $4.41 \pm 0.02 \text{g/ml}$ ) compared to raw and the composite blends. Total bacterial counts reduced significantly with sprouting and fermentation. The dominant microorganisms isolated in this study were all fermenters non-pathogenic microorganisms which are safe for consumption *Staphylococcus species* dominant only in the non-fermented products

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## INTRODUCTION

In most cultures' habits are based on the available agricultural raw materials. Traditionally cereals and grain legumes play an important role in achieving the dietary pattern/habit of many people in Africa and Asia, thus they form the major sources of proteins, carbohydrates, vitamins, and minerals (FAO, 2012). In developing countries including Nigeria, both commercial and traditional, weaning foods are sourced and prepared from cereals (rice, maize, and sorghum, etc.) and legumes (soya-beans and cowpea) (Modu *et al.*, 2005) in the northern and southern parts of Nigeria, flour from various cereals forms the main raw materials used in the production of popular food products like; "ogi", "fura", "ndaleyi" etc.) with high acceptability, good storage characteristics and affordable cost (Nkama *et al.*, 1989). One such food product is "ogi", a fermented product cereal porridge made from sorghum, millet, and maize product using simple processing methods.

A variety of cereals (sorghum) are used either singly or combined to produce a number of fermented beverages and foods many brands of low-cost proprietary weaning foods have been developed from locally available high caloric cereals and legumes in tropical Africa (Living stone *et al.*, 1993). This was proposed by the integrated child development scheme (ICDS) and FAO to combat malnutrition among mothers and children of low socio-economic groups.

The major constraints in the development of sorghum-based foods are the levels of tannins that made them be inferior, in terms of digestibility and bioavailability of mineral elements, hence the need to process these cultivars of cereals to enhance their nutritional value and subsequently introduce them as weaning meals singly or when supplemented with legumes. Some of the processing methods are sprouting, fermentation, dehulling and soaking, etc. since food constituents are enriched nutritionally upon processing other

have their nutritional content depleted or completely removed upon processing. This confirms the use of sprouting and fermentation methods singly or in combination in order to achieve the set objectives.

Sprouting and fermentation are among the simple and easily adaptable technologies for the reduction of bulk densities (high viscosity) and increasing shelf life of cereals and legume-based food formulation (Gernah *et al.*, 2011). Since the traditionally processed foods from cereal/legume blends have short storage stability and spoilage organisms (e.g., *Bacillus cereus*) were found in stored non-fermented traditional complementary foods (Gernah *et al.*, 2012). Challenge tests using food formulations from Africa breadfruit (*Treculia africa*) and soya bean (*Glycine max*) gave growth of *Enterobacteriaceae* and *Staphylococcus* in non-fermented products. Therefore, there is the need to assess the traditionally prepared weaning foods to ascertain their microbiological quality. Even though many works have been conducted on the effect of malting and fermentation of the physicochemical and microbiological quality of food formulations from other cereals/legumes (Gernah *et al.*, 2012; Sefa-Dedeh *et al.*, 2001; Obasi *et al.*, 2009). Information on the combined sprouting and fermentation of sorghum cowpea and groundnut food formulations is very scanty. Such information will be very useful. Earlier studies have documented that combined sprouting and fermentation significantly reduce the antinutritional contents of cereals (sorghum) when compared to using either sprouting, fermentation, dehulling, or soaking alone (Modu *et al.*, 2010). However, information on the combined processing techniques such as sprouting/fermentation and supplementation of grain legumes such as cowpea and groundnut food formulations are inadequate in this part of the country, Nigeria. Thus, this research is an attempt to formulate a cereal-based weaning food for infants.

## MATERIALS AND METHODS

### Source of Materials and Preliminary Treatments

Sorghum (*S. bicolor*), cowpea (*Vigna unguiculata*), and groundnut (*Arachid hypogea*) were used for this study, they were obtained from a seed store at Lake Chad Research Institute Maiduguri Borno State and were identified by a seed breeder same Institute. (Nutrend<sup>®</sup> (a maize-soya bean-based instant food made by Nestle Food<sup>®</sup>, Nigeria Plc, Lagos) was purchased from a local supermarket in Maiduguri. Wister albino rats of weaning age were obtained from the Department of Biochemistry University of Maiduguri Animal breeding unit.

### Pre-Treatment of Samples:

All the grains and legumes samples were manually cleaned by removing the ones that were mouldy or broken. The grains were sprouted as described by Kulkurni *et al.* (1991). Five hundred grams each of the sorghum varieties (mere and chakalari white) were soaked in a plastic bucket containing 300 ml of distilled water and were steeped in water for one hour at room temperature ( $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ). The steep water was discarded by decantation and the steeped grains were germinated for seventy-two hours by spreading on a clean grease-free tray pan thereafter, it was sundried for two-three days by putting it in a sterilized tray pan. The sorghum grains were then milled using a disc attrition mill (Hunt No. 2A Premier Mill Hunt and Co, UK) to an average particle size of less than 0.3mm. The milled grains were then sieved through a fine mesh (0.5  $\mu\text{m}$ ) to obtain the sorghum flour.

### Fermentation of the Sorghum Samples:

The two sorghum grains samples (mere and chakalari white) were washed and soaked in

water, about three times its weight by volume for seventy-two hours i.e., approximately three days. The sorghum grains were covered and kept for seventy-two hours. The fermented samples were washed thoroughly in water and sundried for three days. The dried sorghum grains were milled and sieved through a 0.5 $\mu\text{m}$  mesh screen to obtain the flour. This was done according to the method of kulkarni *et al.* (1991).

### Preparation of the Cowpea Flour

**Cowpea Flour:** Cowpea seeds, about (two hundred grams) of the seeds were cleaned, washed, and then soaked in ordinary water for twenty minutes. The seeds were dehulled, washed to remove the husk, after which it was dried to a constant weight. The cowpea seeds were roasted and then milled into fine powdered flour (Kulkarni *et al.*, 1991).

### Preparation of Groundnut Sample

Two hundred grams (200g) of groundnut was roasted to golden brown colour at  $30^{\circ}\text{C}$  for 30 minutes on cooling; the skin was removed by rubbing between palms. Formulation of Sprouted and Fermented Sorghum flour with Cowpea and Groundnut: groundnut, cowpea, and sorghum flours were mixed together in a ratio of 70:20:10 (W/W). Flow chart for production of traditional weaning foods from cereal/legume grains described by kulkarni *et al.* (1991) was adopted with slight modifications.

### Food Products Formulation

Ten different food formulations from two varieties of sorghum i.e., red and white sorghum were made by blending the different sorghum flours using the laboratory method shown below;

**Table 1:** Ingredients for Weaning Food Designed Formulations (%)

	RCR	SCR	FCR	SFCR R	SFCRF1	RCW	SCW	FCW	SFCF W	SFCWF 2
Sorghum,	100	100	100	100	70	100	100	100	100	70
Cerelac	100	100	100	100	100	100	100	100	100	100
Cowpea	–	–	–	–	20	–	–	–	–	20
Groundnut	–	–	–	–	10	–	–	–	–	10

**Source:** Kulkarni *et al.*, (1991)

**Keys:** RCR: Red Chakalari red, SCR: Sprouted chakalari red, FCR: Fermented chakalari red SFCR: Sprouted/fermented chakalari red and SFCF: Sprouted fermented fortified; RCW: Raw chakalari white, SCW:

Sprouted chakalari, FCW: fermented chakalari white SFCW: Sprouted/fermented chakalari white and SFCWF: Sprouted fortified.

### Determination of Functional Properties

**Water Absorption Capacity:** water absorption capacity was determined by the method of (Bhattacharya *et al.*, 1986). Eighty (80ml) of tap water at 28°C and 50°C were added to Ten grams (10g) of the sample. Pulverized extrudates were allowed to stand for one hour in a One Hundred and Fifty (150ml) beaker. The hydrated extrudates were collected by inverting the beaker over a 20-mesh screen (Bs) for 60sec. The percentage hydration was defined as;

$$\% \text{ hydration} = \frac{\text{wet sample} - \text{initial weight}}{\text{initial weight}} \times 100$$

### Determination of Bulk Density

The bulk density was determined using the method of Okezie and Bello (1988). Ten grams of the sample material were placed in a Twenty-Five Mills (25ml) graduated cylinder and packed by gentle tapping of the cylinder on a benchtop ten times from a height of 5 – 8cm. The final volume of the test material was recorded and expressed as g/ml.

### Viscosity:

Viscosity (AV) The apparent viscosity of slurries was determined by the methods of Beuchat (1982) and was determined by placing Twenty grams of the sample in a measuring cylinder of 100ml of water in boiling water bath of 75 – 80°C. The slurry was constantly stirred until boiling which was continued for five minutes. The slurry was cooled to room temperature 23 – 25°C and their viscosity was measured with a cannon viscometer.

### Microbiological Analysis (Harrigan and Mc Caine, 1976)

Appropriate dilutions of final dried samples were enumerated for counts of bacteria and yeast using nutrient agar, MacConkey agar, sabouraud dextrose agar, and blood agar base. Inoculated plates were incubated at the appropriate time and temperature combinations. Colonies of respective microbial types appearing in inoculated plates were counted and expressed as colony-forming units per gram (Cfu/g). Colonies of bacteria and

yeasts were isolated and subculture to obtain pure cultures.

### Determination of Total Viable Count:

After inoculation, the plates were incubated at 37°C for twenty-four hours. The colonies were obtained and counted with an electric colony counter (Gallenkemp Colony counter model No. 5A0441).

### Isolation and Identification:

One gram of the sample was smeared over one corner of the solidified medium which was sufficiently dried. A nichrome wire loop was sterilized over a spirit lamp allowed to cool and was made to parallel streaks from the main inoculums. The plates were incubated at 37°C for twenty-four hours.

The colonies were separated from one another based on the difference of colony monopoly. One of the separated colonies was taken using a sterilized wire loop and inoculated in another medium then was incubated for twenty-four hours at 37°C. Colonies were obtained on the medium after twenty-four hours

### Statistical Analysis

All determinations were carried out in triplicates. The results obtained were analysed using a one-way analysis of variance (ANOVA). Using pre-packaged computer software (MINITAB 15).

Duncan multiple-range tests were used to compare the difference between the means.

### RESULTS

Table 2 shows the results of Some Functional Properties of the Different Formulations. The sprouted and fermented sorghum flour from the two sorghum varieties had lower bulk density, when compared with the raw unprocessed sorghum flour which was significantly  $P < 0.05$  higher than that of sprouted, (SCR which was 0.45g/ml and SCW was 0.52g/ml), Fermented (FCR was 0.53 g/ml and FCW was 0.50g/ml), Combined Sprouted/Fermented (SFCR was 0.47 g/ml and SFCW was 0.59g/ml) and Combined Sprouted/Fermented Fortified with Cowpea and Groundnut (SFCRF was 0.63g/ml and SFCWF was 0.60g/ml).

There was an increase in water absorption capacity with (6.03g/ml) sprouted flours,

(SCR6.03g/ml, SCW4.41g/ml), Fermented, (FCR6.47g/ml), (FCW 5.43g/ml) combined sprouted/fermented flour (SFCR1.79g/ml), (SFCW1.60g/ml). Sprouted/fermented flour has more water-absorbing capacity than the raw unprocessed red and white sorghum flour (RCR 1.37g/ml and RCW 1.21g/ml) which had lower water absorption capacity. The results of the viscosity values at 25% concentration due to sprouting and fermentation also recorded a

significant ( $P < 0.05$ ) reduction in viscosity for raw unprocessed flour (RCR was 19780cps and RCW was 19520cps), to sprouted (SCR was 3721cps and SCW was 4216cps), fermented (FCR was 6052cps and FCW was 6217cps), combined sprouted/fermented sorghum flour (SFCR was 4540cps and SFCW 4216cps) and combined sprouted/fortified (SFCRF was 2250cps and SFCWF was 2300cps).

**Table 2:** Some Functional Properties of Sprouted, Fermented, Combined Sprouted/Fermented Unfortified and Fortified Sorghum Composite Blends

Formulations	pH	Water Absorption Capacity (g/ml)	Bulk density (g/ml)	Viscosity (cps) (25% Conc.)
RCR	7.56±0.06 <sup>a</sup>	1.37±0.03 <sup>a</sup>	0.70±0.01 <sup>a</sup>	1936.6±2.91 <sup>a</sup>
RCW	7.55±0.05 <sup>a</sup>	1.21±0.04 <sup>a</sup>	0.71±0.02 <sup>a</sup>	1955.6±3.01 <sup>a</sup>
FCR	7.37±0.08 <sup>a</sup>	6.47±0.00 <sup>b</sup>	0.53±0.03 <sup>b</sup>	614.7±5.32 <sup>b</sup>
FCW	7.27±0.05 <sup>a</sup>	5.43±0.01 <sup>b</sup>	0.50±0.02 <sup>b</sup>	625.3±6.20 <sup>ca</sup>
SCR	7.22±0.07 <sup>ba</sup>	6.03±0.00 <sup>c</sup>	0.45±0.06 <sup>c</sup>	375.6±3.81 <sup>d</sup>
SCW	7.16±0.05 <sup>ca</sup>	4.41±0.02 <sup>c</sup>	0.52±0.04 <sup>db</sup>	415.7±3.91 <sup>e</sup>
SFCR	5.51±0.09 <sup>d</sup>	1.79±0.06 <sup>d</sup>	0.47±0.00 <sup>ec</sup>	458.4±3.82 <sup>f</sup>
SFCW	5.53±0.06 <sup>ed</sup>	1.38±0.04 <sup>d</sup>	0.59±0.07 <sup>f</sup>	253.5±2.50 <sup>g</sup>
SFCRF	6.53±0.05 <sup>f</sup>	1.38±0.06 <sup>a</sup>	0.63±0.00 <sup>g</sup>	235.4±3.02 <sup>hg</sup>
SFCWF	6.74±0.03 <sup>gf</sup>	1.60±0.00 <sup>e</sup>	0.60±0.02 <sup>hg</sup>	242.6±2.21 <sup>ig</sup>

Value recorded as mean ± SEM of three determinations, value in the same row with different superscript is significantly different ( $P < 0.05$ )

**Keys:**

RCR = Raw Chakalari Red FCR = Fermented Chakalari SCR = Sprouted Chakalari Red SFRC = Sprouted / Fermented Chakalari Red SFCRF = Sprouted / Fermented Fortified Chakalari Red RCW = Raw Chakalari White FCW = Fermented Chakalari White SCW – Sprouted Chakalari White SFCW = Sprouted / Fermented Chakalari White SFCWF – Sprouted / Fermented Fortified Chakalari White

Table 3 presents the results of the micro-organism isolated in the steep water during (72hours) of fermentation of the two sorghum varieties used. The water used for steeping the grains at zero hours did not show any growth of micro-organisms. However, after 24 hours of fermentation, *corynebacteria* species and *Staphylococcus albus* were identified in the

steep water. In addition, *Streptococcus Lactics* and *Lactobacillus* were identified on the second day (48hours).

The bacteria identified in the first, second, and third days of steeping were all fermentors (Table 3) non-pathogenic micro-organisms which are safe for consumption.

**Table 3:** Microorganisms Isolated in Sorghum (grains) from two Sorghum Varieties

Variables		0hr	Day 1 (24hr)	Day 2 (48hr)	Day 3 (72hr)
Chakalari steep water	Red	No growth	<i>Corynebacteria spp</i> <i>Staphylococcus albus</i>	<i>Streptococcus lactics</i> <i>Lactobacillus</i>	<i>Sacharonyces cerevisiae</i> <i>Bacillus subtilis</i>
Chakalari steep Water	White	No growth	<i>Corynebacteria spp</i> <i>Lactobacillus</i>	<i>Streptococcus lactics</i> <i>Lactobacillus</i>	<i>Lactobacillus</i> <i>Sacchronymes cerevisiae</i>

**Keys**

CR = Chakalari Red

CW = Chakalari White

Table 4 shows the results of micro-organisms isolated and identified in raw (Unprocessed), processed unfortified, and fortified sorghum flour from two sorghum varieties.

The microorganisms isolated are shown in Table 4. No growth or mould was observed at zero hours. However, in the first d of fermentation *Staphylococcus aureus* established itself in the raw samples (RCR) and (RCW) and later disappeared after the second fermentation. The microorganisms isolated in the second and third days of fermentation were all fermenters. *Saccharomyces cerevisiae* and *Lactobacillus* appeared on the second day of steeping. Although, *Corynebacterium* species disappeared on the third day. These are the dominant micro-organisms in sorghum flour isolated and identified (Table 4). When the sorghum grains were subjected to the combined processing techniques i.e., sprouted/fermented. After the grains were dried to a constant weight, the number of micro-organisms reduced consecutively

Table 5: Presents the results of the total bacterial count in steep water used during the Fermentation of two sorghum grain varieties. The total bacterial count at zero hour of steeping was  $25 \times 10^3$  (cfu/ml) for Chakalari (RCR) presented in table 4.6 dropped to  $17 \times 10^3$  (cfu/ml) in the first day (24hrs),  $9 \times 10^3$  (cfu/ml) after second days (48hrs) and  $2.0 \times 10^3$  (cfu/ml) was recorded after third day (72hrs). There was virtually no growth of bacteria recorded. The same trend was observed for Chakalari white where the highest bacterial count recorded at zero hours (day 1) was  $19 \times 10^3$  (cfu/ml). The total bacterial count that was obtained after 24hours was  $10 \times 10^3$  (cfu/ml),  $6 \times 10^3$  (cfu/ml) at 48hours while  $1 \times 10^3$  (cfu/ml) was also recorded after 72hrs (day 3) for Chakalari White.

**Table 4:** Microorganisms Isolated and Identified in Raw (Unprocessed) and Processed Formulated Sorghum Flour from two Sorghum Varieties

Formulations	0hrs	Day 1	Day 2	Day 3
RCR	No growth	<i>Staphylococcus albus</i> <i>Corynebacteria spp</i>	<i>Streptococcus lactics</i> <i>Lactobacillus</i>	<i>Saccharomyces cerevisae</i> <i>Lactobacillus</i>
RCW	No growth	<i>Bacillus subtilis</i> <i>Staphylococcus albus</i>	<i>Corynebacteria</i> <i>Streptococcus lactic</i>	<i>Sacchromyces cerecisae</i> <i>Lactonacillus</i>
FCR	No growth	<i>Bacillus subtilis</i> <i>Corynebacteria spp</i>	<i>Corynebacteria spp</i> <i>Saccharomyces cerevisae</i>	<i>Sacchromyces cerevisae</i>
FCW	No growth	<i>Lactobacillus</i> <i>Streptococcus lactic</i>	<i>Saccharomyces cerevisae</i> <i>Lactobacillus</i>	<i>Sacchromyces cerevisae</i> <i>Lactobacillus</i>
SCR	No growth	<i>Lactobacillus</i> <i>Streptococcus lactic</i>	<i>Saccharomyces cerevisae</i> <i>Corynebacteria spp</i>	<i>Sacchromyces cerevisae</i> <i>Lactobacillus</i>
SCW	No growth	<i>Corynebacteria spp</i> <i>Bacillus subtilis</i>	<i>Saccharomyces cerevisae</i> <i>Corynebacteria spp</i>	<i>Sacchromyces cerevisae</i> <i>Lactobacillus</i>
SFCR	No growth	<i>Streptococcus lactics</i> <i>Bacillus subtilis</i>	<i>Streptococcus lactics</i> <i>Lactobacillus</i>	<i>Sacchromyces cerevisae</i>
SFCW	No growth	<i>Corynebacteria spp</i> <i>Lactobacillus</i>	<i>Sacchromyces cerevisae</i>	<i>Sacchromyces cerevisae</i>
SFCRF	No growth	<i>Streptoplastic</i>	<i>Sacchromyces Cerevisae</i>	<i>Sacchromyces cerevisae</i>
SFCWF	No growth	<i>Bacillus subtilis</i> <i>Streptococcus lactic</i>	<i>Sacchromyces Cerevisae</i>	<i>Sacchromyces Cerevisae</i>

**Keys:**

RCR = Raw Chakalari Red FCR = Fermented Chakalari SCR = Sprouted Chakalari Red SFRC = Sprouted / Fermented Chakalari Red SFCRF = Sprouted / Fermented Fortified Chakalari Red RCW = Raw Chakalari White FCW = Fermented Chakalari White SCW – Sprouted Chakalari White SFCW = Sprouted / Fermented Chakalari White SFCWF – Sprouted / Fermented Fortified Chakalari White

**Table 5:** Total Bacteria Count in the Steep Water of Two Sorghum Varieties

Sample	Total Bacterial Count (cfu/ml)			
	0hr	24hr	48hr	72hr
Chakalari Red Sorghum (RCR) Steep Water	25 x 10 <sup>3</sup>	17 x 10 <sup>3</sup>	9 x 10 <sup>3</sup>	2.0 x 10 <sup>3</sup>
Chakalari White Sorghum (RCW) Steep Water	19 x 10 <sup>3</sup>	10 x 10 <sup>3</sup>	6 x 10 <sup>3</sup>	1 x 10 <sup>3</sup>

**Key:** RCR= Raw Chakalari Red, RCW= Raw Chakalari White

Table 6: Total Bacterial Count in the Unprocessed, Processed, and Processed Fortified Sorghum Composite Blends from Two Sorghum Varieties.

The total bacterial count in the first day of fermentation (24hrs) was  $20 \times 10^3$  (cfu/ml) for Raw Chakalari Red (RCR) presented in (table 6) which dropped to  $16 \times 10^3$  (cfu/ml) by the second day of fermentation (48hrs) and  $14 \times 10^3$  (cfu/ml) in the day 3 (72hrs). The same trend was also observed for Raw Chakalari White where the highest bacterial count recorded at day 1 (24hrs) was  $25 \times 10^3$  (cfu/ml) which dropped to  $18 \times 10^3$  (cfu/ml) by the second day (48hrs) and  $11 \times 10^3$  (cfu/ml) in the third day of fermentation (72hrs). The total bacterial count

in the fermented samples dropped from  $5.0 \times 10^3$ ,  $3.0 \times 10^3$  to  $1.5 \times 10^3$  in the first, second, and third days of fermentation for FCR and that of FCW also dropped from  $2.0 \times 10^3$ ,  $1.5 \times 10^3$  to  $1.0 \times 10^3$  respectively. The total bacterial count was found to be higher in the raw samples than in the processed samples. Significant reduction in the total bacterial count, was recorded in the fermented, combined sprouted/fermented, and combined sprouted/fermented samples. This indicates that fermentation, sprouting, and combined fermentation and sprouting significantly reduced the total bacterial count.

**Table 6:** Total Bacterial Count in the Raw, Processed and Processed Unfortified and Fortified Chakalari Red and White Sorghum Composite Blends

Sample		RCR	FCR	SCR	SFCR	SFCRF
	<b>Time Hours</b>					
Total Bacterial count (cfu/ml)	24 hrs	$20 \times 10^3$	$2.0 \times 10^3$	$9.0 \times 10^3$	$7.0 \times 10^3$	$3.0 \times 10^3$
	48 hrs	$16 \times 10^3$	$1.5 \times 10^3$	$4.0 \times 10^3$	$3.0 \times 10^3$	$2.0 \times 10^3$
	72 hrs	$14 \times 10^3$	$1.0 \times 10^3$	$2.0 \times 10^3$	$1.6 \times 10^3$	$1.0 \times 10^3$
		RCW	FCW	SCW	SFCW	SFCWF
Total Bacterial count (cfu/ml)	24 hrs	$25 \times 10^3$	$5.0 \times 10^3$	$9.0 \times 10^3$	$6.0 \times 10^3$	$4.0 \times 10^3$
	48 hrs	$18 \times 10^3$	$3.0 \times 10^3$	$7.0 \times 10^3$	$3.0 \times 10^3$	$2.5 \times 10^3$
	72 hrs	$11 \times 10^3$	$1.5 \times 10^3$	$4.0 \times 10^3$	$1.6 \times 10^3$	$1.2 \times 10^3$

**Keys:**

RCR = Raw Chakalari Red FCR = Fermented Chakalari SCR = Sprouted Chakalari Red  
 SFRC = Sprouted/Fermented Chakalari Red SFCRF = Sprouted/Fermented Fortified Chakalari Red  
 RCW = Raw Chakalari White FCW = Fermented Chakalari White SCW = Sprouted Chakalari White  
 SFCW = Sprouted/Fermented Chakalari White SFCWF = Sprouted/Fermented Fortified Chakalari White.

## DISCUSSIONS

### Functional Properties

The significant reduction ( $P < 0.05$ ) in bulk density, due to sprouting and fermentation could be as a result of the absorption of water that tends to soften the seeds, this making milling easier with smaller particle sizes than that of unsprouted and unfermented grain, hence the reduction in bulk density. The significance of this is that

the less bulky flours will have higher nutrient density since more flour can be packed in the same given volume. The increased solubility could be a result of the increase in the number of soluble sugars present in the malted and fermented flours. Eneche (2009) also reported water absorption capacity with the soaking of maize grains. The significant ( $P < 0.05$ ) decrease in viscosity due to sprouting,

fermentation could be due to starch degradation caused by the action of hydrolytic enzymes ( $\alpha$  and  $\beta$  amylases) that developed during the sprouting process this hydrolysed some of the starch into limited dextrin and maltose, which do not swell when cooked. Fermentation further decreases the total amount of carbohydrates and other nutrients since microbial activity requires energy and nutrients (Onimawo *et al.*, 2001). Flour from sprouted and fermented grains can therefore be used in greater amounts to giving the same viscosity as flour from unsprouted grains, thereby giving higher nutrient and energy density. This is in line with an earlier work reported by Gernah *et al.* (2012)

### Microbiological Analysis

Data on the microbiological analysis of the unprocessed and processed samples are presented in Tables 5 and 6. The microbiological analysis was carried out to ascertain the safety of the products for consumption. The consecutive reduction in the total bacterial count in the steep water and processed flour could be due to acid production, in the fermentation medium due to microbial activity, since not all micro-organisms can survive in the severe acidic medium. The result of the bacterial counts in this study is in accordance with the values recorded by (Mensah, *et al.*, 1990).

In a related fermentation study for the production of cereal-based fermented products. The micro-organisms identified in this study are all similar to earlier

bacterial isolated and identified in similar fermentation studies for the production of other indigenous fermented food products. (Modu, 2003; Modu *et al.*, 2012; Laminu *et al.*, 2011). The consecutive reduction of micro-organisms isolated in this study could be as a result of the various processing techniques to which sorghum was subjected and could also be possibly due to the acid production since acidity increases as fermentation time progresses. (Mbata *et al.*, 2006).

The predominant micro-organisms in this study are *Lactobacillus plantarum*, *Streptococcus*, *Corynebacterium*, and *Saccharomyces cerevisiae*. This agreed with the findings of (Modu *et al.*, 2012). Most of these isolates are non-pathogenic and may not be of public health concern. These isolates may also have been introduced from the environment, processing equipment, and water used. However, the high temperature of cooking is expected to reduce the micro-organisms.

### CONCLUSION

Sprouting, fermentation, and sprouting/fermentation significantly ( $p < 0.05$ ) decreased gruel viscosities, leading to improved nutrient density. There was also a significant ( $p < 0.05$ ) decrease in bulk density while water absorption capacity increased. Natural lactic fermentation significantly ( $p < 0.05$ ) affected the microbiological composition and enhanced the microbiological safety of the food products by increasing the dominance of lactic acid bacteria and inhibiting the growth of pathogenic micro-organisms.

**REFERENCES**

- Beuchart, A.A.(1982). World Food and Nutrition Problems. *Cereal Food World* 27:562
- Bhattacharya, M., Hynna, M.A. and Kaufmann R.E. (1986). Textural properties of extruded plant protien blend. *Journal of Food Sci.* 51 (4); 988 – 993.
- Eneche, H.E., (2009). Effect Rate of Water Absorption in Maize Grains During Soaking. *Proceedings of the AGM/Conference, (AGMC 09), Nigeiran Institute of Foods Science and Technology, Yola, pp: 41 – 42.*
- F.A.O (1994)-Production Year Book, F.A Olun Rome 38:120.
- Gernah, D.I., Ariahu , and E.U Umeh, (2012). Physical and Microbilogical Evaluation of Food Formulations From Malted and Fermented Maize (*zea mays L.*) Fortified With Defatted Sesame (*sesamun indicum L.*) flour. *Advance J.food science and Technology* 4(3): 148 – 154.
- Gernah, D.I., C.C. Ariahu, E.K. Ingbain and A.I Sengeve, (2011). Storage and Sheiflife Evaluation of Food Formulations From Malted and Fermented Maize (*zea mays L.*) Fortified With Defatted Sesame (*sesamun indicum L.*) *Nig. J. Nutr. Sci.*, 32(1): 45 – 54.
- Harrigan, W. F. and McCain, M. E. (1987). *Laboratory methods in food and dairy microbiology.* Academic Press, London.13: 132-133
- Kulkarni, K.D; D.N. Kulkani and U.M Ingle (1991)-Sorghum Malt – Based Weaning Food Formulations: Properties, Functional Properties, Nutritive Value *Food Nutr. Bull;* 13: 322 – 329.
- Living Stone, A.S; Feng, J.J. and Maleshi, N.G (1993)-Development and Nutritional Quality Evaluation of Weaning Foods Based on Malted, Popped Roller Dried Wheat and Chikpea. *Int. S. Food Sci. Technol.* 28: 35 – 43.
- Mensah, P., Tomkins A.M., Brasan, B.S and Harrison, T.J. (1990). Fermentation of cereal for Reduction of Bacterial contamination of weaning food in Ghana. *Lancet* 336: 140 – 143.
- Mbata, T. T., Ikenebomeh, M.J. and Ahonkhai. 2006. Improving the Quality and Nutritional Status of Maize Fermented Meal by Fortification with Bambara-nutt. *The internet Journal of Microbiology* 2 (2).
- Modu, S., Falmata, A.S., Laminu, H.H., and Bintu, B. P. (2012). Production and Evaluation of Chemical Composition, Tannin, Invitro protein Digestibility and Microbiological Studies of Fermented local Variety of Sorghum, Fortified With Cowpea and Groundnut. *Bioscience Research:* 99 – 105.
- Modu, S., Laminu, H.H., Abba, S.F (2010). Evaluation of the Nutritional Value of a Composite Meal Prepared From Pearl Millet and Cowpea. *Bayero J. of pure and Applied sci.* 30: 1664 – 158.
- Modu, S., Laminu, H.H and Nkama, I. (2005). Production, Chemical and Sensory Properties of Ogi From Different Pearl Millet Varieties. *J. Biol.sci* 5(2): 103 – 106.
- Modu, S., Laminu, H.H. and Abba Sanda, F. (2010) Evaluation of The Nutritional Value of a Composite Meal Prepared From Pearl Millet (*pennisetum typhoideum*) and Cowpea (*vigna unguiculata*).
- Nkama, I. and Malleshi (1989).Production and Nutritional Quality of Traditional Nigerian Masa From Mixtures of Rice, Pearl Millet, Cowpea and Groundnuts: *Food Nutr. Bull.* 19: 336 – 373.
- Obassi, N. E., L. Agim and N. Uchechukwu,(2009).Effect of Different Soaking Periods on the Chemical Composition of Pearl

- Millet Grains (*Pennisetum glaucum*). Proceedings of the AGM/Conference of the *Nigerian Institute of food Science and Technology* (N. F. Saunders, R.M., Conner, M.A., Booth, E.M., Bickoff and Kohler, C.o.,(S. T Saunders, R.M., Conner, M.A., Booth, E.M., Bickoff and Kohler, C.o.,), Yola, pp. 57 – 58 April, 1986, ICRISAT Center India.
- Okezie, B.O. AND Bello, a. e(1988). Physicochemical and functional properties of winged bean flour and isolate compared with soya isolate, *Journal of Food Sciences*, 53: 450-455.
- Onimawo, A.I. and Egbekun, K.M. (1998). *Comprehensive Food Science and Nutrition. Macmillan Press. Ibadan. p. 228.*
- Dedeh, S. and Stanley, D.W.(1979). *The Relationship of Microstructure Academic Press, New York. Pp. 75 – 809*
- Sefa-Dedeh, S. and Stanley, D.W.(1979). *The Relationship of Microstructure of Cowpeas to water Absorption and Dehulling Properties. Cereal Chem 56:379-386*