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Fermented Millet "*Ibyer*" Beverage Enhanced with Ginger Powder: An Assessment of Microbiological, Pasting, Proximate, and Sensorial Properties

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Abstract: A fermented millet flour called "*Ibyer*" traditionally available in Nigeria is increasingly being enhanced with ginger powder, of which its quality characteristics to our best knowledge appears not yet reported. To supplement existing information, therefore, the microbiological (which involved bacteria and fungi counts), pasting (which involved peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature), proximate (which involved moisture, ash, crude fat, fiber, protein, as well as carbohydrates), and sensory (which involved appearance, aroma, mouth-feel, consistency, taste, and overall acceptability) properties of fermented millet "*ibyer*" beverage enhanced with ginger powder were investigated. The major experimental stages included assembly of millet flour and ginger powder, preparation of blend formulation, making of "*ibyer*" beverage blends, and laboratory analysis. The blend involved fermented millet flour (FMF) decreasing, and ginger powder (GP) increasing, by proportions. Results showed noticeable microbiological, pasting, proximate, and sensory differences between blend samples and control. Compared to control, the blend samples obtained reduced bacterial and fungal counts, with increased peak, trough, final, set back viscosities, peak time, and pasting temperature, as well as moisture, ash, crude fat, crude fiber, and crude protein contents, but yet, with decreased sensory appearance, aroma, mouthfeel, taste, and overall acceptability.

Keywords: consumer appeal; fermentation; food processing; ginger powder; millet flour; consumer wellbeing

1. Introduction

Collectively, millet encompasses a group of small-seeded annual cereal grains. Most important millet species include the finger, foxtail, pearl, and proso types, which are cultivated in different parts of the globe [1–3]. Millet, aside from its indigenous nature, has been with human for about 7000 years, and still remains indispensable largely within the semi-arid tropic regions of the globe. Millet is also very vital for human consumption, considering the useful calorie source [4,5]. In Africa as well as Asia, millet is key within the traditional food systems. In the USA, millet is economically important, sold in health

food stores, different from the Western Hemisphere where it serves as catch and a forage crop [6]. Among important global cereal crops, millet has reasonable nutritional and medicinal components. For instance, the chemical composition of millet is believed to comprise antioxidants, essential amino acids, dietary fiber, dietary minerals, phytochemicals, polyphenols, vitamin B, as well as its zero gluten content [2,7–9]. Besides, millets are able to slowly release their sugars, which as a result, bring about a low glycemic index [10]. Additionally, in vivo studies have demonstrated a millet-based diet with significantly lower blood glucose when compared to other cereals [11–13]. Further, millets comprise fatty acids, specifically the highly polyunsaturated types, as well as non-starchy polysaccharides [2,14].

Processing of millets has largely involved two basic food processing methods that include fermentation and malting, both of which deliver a diversity of products. Beverages, whether alcoholic or nonalcoholic, produced from millet appear increasingly prevalent over other (cereal) product types [3]. Fermentation is economically important because, through the microbial action, the process transforms substrates into new products. Biochemical changes during this process result in modification of substrate, and production of volatiles [15–17]. Activating the enzymes with pH variations, the fermentation process enhances the enzyme performance of amylases, hemicellulases, and proteases [17]. Fermented food production, largely underpinned by either natural or spontaneous (fermentation) processes, requires microorganisms, some of which are undesirable [3] Specifically, the microorganisms involved in the fermentation process of millet include lactic acid bacteria and yeasts [16,17]. The fermentation process in pearl millet involves noticeable changes in chemical composition, mineral contents, etc. [17,18]. Such fermentation-led changes also appear beneficial. Fermentation process of cereals is believed to improve the nutritional value [19], reduce anti-nutritional factors such as phytate, which could influence both digestibility and rheology of starch-protein [20], and decrease the solubility of such minerals as calcium, iron, and zinc [21]. Besides, malting of millet remains a traditional practice in Africa, where the malt is employed in alcoholic fermented/lactic acid oriented beverages [22]. Malting can activate proteases that degrade protein, to improve its bioavailability [3], increase the extractability of calcium, iron, and zinc in millets, and reduce its phytic acid [3]. The malting process comprises three main operations, which include (a) soaking; (b) germination; and (c) drying/kilning. The modern-day malting process has been met with ample debate among researchers, with different propositions being suggested [3].

Ginger (*Zingiber officinale*) is not only a flowering plant with rhizome, but also a common spice employed by diverse cultures across the globe [23,24]. Ginger positions itself, as per folk medicine, in the context of diuretic food, tonic, as well as disinfectant, based on components like glucosinolate, sterols, and triterpenes [23]. Characteristic and organoleptic properties of ginger is substantiated by volatile oil as well as extractable pungent solvent component. The evidence of pleasant aroma of ginger is by constituents like sesquiterpene hydrocarbon, whereas the pungent taste like gingerols and zingerone [24,25]. Ginger contains fiber, beta-carotene, ascorbic acid, terpenoids, alkaloids, flavonoids, flavones glycosides, etc., which help in treatment of numerous ailments [26]. As a flavoring agent, ginger powders can increase body mass, and improve feed conversion ratio [27,28]. Ginger remains a potential ingredient and very positive health promise to consumers given its functional nutraceutical properties, and its position for many food preparations [25].

There is an indigenous beverage made of fermented millet flour called "*Ibyer*" traditionally familiar to the Tiv people of Nigeria. Importantly, it is becoming popular with high promise to extend into the West African region. Additionally, this indigenous beverage is increasingly enhanced with ginger powder, which specifically targets the elevation of its nutritive value. No study, to the best of our knowledge, appears to have documented the quality attributes of this edible fermented beverage blended with ginger. The output of this kind of study will help to generate data that will reveal the nutritive aspects of this beverage product particularly the added-value of ginger supplementation, given the growing number of consumers that patronize this product in Nigeria. In this current work,

therefore, the microbiological, pasting, proximate, and sensory properties of fermented millet "*ibyer*" beverage enhanced with ginger powder was investigated. The target is to report the impact of decreasing millet flour as well as increasing ginger powder quantities as a whole on the microbiological, pasting, proximate, and sensory properties of this fermented millet "*ibyer*" beverage blends.

2. Materials and Methods

2.1. Overview of Experimental Program

The schematic overview of the experimental program, demonstrating the key/major stages from the assembly and making of both fermented millet flour, together with the ginger powder, through blend formulation to make the "*Ibyer*" beverage, and then the laboratory analyses, is shown in Figure 1. For emphasis, the design of this current study was to determine the microbiological (which involved bacteria and fungi counts), pasting (which involved peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature), proximate (which involved moisture, ash, crude fat, fiber, protein, as well as carbohydrates), and sensory (which involved appearance, aroma, mouth-feel, consistency, taste, and overall acceptability) properties of fermented millet "*ibyer*" beverage enhanced with ginger powder. Triplicate determinations using representative samples have been allocated *as per* parameter, unless otherwise stated. Chemicals and reagents used for laboratory analysis were obtained from certified sources and were of standard analytical grade.

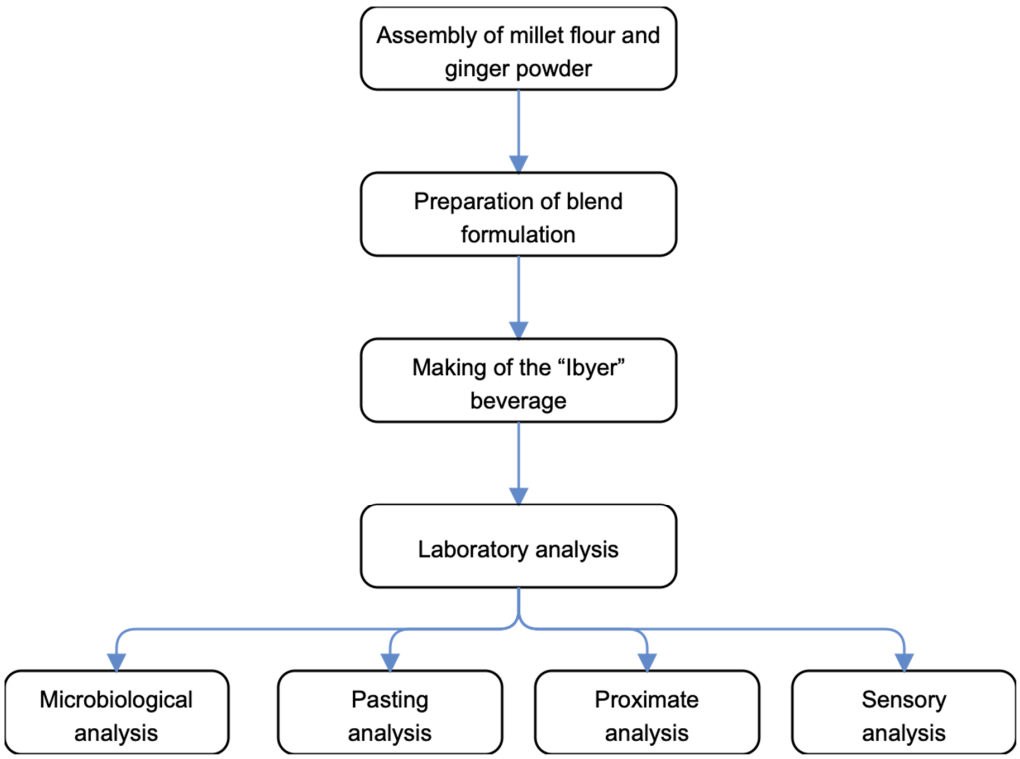

Figure 1. Schematic overview of the experimental program, demonstrating the key/major stages from the assembly and making of both fermented millet flour, together with the ginger powder, through blend formulation to make the "*ibyer*" beverage, and the laboratory analyses.

2.2. Fermented Millet Flour Preparation

The schematic diagram of making the fermented millet flour can be seen in Figure 2, which followed the method described by Sengev, Ingbian, and Gernah [29] with slight modifications. Whole (pearl) millet grains have been sorted and cleaned to remove unwanted materials, and subsequently, thoroughly washed with running tap water. Thereafter, it was

steeped for 72 h, after which the grains were drained, followed by sun-drying, then milling and sieving, which helped to achieve the fermented millet flour.

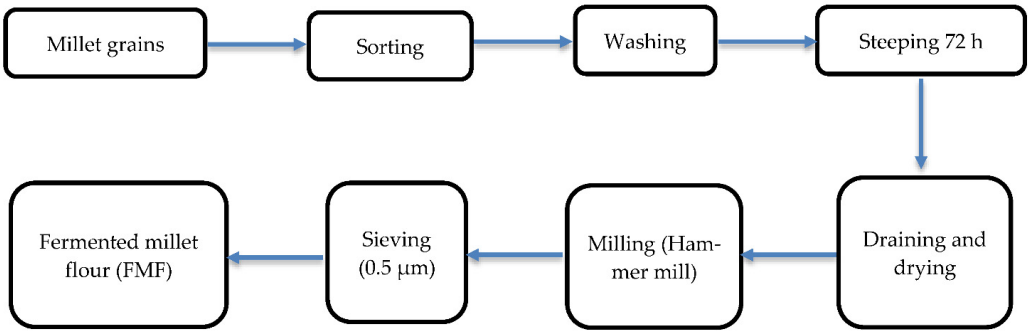

Figure 2. The schematic diagram of making the fermented millet flour (Sources: Sengev et al. [29]).

2.3. Preparation of Ginger Powder

The schematic diagram of making the ginger powder can be seen in Figure 3, following the method described by Sekwati-Monang [30] with slight modifications. Briefly, the fresh ginger roots were sorted, and thereafter soaked in water for ~30 min. After this, it was washed with running tap water. The cleaned roots were thereafter subjected to draining, slicing, sun-drying, milling using a hammer mill, and finally sieving to achieve the ginger powder.

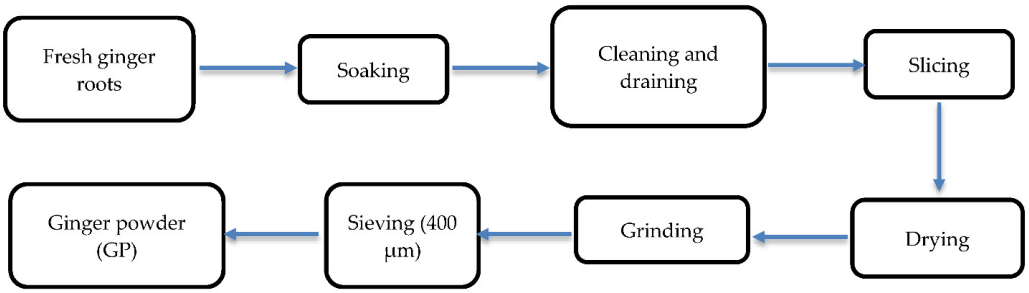

Figure 3. The schematic diagram of making the ginger powder (Source: Sekwati-Monang [30]).

2.4. Preparation of Fermented Millet—Ginger "Ibyer" Beverage Blends

The schematic diagram depicting the major steps in which fermented millet flour and ginger powder makes the "*Ibyer*" beverage can be seen in Figure 4, which followed the method described by Kure and Wyasu [31] with slight modifications. Herein, fermented millet flour and ginger powder are proportionally mixed with water to form a slurry. For each blend formulation, sample codes were allocated as shown in Table 1, in which the millet flour/ginger powder ratio has been varied by proportion. This was such that quantities of millet flour (FMF) were decreased, whereas those of ginger powder (GP) were increased, namely: Control sample 716 = FMF_{100} (Control), blend sample 924 = $FMF_{95}GP_5$, blend sample 839 = $FMF_{90}GP_{10}$, blend sample 746 = $FMF_{85}GP_{15}$, blend sample 958 = $FMF_{80}GP_{20}$, blend sample 469 = $FMF_{75}GP_{25}$, and blend sample 577 = $FMF_{70}GP_{30}$. To make these blend samples, the process involved the fermented millet flour and dried ginger powder mixed with 10 mL of clean water to form a slurry mixture, after which a 12-h fermentation process was conducted. Subsequently, ~200 mL of boiled water was added to the slurry mixture. This was followed by heating at ~100 °C for 10 min with continuous stirring to obtain the beverage, after which it was allowed to cool to 40 °C for ~5 min.

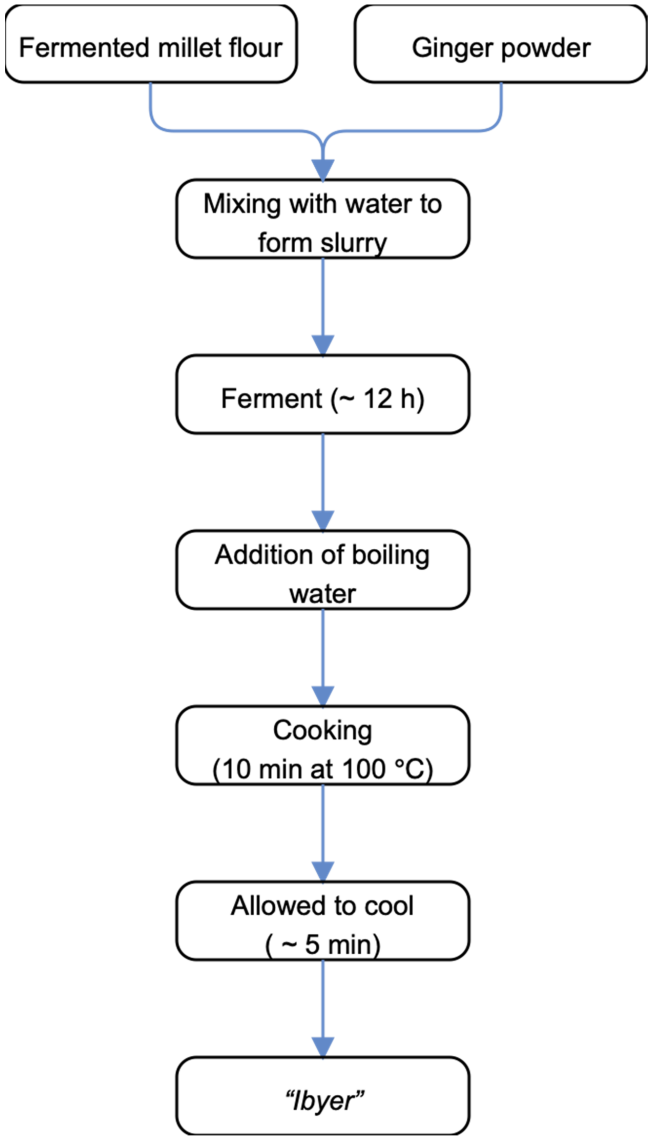

Figure 4. The schematic diagram depicting the major steps fermented millet flour enhanced with ginger powder makes the "*Ibyer*" beverage (Adapted from Kure and Wyasu [31]).

Table 1. Blend formulation of fermented millet flour enhanced with ginger powder for "ibyer" production.

Sample Code	716	924	839	746	958	469	577
Millet	10	9.5	9	8.5	8	7.5	7
Ginger	-	0.5	1	1.5	2	2.5	3
Corn starch	70	70	70	70	70	70	70
Vitalyte	5	5	5	5	5	5	5
Rice husk	5	5	5	5	5	5	5
Sucrose	10	10	10	10	10	10	10
Total	100	100	100	100	100	100	100

Note: KEY: 716 = FMF_{100} (Control), 924 = $FMF_{95}GP_{5}$, 839 = $FMF_{90}GP_{10}$, 746 = $FMF_{85}GP_{15}$, 958 = $FMF_{80}GP_{20}$, 469 = $FMF_{75}GP_{25}$, 577 = $FMF_{70}GP_{30}$, FMF = Fermented millet flour; GP = Ginger powder.

2.5. Microbiological, Pasting, Proximate, and Sensorial Analyses of Fermented Millet "Ibyer" Beverage Enhanced with Ginger Powder

2.5.1. Microbiological Analysis

The microbiological analysis was carried out following the pour-plate method. Sampled quantities of blend of ~2 g were homogenized for ~60 s with 15 mL of diluents. Essentially, ~28 g of Nutrient Agar (NA) (Merck KGaA, Darmstadt, Germany) (for bacteria) and ~39 g of Potato Dextrose Agar (PDA) (Merck KGaA, Darmstadt, Germany) (for the fungi) were separately weighed, and each subsequently suspended in (~1 L) diluent. As specified by manufacturers, the NA media comprised agar(15 g/L), meat extract (1 g/L), peptone (5 g/L), and sodium chloride (5 g/L), while the PDA comprised agar (15 g/L), dextrose (20 g/L), and potato extract (4 g/L). To suppress the bacterial growth, 1 mL of 10% sterile lactic acid has been added to PDA to drop the pH to ~3.5. Both solutions were swirled to ensure thorough dissolution. Both media were brought to boil to dissolve completely and were subsequently autoclaved at 121 °C for ~15 min and cooled at 45 °C using the water bath method. A serial 10-fold dilution of homogenate was prepared. With Petri dishes arranged accordingly, 0.1 mL of aliquots were pipetted and, thereafter, cooled molten NA and PDA media were poured, and gently swirled 2–3 times. Thereafter, the plates were allowed to solidify at room temperature. After solidification, the plates were incubated in an inverted position at 37 °C for ~48 h for the bacteria, and ~72 h for the fungi counts. The microbiological analysis were expressed as colony forming units (CFU/mL) of the sample.

2.5.2. Pasting Analysis

Pasting analysis of samples was conducted using the Visco Analyzer. Approximately 2.5 g of sample were measured into a dried empty canister and 25 mL of distilled water were added into the canister containing the sample. The solutions were thoroughly mixed, and the canister was well-fitted into the viscometer. The slurry mixture was heated between 50–95 °C, with a holding time of ~2 min, followed by temperature reduction to 50 °C, with a ~2 min holding time. The peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature were read from the pasting profile, with the help of thermocline software [32].

2.5.3. Proximate Analysis

Determination of Moisture

The moisture of samples was determined as described by the AOAC method [33]. Empty crucibles were washed, dried in an oven at 100 °C for ~1 h, and measured as (W_1). A sample of ~2 g was measured into the crucible (W_2) and dried at 70 °C to a constant weight obtained as (W_3) [33], and moisture content was calculated from Equation (1) below:

$$Moisturecontent(\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (1)$$

Hence, W_1 = weight of empty crucible
W_2 = weight of crucible + sample before drying
W_3 = weight of crucible + sample after drying

Determination of Ash

The ash of samples were determined as described by the AOAC method [33] with slight modifications. A crucible was preheated and cooled in a desiccator, thereafter weighed as (W_1). Approximately 2 g sample was added into the crucible and its content weighed as (W_2). A crucible with its content was then heated in a muffle furnace up to 550 °C for ~7 h. The crucible temperature was reduced in a desiccator and measured again after reaching room temperature, and weighed as (W_3) [33]. The ash content was as calculated from Equation (2) below:

$$Ashcontent(\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (2)$$

Hence: W_1 = Weight of empty crucible
W_2 = Weight of crucible + weight of sample before ashing
W_3 = Weight of crucible + weight of sample after ashing

Determination of Crude Fat

The crude fat of samples was determined based on the Soxhlet extraction method as described by the AOAC method [33] with slight modifications. Approximately 2 g of sample was measured into a labeled extraction thimble and placed in an extraction flask. Approximately 300 mL of diethyl ether was added to the flask. The extraction thimble was sealed and (extraction) carried out for ~6 h. At the end of extraction, the diethyl ether was removed by evaporation and dried at 70 °C for an hour in the oven, and the temperature was reduced in desiccators before it was measured, following the method of AOAC [33], as calculated from Equation (3) below:

$$Fatcontent(\%) = \frac{Weightoffat}{Weightofsample} \times 100 \quad (3)$$

Determination of Crude Fiber

The crude fiber of samples was determined as described by the AOAC method [33], with slight modifications. Approximately 2 g of defatted samples with diethyl ether, 0.255 M sulphuric acid (200 mL H_2SO_4) and dilute sodium hydroxide (200 mL NaOH) were added. The mixture was heated to boiling point and the insoluble material was transferred to a filter paper through a Buchner funnel connected to a vacuum pump. The filtrate was heated at 130 °C for ~2 h, cooled in a desiccator, and measured. Filtrates were transferred to a muffle furnace and ashed at 550 °C for ~30 min, cooled, and weighed. The percentage of crude fiber content was thus calculated:

$$\% \text{ Crude fiber} = \text{the loss in weight after incineration} \times 100 \quad (4)$$

Determination of Crude Protein

The crude protein was determined as described by the AOAC method [33], with slight modifications. Approximately 2 g sample was measured into a Kjeldahl digestion flask, followed by the addition of 0.1 g potassium sulphate with 1.0 mL copper sulphate solution. Approximately 25 mL concentrated sulphuric acid was added with few boiling catalysts. The flasks were heated in a fume chamber to a clear solution. The solution was cooled to room temperature for ~25 min. The solution was transferred into a 250 mL volumetric flask, made up to the level with distilled water. Approximately 5 mL digest in a measuring cylinder was pipetted into the apparatus, diluted by adding 5 mL of 50% NaOH aqueous. A conical flask (receiving flask) containing 50 mL of boric acid was placed under the condenser with two drops of methyl red as an indicator. The distillation flask of distillate of ammonium sulphate was heated to 100 mL, collected by the receiving flask, and then followed by titration with 0.1 M HCl, until a pink color was achieved. A similar procedure was carried out on the blank.

$$Crudeprotein(\%) = \frac{V_s - (V_s \times N)}{W_s} \times 100 \times 6.25N \quad (5)$$

Hence: vs. = volume (mL) of acid required to titrate the sample
V_s = volume (mL) of acid required to titrate the blank
N = Normality of acid (0.1 N)
W_s = Weight of sample (g)

Determination of Carbohydrates

As described by the AOAC method [33], the carbohydrates of samples were determined by the method of difference, subtracting crude protein values (%), moisture values (%), fat values(%), crude fiber values (%), and ash values (%) from 100%, as below:

$$Carbohydrates(\%) = 100\% - \{protein + fat + moisture + fibre + ash\}\% \quad (6)$$

2.5.4. Sensory Analysis

The freshly prepared "*Ibyer*", which has been formulated from the fermented millet flour enhanced with ginger powder, was subjected to sensorial analysis, following the method described by Iwe [34] with slight modifications. The sensorial analysis was conducted by 20 panelists, which comprised staff and students of the Department of Food Science and Technology, Federal University of Agriculture Makurdi, Benue State, Nigeria. Information about panelists like age range and gender were not recorded. Specifically, the sensorial training was provided to panelists regarding the attributes of appearance, aroma, mouth-feel, consistency, taste, and overall acceptability, which was conducted prior to their participation. The selection criteria to participate was based on the completion of the sensory training specific to this study. The panelists' participation at this study was voluntary. Additionally, consent was taken orally prior to the panelists' participation. During the sensory evaluation, each panelist was provided adequate space, to sample the coded blend samples presented in white plastic cup. Each panelist evaluated the samples independently without any co-operation with another. The sensory attributes of freshly prepared "*Ibyer*" blends involved appearance, aroma, mouth-feel, consistency, taste, and overall acceptability, which were considered based on a 9-point Hedonic scale, wherein the least value (numeric value = 1) was assigned as 'disliked extremely', and the highest value (numeric value = 9) was assigned as 'liked extremely'.

2.6. Statistical Analysis

One-way analysis of variance (ANOVA) was used to implement the emergent data. Results were presented as mean ± standard deviation (SD) of triplicate determinations, unless otherwise stated. The Fischer's least significant differences (LSD) test was used to resolve mean differences at *post-hoc* condition(s). The level of statistical significance was set at $p < 0.05$ (95% confidence interval). IBM SPSS Software (version 20, IBM, New York, NY, USA) was used to run the data analysis.

3. Results and Discussion

3.1. Variations in Microbial Counts of Fermented Millet "Ibyer" Beverage Enhanced with Ginger Powder

Table 2 shows the microbial counts of fermented millet "*Ibyer*" beverage enhanced with ginger powder. Both bacterial and fungi counts significantly differed ($p < 0.05$) across the blend samples. The control sample (FMF_{100}) obtained the highest bacteria (3.40×10^4 CFU/mL) and fungi (0.45×10^1 CFU/mL) counts. However, blend sample $FMF_{70}GP_{30}$ obtained the least bacterial (0.15×10^4 CFU/mL) and fungi (0.01×10^1 CFU/mL) counts. Bacterial counts were significantly higher ($p < 0.05$) than the fungi counts, across all the samples. Between blend samples $FMF_{95}GP_5$ and $FMF_{70}GP_{30}$, both bacterial and fungi counts decreased with millet quantities, as the ginger powder quantities were increased. This suggested the antimicrobial efficacy of ginger powder, in agreement with the report of Adesokan et al. [35], who demonstrated ginger's influence to extend the shelf-life of ogi, a Nigerian traditional fermented food.

Generally, spices are widely understood to demonstrate some form of antimicrobial activity against microorganisms, like bacteria, yeast, molds, and viruses, which the active compounds like gingerol in ginger might be responsible for [24–26]. The preservation of fermented millet product could be from the presence of both alkaline acetic acid, and lactic acid [3], as well as its (fermentation) ability to suppress the growth/survival of undesirable microflora [36]. Fractions and extracts obtained from millet grain are believed to show

some degree of antimicrobial activity [17]. Protein extracts obtained in pearl millet are also believed to slow down the growth of phytopathogenic fungi [37]. Phenolic acids present in millet milled fractions (whole flour, seed coat, 3%, 5%, and 7%) have been shown to possess some antimicrobial capacity against such microbial entities like *Bacillus cereus* and *Aspergillus flavus* [38].

Table 2. Microbial counts of fermented millet "*Ibyer*" beverage enhanced with ginger powder.

Sample Code	Bacteria Counts (CFU/mL) × 10^4	Fungi Counts (CFU/mL) × 10^1
716	3.40 ± 0.28 ^{a}	0.45 ± 0.07 ^{a}
924	2.80 ± 0.00 ^{b}	0.35 ± 0.10 ^{ab}
839	2.40 ± 0.28 ^{bc}	0.25 ± 0.07 ^{bc}
746	2.20 ± 0.28 ^{c}	0.15 ± 0.10 ^{c}
958	2.00 ± 0.28 ^{c}	0.15 ± 0.07 ^{c}
469	0.22 ± 0.01 ^{d}	0.10 ± 0.00 ^{c}
577	0.15 ± 0.01 ^{d}	0.01 ± 0.00 ^{c}

Note: Values are means ± standard deviation (SD) of triplicate determinations; Means with the same superscript in the same column are not significantly ($p > 0.05$) different. KEY: 716 = FMF_{100} (Control), 924 = $FMF_{95}GP_5$, 839 = $FMF_{90}GP_{10}$, 746 = $FMF_{85}GP_{15}$, 958 = $FMF_{80}GP_{20}$, 469 = $FMF_{75}GP_{25,}$577 = $FMF_{70}GP_{30}$ where, FMF = Fermented millet flour; GP = Ginger powder.

3.2. Variations in Pasting Properties of Fermented Millet "Ibyer" Beverage Enhanced with Ginger Powder

Table 3 shows the pasting properties of fermented millet "*Ibyer*" beverage enhanced with ginger powder. Pasting properties differed significantly ($p < 0.05$) across all blend samples compared with the control. For instance, the control samples obtained peak breakdown viscosity, which decreased significantly ($p < 0.05$) in blend samples as the ginger powder increased. Particularly between blend samples $FMF_{95}GP_5$ and $FMF_{70}GP_{30}$, the ginger powder increased with peak (from 367.10 to 384.00 cP), trough (from 93.50 to 222.00 cP), final (from 273.20 to 652.00 cP), and set back (from 178.00 to 424.00 cP) viscosities, as well as peak time (from 4.79 to 5.69 cP) and pasting temperature (from 78.43 to 88.20 cP). High peak viscosity was associated with starch damage and its binding capacity [39]. Higher water-binding capacity increases gelatinization and lowers swelling property of starch, given the high degree of association between starch granules [40]. Increases in final viscosity in the blend samples is indicative of how the starch forms either a paste or gel after cooling, which becomes less stable with increased breakdown viscosity [41], which might explain why increases in the setback viscosity occurred in the blend samples. Higher setback viscosity suggests the blend samples might undergo some retrogradation during the cooling process [42]. Decreasing breakdown viscosity (from 273.60 to 162.00 cP) might increase the ability of (millet) flours to withstand both heating and shear stress that occurred during processing [43]. Peak time of control sample FMF_{100} (4.79 ± 0.45 min) and blend sample $FMF_{95}GP_5$ (4.79 ± 0.17 min) were similar ($p > 0.05$). Besides similar increased peak time ($p > 0.05$), the peak pasting temperature in blend samples with 30% ginger powder were significantly ($p < 0.05$) higher compared to control.

3.3. Variations in Proximate Composition of Fermented Millet "Ibyer" Beverage Enhanced with Ginger Powder

Table 4 shows the proximate composition of fermented millet "Ibyer" beverage enhanced with ginger powder. The control FMF_{100} obtained lower moisture (8.13%), ash (2.66%), fat (2.40%), crude fiber (2.05%), and protein (3.87%), but higher in carbohydrate (80.89%) contents compared to the blend samples. Particularly between blend samples $FMF_{95}GP_5$ and $FMF_{70}GP_{30}$, significant ($p < 0.05$) increases occurred in moisture (from 8.13 to 9.43%), ash (from 3.23 to 4.66%), fat (from 2.93 to 4.24%), crude fiber (from 2.48 to

3.58%), and crude protein (from 5.43 to 8.27%), but decreases were found only in carbohydrate (from 77.63 to 69.82%) contents. Increases in the ash contents might suggest the measured food samples to be a good mineral [44]. Across the blend samples, the crude fat increased ($p < 0.05$) significantly with ginger powder (Table 4), which Farinde [45] has attributed to (presence of crude fat in) the (ginger) rhizomes. Significant increase ($p < 0.05$) in protein content across blend samples (Table 4) could be owed to the millet bio-fermentation process [45], probably accounting for gradual increases in moisture content, and other noticeable changes in chemical composition [17,18]. The moisture of control FMF_{100} (8.13 ± 0.30%) resembled ($p > 0.05$) the blend sample $FMF_{95}GP_5$ (8.30 ± 0.10%), but significantly differed ($p < 0.05$) from other proximate contents. Carbohydrate content decreased as ginger powder increased (Table 4). Decreases in carbohydrate content with millet flour makes this current "*Ibyer*" beverage blend very promising for diabetic management. Moreover, this blend beverage formulation could increase micronutrient absorption and nutrient utilization.

Table 3. Pasting properties of fermented millet "*Ibyer*" beverage enhanced with ginger powder.

Sample Codes	Peak Viscosity (cP)	Trough Viscosity (cP)	Breakdown Viscosity (cP)	Final Viscosity (cP)	Setback Viscosity (cP)	Peak Time (min)	Pasting Temperature (°C)
716	367.10 ± 1.56 ^{a}	93.50 ± 0.57 ^{a}	273.60 ± 2.19 ^{e}	273.20 ± 4.53 ^{a}	178.00 ± 2.83 ^{a}	4.79 ± 0.45 ^{a}	78.43 ± 1.38 ^{a}
924	369.00 ± 1.41 ^{a}	130.90 ± 6.51 ^{b}	238.10 ± 1.56 ^{d}	349.00± 1.41 ^{b}	238.20 ± 1.70 ^{b}	4.79 ± 0.17 ^{a}	79.58 ± 0.60 ^{ab}
839	370.50 ± 2.12 ^{b}	132.40 ± 6.51 ^{b}	238.10 ± 7.21 ^{d}	413.50 ± 7.78 ^{b}	277.00 ± 1.41 ^{c}	4.85± 0.07 ^{a}	80.55± 0.78 ^{ab}
746	373.00 ± 7.07 ^{b}	155.00 ± 0.71 ^{d}	218.00 ± 1.41 ^{c}	461.00 ± 1.41 ^{d}	312.00 ± 1.41 ^{d}	4.92± 0.30 ^{a}	81.40± 0.99 ^{b}
958	378.00 ± 1.41 ^{b}	186.90 ± 1.41 ^{e}	191.10 ± 1.49 ^{b}	531.50 ± 13.44 ^{e}	348.10 ± 2.90 ^{e}	5.60 ± 0.85 ^{a}	84.03 ± 0.11 ^{c}
469	381.50 ± 0.71 ^{b}	211.90 ± 10.68 ^{f}	169.60 ± 0.78 ^{a}	596.00 ± 2.90 ^{f}	396.10 ± 2.97 ^{f}	5.67 ± 0.71 ^{a}	87.78 ± 0.88 ^{d}
577	384.00 ± 1.41 ^{c}	222.00 ± 1.56 ^{g}	162.00 ± 9.90 ^{a}	652.00 ± 1.41 ^{g}	424.00 ± 1.41 ^{g}	5.69 ± 0.73 ^{a}	88.20± 1.34 ^{d}

Note: Values are means ± standard deviation (SD) of triplicate determinations; Means with the same superscript in the same column are not significantly ($p > 0.05$) different. KEY: 716 = FMF_{100} (Control), 924 = $FMF_{95}GP_5$, 839 = $FMF_{90}GP_{10}$, 746 = $FMF_{85}GP_{15}$, 958 = $FMF_{80}GP_{20}$, 469 = $FMF_{75}GP_{25}$, 577 = $FMF_{70}GP_{30}$. FMF = Fermented millet flour; GP = Ginger powder.

Table 4. Proximate composition of fermented millet "*Ibyer*" beverage enhanced with ginger powder.

Sample Code	Moisture (%)	Ash (%)	Crude Fat (%)	Crude Fibre (%)	Protein (%)	Carbohydrate (%)
716	8.13 ± 0.30 ^{d}	2.66 ± 0.57 ^{d}	2.40 ± 0.52 ^{d}	2.05± 0.44 ^{d}	3.87 ± 0.12 ^{d}	80.89 ± 1.75 ^{a}
924	8.30 ± 0.10 ^{d}	3.23 ± 0.40 ^{cd}	2.93 ± 0.36 ^{cd}	2.48 ± 0.31 ^{cd}	5.43 ± 0.23 ^{c}	77.63 ± 0.85 ^{b}
839	8.46 ± 0.29 ^{cd}	3.66 ± 0.57 ^{bc}	3.33 ± 0.52 ^{bc}	2.82 ± 0.44 ^{bc}	6.82 ± 0.76 ^{bc}	74.91 ± 0.88 ^{c}
746	8.56 ± 0.37 ^{bcd}	3.73 ± 0.40 ^{bc}	3.39 ± 0.36 ^{bc}	2.87 ± 0.31 ^{bc}	6.87 ± 0.71 ^{bc}	74.58 ± 0.24 ^{c}
958	8.86 ± 0.05 ^{bc}	4.43 ± 0.37 ^{ab}	4.03 ± 0.34 ^{ab}	3.41 ± 0.29 ^{ab}	7.12 ± 0.79 ^{abc}	72.15 ± 1.60 ^{d}
469	8.96 ± 0.20 ^{b}	4.56 ± 0.40 ^{ab}	4.15 ± 0.34 ^{ab}	3.51 ± 0.29 ^{ab}	7.91 ± 1.25 ^{ab}	70.91 ± 1.21 ^{de}
577	9.43 ± 0.20 ^{a}	4.66 ± 0.57 ^{a}	4.24 ± 0.52 ^{a}	3.58 ± 0.44 ^{a}	8.27 ± 1.05 ^{a}	69.82 ± 0.38 ^{e}

Note: Values are means ± standard deviation (SD) of triplicate determinations; Means with the same superscript in the same column are not significantly ($p > 0.05$) different. KEY: 716 = FMF_{100} (Control), 924 = $FMF_{95}GP_5$, 839 = $FMF_{90}GP_{10}$, 746 = $FMF_{85}GP_{15}$, 958 = $FMF_{80}GP_{20}$, 469 = $FMF_{75}GP_{25}$, 577 = $FMF_{70}GP_{30}$. FMF = Fermented millet flour; GP=Ginger powder.

3.4. Variations in Sensory Attributes of Fermented Millet "Ibyer" Beverage Enhanced with Ginger Powder

Table 5 shows sensory attributes of fermented millet "*Ibyer*" beverage enhanced with ginger powder. Particularly between the blend samples $FMF_{95}GP_5$ and $FMF_{70}GP_{30}$, a decreasing trend was found in sensory appearance (from 7.60 ± 1.05 to 5.58 ± 1.80), aroma (from 7.30 ± 0.98 to 5.84 ± 1.64), mouthfeel (from 7.85 ± 0.98 to 4.74 ± 2.07), and taste (from 7.40 ± 1.23 to 4.32 ± 1.97), but not so for consistency (from 8.05 ± 1.93 [$FMF_{95}GP_5$] to 4.75 ± 1.86 [$FMF_{85}GP_{15}$], then to 6.25 ± 2.12 [$FMF_{80}GP_{20}$], and then to 5.47 ± 1.98 [$FMF_{70}GP_{30}$]) attributes. These individual decreasing trends probably cumulated to that obtained at the overall acceptability (from 8.80 ± 1.25 to 4.47 ± 1.89). As ginger powder was added, the consistency, mouthfeel, and overall acceptability of control sample FMF_{100}

statistically differed ($p < 0.05$) compared to blend sample $FMF_{95}GP_5$. Further, the mouthfeel of food particles, as mentioned in Okoye and Ojobor [44], could depend on such sensory attributes like coarseness, crunchiness, size, and viscosity.

Table 5. Sensory attributes of fermented millet "*Ibyer*" beverage enhanced with ginger powder.

Sample Code	Appearance	Aroma	Mouthfeel	Consistency	Taste	Overall Acceptability
716	7.35 ± 1.09 ^{a}	7.30 ± 0.86 ^{a}	7.30 ± 1.30 ^{a}	5.35 ± 2.03 ^{a}	7.40 ± 0.99 ^{a}	7.30 ± 1.42 ^{a}
924	7.60 ± 1.05 ^{a}	7.30 ± 0.98 ^{a}	7.85 ± 0.98 ^{ab}	8.05 ± 1.93 ^{c}	7.40 ± 1.23 ^{a}	8.80 ± 1.25 ^{ab}
839	7.35 ± 1.09 ^{a}	7.15 ± 1.08 ^{ab}	6.40 ± 1.23 ^{abc}	4.85 ± 1.98 ^{a}	6.60 ± 1.39 ^{ab}	6.80 ± 1.15 ^{ab}
746	7.05 ± 1.43 ^{ab}	6.95 ± 1.46 ^{ab}	6.10 ± 1.55 ^{bcd}	4.75 ± 1.86 ^{a}	6.15 ± 1.76 ^{b}	6.10 ± 1.33 ^{bc}
958	6.33 ± 1.85 ^{b}	6.19 ± 1.24 ^{b}	5.65± 1.73 ^{de}	6.25 ± 2.12 ^{ab}	5.05 ± 1.54 ^{c}	5.15 ± 1.66 ^{cd}
469	6.05 ± 1.66 ^{c}	6.15 ± 1.81 ^{bc}	5.14 ± 2.03 ^{de}	5.76 ± 1.55 ^{ab}	4.28 ± 1.79 ^{c}	4.90 ± 2.04 ^{d}
577	5.58 ± 1.80 ^{c}	5.84 ± 1.64 ^{c}	4.74 ± 2.07 ^{e}	5.47 ± 1.98 ^{ab}	4.32 ± 1.97 ^{c}	4.47 ± 1.89 ^{d}

Note: Values are means ± standard deviation (SD) of 20 panelists: Means with the same superscript in the same column are not significantly ($p > 0.05$) different. KEY: 716 = FMF_{100} (Control), 924 = $FMF_{95}GP_5$, 839 = $FMF_{90}GP_{10}$, 746 = $FMF_{85}GP_{15}$, 958 = $FMF_{80}GP_{20}$, 469 = $FMF_{75}GP_{25}$, 577 = $FMF_{70}GP_{30}$. FMF = Fermented millet flour; GP = Ginger powder.

In terms of appearance, the blend sample $FMF_{95}GP_5$ (7.60 ± 1.05) resembled ($p > 0.05$) $FMF_{90}GP_{10}$ (7.35 ± 1.09) compared with the control FMF_{100} (7.35 ± 1.09), whereas the blend sample $FMF_{75}GP_{25}$ (6.05 ± 1.66) did not significantly differ ($p > 0.05$) from $FMF_{70}GP_{30}$ (5.58 ± 1.80). Yet, the appearance of both blend samples $FMF_{75}GP_{25}$ and $FMF_{70}GP_{30}$ were significantly different ($p < 0.05$), compared to control. In terms of aroma, the blend samples $FMF_{90}GP_{10}$ (7.15 ± 1.08) resembled ($p > 0.05$) $FMF_{85}GP_1$ (6.95 ± 1.46), but both were significantly different ($p < 0.05$) compared to the control. Adding that the acceptance aspect of food sensory evaluation is very important, the aroma aspect is equally an integral aspect, together with taste, all of which makes the food appear acceptable to the consumer prior to it being placed in the mouth [46]. In terms of mouthfeel, all the blend samples were significantly different ($p < 0.05$) compared to control FMF_{100}. In terms of consistency, the blend samples $FMF_{90}GP_{10}$ (4.85 ± 1.98) and $FMF_{85}GP_{15}$ (4.75 ± 1.86) were similar ($p > 0.05$) to the control (5.35 ± 2.03). In terms of taste, the blend samples $FMF_{80}GP_{20}$ (5.05±1.54), $FMF_{75}GP_{25}$ (4.28 ± 1.79), and $FMF_{70}GP_{30}$ (4.32 ± 1.97) resembled ($p > 0.05$) each other, but all were significantly different ($p < 0.05$) compared to control FMF_{100} (7.40 ± 0.99). In terms of overall acceptability, the blend samples $FMF_{95}GP_5$ (8.80 ± 1.25) and $FMF_{90}GP_{10}$ (6.80 ± 1.15) appeared similar ($p > 0.05$), the same when both blend samples $FMF_{75}GP_{25}$ (4.90 ± 2.04) and $FMF_{70}GP_{30}$ (4.47 ± 1.89) were compared. Besides, the overall acceptability of blend samples $FMF_{95}GP_5$, $FMF_{90}GP_{10}$, $FMF_{75}GP_{25}$, and $FMF_{70}GP_{30}$ appeared statistically different ($p < 0.05$) compared to control FMF_{100} (7.30 ± 1.42). Clearly, increasing ginger powder quantities resulted in noticeable ($p < 0.05$) decreases in the overall acceptability. Compared to the blend sample $FMF_{70}GP_{30}$ with the lowest (overall acceptability) score (~4.47), the blend sample $FMF_{95}GP_5$ that obtained peak overall acceptability score (~8.80) appears to be the most preferred.

4. Conclusions

To the best of our knowledge, this is the first study to document the microbiological, pasting, proximate, and sensory properties of this fermented "*Ibyer*" beverage blend product enhanced with ginger powder. Results showed bacterial/fungi counts decreased with increased ginger powder quantities, which suggested the antimicrobial efficacy of ginger powder. Proximate composition across samples obtained diverse ranges. Despite the ranges in pasting properties, the addition of ginger powder minimally affected both peak time and temperature values. Between the blend samples, decreasing trends were found in appearance, aroma, mouthfeel, taste, but not consistency sensory attributes. Decreases in overall acceptability might probably be owed to the cumulative decreases in sensory appearance, aroma, mouthfeel, and taste attributes. Decreases in carbohydrate content

with millet flour makes this current "*Ibyer*" beverage blends very promising for diabetic management. The direction of future studies should evaluate the shelf-life of this current "*Ibyer*" beverage enhanced with ginger powder, particularly under different storage conditions. Such future studies should incorporate the determinations of lactic acid bacteria, together with other fermentation-specific biochemical and microbial analysis, in the view to supplement existing information.

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